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Feasibility regimes and the limits of Voluntary Travel Behaviour Change: evidence from a MaaS-enabled university experiment

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Abstract

European metropolitan areas face increasing pressure to reconcile everyday mobility with decarbonisation, congestion mitigation and social equity. In this context, Mobility as a Service (MaaS) and Voluntary Travel Behaviour Change (VTBC) programs are widely promoted as demand-side instruments capable of fostering sustainable modal shifts through information, integration and personalised support. Yet their behavioural effectiveness remains empirically fragile and theoretically under-specified. In particular, existing evaluations largely rely on average treatment effects and attitudinal models, while neglecting the structural constraints and stabilisation mechanisms that govern everyday mobility.

This thesis advances a regime- and threshold-based interpretation of voluntary travel behaviour change. It develops an integrated theoretical framework that combines process models of change, intention-formation theories and dual-process accounts of habit, and reconceptualises the intention–action gap as a feasibility problem generated by coordination costs, reliability risks and routine anchoring. Behavioural change is theorised as a discontinuous phenomenon: durable reconfiguration occurs only when interventions enable travellers to cross feasibility thresholds separating bounded internal rebalancing from genuine regime-level transitions.

The framework is examined through a staged, longitudinal MaaS-enabled VTBC experiment implemented in a complex metropolitan university context. The empirical strategy integrates revealed and stated preference data, personalised travel planning, differentiated exposure conditions and multi-phase behavioural tracking. Rather than estimating population-average effects, the study adopts a mechanism-oriented evaluation design that distinguishes regime-level change from reactivity, bounded adaptation and engagement filters, and treats selective participation and attrition as analytically meaningful scope conditions.

The results demonstrate a systematic dominance of bounded internal rebalancing within stable feasibility regimes. MaaS-enabled choice contexts consistently increase salience and reflective activation and induce limited portfolio reweighting, but fail to trigger durable regime reconfiguration in the absence of substantial feasibility gains. Behavioural stability emerges as an adaptive response to systemic fragility rather than as attitudinal rigidity or resistance.

The thesis contributes a regime–threshold theory of VTBC, a feasibility-centred mechanism map linking habits, behavioural control and system architectures, and a governance-oriented reinterpretation of MaaS as a feasibility device rather than a mere informational interface. It concludes that soft behavioural interventions can support sustainable mobility transitions only when embedded in integrated governance arrangements capable of reducing coordination burdens and implementation risks, thereby transforming sustainable options from desirable alternatives into credible and stable everyday practices.

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Introduction

European metropolitan mobility systems are increasingly characterised by a tension between ambitious sustainability objectives and the practical organisation of everyday travel. While decarbonisation targets, air-quality standards, and equity concerns have become central to transport policy agendas, daily mobility remains structured by routines, time constraints, reliability concerns, and institutional fragmentation. In such contexts, travel behaviour is not the outcome of isolated choices, but of stabilised organisational arrangements that make *everyday mobility feasible under constraint*.

From this perspective, the challenge of sustainable mobility is fundamentally a behavioural one. Travel practices are embedded in routines, portfolio strategies, and compensatory mechanisms that allow individuals to cope with uncertainty, coordination demands, and rigid temporal schedules. Behavioural persistence in metropolitan systems should therefore not be interpreted primarily as resistance to change or lack of motivation, but as the result of stabilisation logics that protect feasibility in complex and demanding environments. Mobility policy, accordingly, cannot be reduced to the provision of additional options: what matters is whether alternative practices can be integrated into daily life in ways that are *credible, implementable, and stable over time*.

Within this behavioural and organisational framing, Voluntary Travel Behaviour Change (VTBC) approaches have gained prominence as demand-side instruments aimed at encouraging more sustainable mobility practices without coercion. Through information provision, personalised feedback, self-monitoring, incentives, and behavioural framing, VTBC interventions seek to activate reflection and support shifts in everyday travel choices. Yet empirical evidence on their effectiveness remains mixed. Many interventions produce observable behavioural variation, but it is often unclear whether such variation constitutes genuine behavioural change or merely bounded adaptation within pre-existing routines. A recurring challenge in VTBC research is therefore to distinguish between short-term reactivity, experimentation effects, and durable reconfiguration of mobility practices.

A central limitation of much existing VTBC research lies in its partial treatment of constraint. Behavioural models frequently privilege intention, attitudes, or perceived behavioural control, while underplaying the organisational and structural conditions that determine whether intentions can be implemented in practice. In metropolitan contexts characterised by long-distance commuting, fragmented service provision, and high coordination costs, pro-sustainability intentions may form without translating into action. Under such conditions, behavioural change is better understood not as a smooth, continuous response to intervention exposure, but as a regime- and threshold-governed process, in which observable variation can occur without undermining the stabilisation logic of existing mobility regimes.

It is against this background that Mobility as a Service (MaaS) enters the analytical frame of this thesis. MaaS has been promoted as a tool capable of reshaping the choice context by integrating

information, planning, booking, and payment across multiple transport modes, thereby potentially reducing coordination burden and implementation risk. In policy discourse, MaaS is often implicitly treated as a facilitator of voluntary behavioural change: by simplifying access to multimodal options, it is expected to enable more sustainable travel practices. However, whether and under which conditions MaaS-enabled choice contexts can meaningfully relax feasibility constraints and support durable behavioural change remains an open empirical and theoretical question.

This thesis takes that question seriously. It starts from the premise that the key analytical issue is not whether MaaS can promote “better choices” in principle, but whether MaaS-enabled choice contexts can alter the feasibility calculus that anchors everyday mobility behaviour. The argument developed here is that voluntary behavioural change should be analysed as a threshold phenomenon: under strongly binding constraints, interventions may generate salience, experimentation, and internal reweighting without producing regime-level reconfiguration. Distinguishing bounded adaptation from threshold-crossing change is therefore essential for both theory and policy.

This research was developed within the framework of the National Recovery and Resilience Plan (PNRR), as part of the activities of the National Centre for Sustainable Mobility (CNMS). More specifically, the thesis contributes to the research agenda of *Spoke 8 – Mobility as a Service (MaaS) and innovative services*, within Work Package 1. The empirical work and analytical framework presented here are aligned with the broader objective of advancing demand-side and context-enabling strategies for sustainable mobility transitions in complex metropolitan systems.

Mobility behaviour, sustainability, and demand-side governance

The thesis is situated at the intersection of three strands of scholarship and policy practice.

First, the new mobility paradigms reframe transport policy away from the narrow optimisation of traffic flows and toward system outcomes: accessibility, environmental performance, safety, and equity. This perspective challenges supply-oriented approaches that accommodate demand through capacity expansion and instead legitimises demand-side action, intervening on the conditions under which mobility demand is produced and sustained.

Second, Travel Demand Management (TDM) provides a policy language for acting on demand through integrated packages of measures. Rather than treating demand as an external constraint, TDM conceptualises it as a policy target shaped by pricing, regulation, service design, land use, information, and behavioural interventions. Within this space, the Avoid–Shift–Improve (ASI) model offers a practical organising logic: reduce unnecessary travel (Avoid), shift trips to more sustainable modes (Shift), and improve the performance of remaining travel through cleaner technologies and operations (Improve). Importantly, ASI is not only a taxonomy of measures; it is a reminder that behaviour-sensitive policy is most effective when it is *integrated*, aligning soft measures with structural conditions.

Third, Voluntary Travel Behaviour Change (VTBC) research explicitly addresses how soft measures (information, personalised travel planning, feedback, gamification, incentives) can support behavioural change without coercion. Yet VTBC evidence often struggles with the inferential problem of separating true change from reactivity, novelty effects, measurement artefacts, and selection processes (who participates, who drops out, who remains observable). Moreover, VTBC approaches sometimes rely on psychological models that privilege intention, attitudes, or perceived control without fully integrating the organisational and system constraints that determine whether intentions can be implemented.

This thesis uses MaaS as a strategic case to connect these three domains. MaaS is treated neither as a technological innovation nor as a guaranteed catalyst of modal shift. Rather, it is analysed as a *choice context* and, potentially, as a *feasibility device*: something that may (or may not) reduce coordination burden, uncertainty, and implementation risk—precisely the conditions that often block the translation of pro-sustainability intentions into action.

The overall research question and the thesis’ interpretive stance

The overall research question guiding the thesis is:

To what extent and through which mechanisms can a MaaS-enabled choice context support voluntary travel behaviour change toward more sustainable mobility practices in complex metropolitan urban systems?

The thesis argues that answering this question requires a conceptual shift. “Extent” cannot be interpreted only as an average change in modal shares. “Mechanisms” cannot be reduced to generic claims about information or motivation. Instead, the relevant unit of analysis is the *mobility regime* through which everyday travel is stabilised: the configuration of routines, portfolio architectures, compensatory strategies, and control perceptions that render mobility feasible under constraint. On this view, behavioural change becomes a *threshold phenomenon*: what matters is whether an intervention enables travellers to cross feasibility thresholds that separate bounded internal rebalancing from genuine regime-level reconfiguration (e.g., durable weakening of routine anchoring, credible expansion of the effective feasible set, restructuring of the mobility portfolio, displacement of backbone-mode reliance).

This stance has two immediate implications for evaluation.

1. *Observed variation is not sufficient evidence of change.* Mobility behaviour is naturally variable. The thesis therefore adopts a “strong” criterion of change that treats many forms of variation as compatible with regime stability.
2. *Selection and engagement are part of the phenomenon.* In voluntary, digitally mediated experimentation, participation itself is a feasibility test: attrition and disengagement are not

merely technical noise but analytically meaningful outcomes that shape what can be observed and what interventions can plausibly achieve.

An integrated theoretical framework for VTBC under constraint

To build an explanation capable of supporting policy-relevant inference, the thesis develops an integrated theoretical framework that combines three complementary perspectives commonly used in behaviour-change research:

- a *process logic (stage-oriented)* that foregrounds the critical transitions through which change becomes implementable;
- an *intention formation logic* that clarifies how attitudes, norms, and perceived and actual behavioural control contribute to readiness and intention;
- a *dual-process logic* that captures the coexistence of reflective and automatic mechanisms (habits), and highlights the structural nature of the intention–action gap.

The contribution is not to restate these theories, but to integrate them into a mechanism map centred on feasibility. In the resulting framework, the key bottleneck is not merely “forming intention”, but crossing the boundary where preparation becomes action under real-world constraints, where implementation burden, reliability risk, and coordination costs become decisive.

Empirical strategy and case

The thesis investigates these issues through a real-world MaaS-enabled VTBC experiment implemented in a metropolitan context characterised by complexity and binding constraints. The empirical design is staged and longitudinal, combining behavioural tracking with differentiated exposure conditions. This staged logic allows the thesis to probe, sequentially, the contribution of reflective activation and self-monitoring, and then the added value, if any, of MaaS-enabled operational integration as the point where informational choice contexts would be expected to translate into implementable action.

Rather than treating the study as a conventional trial designed to estimate a population-average treatment effect, the thesis treats it as a *mechanism-oriented probe* of feasibility and thresholds in a concrete metropolitan “corridor” of mobility regimes. The analysis is organised to separate different sources of behavioural movement (bounded internal rebalancing, tracking-induced reactivity, and engagement/attrition as scope conditions) from the stronger phenomenon of regime-level reconfiguration.

This inferential posture is deliberately cautious. The final effective sample is limited, participation is selective, and observation is time-bounded. The thesis therefore does not claim statistical generalisation about MaaS effectiveness “in general”. Instead, it uses the empirical material to make a theoretically disciplined claim: within the observed feasibility corridor, the most robust effects of

staged exposure are located upstream of implementation (salience, reflective activation, bounded reweighting), while threshold-crossing regime change appears contingent on feasibility gains that exceed what a choice context alone can deliver.

Policy relevance: from persuasive interventions to feasibility governance

The policy implication of this approach is not that “soft measures do not matter”. Rather, it is that soft measures matter *differently* depending on the regime of departure and the feasibility thresholds at stake. Within TDM and ASI, MaaS-enabled VTBC is most plausibly understood as part of an integrated package:

- as a *Shift-supporting mechanism* where alternatives are already close to feasible and can be stabilised through lower coordination cost and better implementation support;
- as a complement to *Avoid strategies* where activity patterns, accessibility, and trip-chaining constraints can be reorganised;
- and as an interface that can amplify *Improve measures* when service reliability and institutional integration make sustainable options credible.

In metropolitan systems where institutional fragmentation and reliability risks are central constraints, MaaS cannot be treated as a mere front-end application. Its behavioural relevance depends on governance: fare integration, service commitments, disruption management, guarantees, and operational assistance. The thesis therefore positions MaaS not simply as a user-facing innovation, but as a potential *governance device*, one whose behavioural effects depend on the depth of integration achieved in the system.

Contributions and thesis structure

Taken together, the thesis advances three overarching contributions.

1. A *conceptual contribution*: a regime–threshold interpretation of voluntary travel behaviour change that redefines “what counts” as change and clarifies why sub-threshold effects (salience, bounded rebalancing) may be the modal outcome of soft interventions under constraint.
2. A *theoretical integration*: a mechanism map that links process dynamics, intention formation, habits, and behavioural control to feasibility architectures—treating the intention–action gap as a structurally generated threshold problem rather than a purely motivational deficit.
3. A *policy-oriented interpretation of MaaS*: MaaS-enabled choice contexts are behaviourally relevant insofar as they function as feasibility devices within TDM/ASI packages, reducing coordination burden and implementation risk, and thereby helping to open regime boundaries where sustainable practices can be consolidated.

The remainder of the thesis develops this argument in a cumulative way: it first establishes the sustainability and demand-side governance context (including TDM and ASI), then develops the integrated theoretical framework for VTBC under constraint, then presents the empirical design and

interpretive strategy, and finally reconstructs the experimental findings through a regime/threshold lens to answer the overall research question in mechanism terms and to derive cautious but policy-relevant implications for mobility management and integrated measure design.

In doing so, the thesis aims to contribute not only to academic debates on MaaS and behaviour change, but also to the practical problem faced by metropolitan policy actors: how to design interventions that do not merely *inform* sustainable choices, but make them *feasible, implementable*, and *stable* within the constrained realities of everyday urban life.

Part 1: Theoretical framework

Mobility and sustainability

This chapter introduces the conceptual foundations that frame contemporary debates on mobility and sustainability, positioning mobility not only as a functional response to spatial separation but also as a socio-economic and technical phenomenon embedded in infrastructures, institutions, and everyday practices. The discussion draws on two influential and complementary strands of literature. First, the New Mobilities Paradigm developed by Sheller and Urry (Sheller & Urry, 2006; Urry, 2007; Sheller & Urry, 2016) is used to capture the “mobility turn” in the social sciences and to highlight how movement, immobility, and networked connections shape social relations, inequalities, and access to services and opportunities (Hansen, 1959). Second, the chapter introduces the Sustainable Mobility Paradigm proposed by Banister (Banister, 2008), which shifts the analytical and normative focus from mobility to accessibility, and from traffic growth to demand management and behavioural change in line with environmental limits and quality-of-life goals.

By linking mobilities research to sustainability-oriented transport scholarship, the chapter clarifies why transport planning must move beyond supply expansion and technological efficiency alone, and instead address the behavioural, spatial, and institutional drivers of mobility demand. This theoretical positioning anticipates the subsequent chapters, which progressively examine some of key dimensions of the mobility system, such as travel demand and travel behaviour, and then policy instruments, particularly Travel Demand Management and Voluntary Travel Behaviour Change programs, aimed at shaping mobility choices toward more sustainable patterns (Ison & Rye, 2008; Banister, 2008; Holden et al., 2020).

The New mobilities paradigm

Already two decades or so ago, Sheller and Urry formulated a new theory known as New mobilities paradigm (NMP) (Sheller, Urry 2006, Urry 2007), developed within a scientific community when anomalous facts arise that didn't make sense within then existing paradigm. Diverse yet intersecting and on immense scale mobilities were emerged where demand for mobility has not only increased but further has changed from becoming more frequent, more diversified in regard to its structure compared to the past, more differentiated in terms of purpose and more widespread as to diversification of the territorial location of generators and attractors of mobility flows, resulting from the settlement dispersion processes of the current urbanization phase (Colleoni 2019). Such turn in mobility had many consequences for different peoples and places that were located in the fast and slow lanes across the globe (Sheller, Urry 2006). There were new places and technologies that

enhanced the mobility of some populations and places and heighten the immobility of others (Verstraete 2004).

Besides, more and more different forms of virtual and imaginative travel became part of our life involving new ways of interacting and communicating on the move, of being in a sense present while apparently absent. This so-called mobility turn (Urry 2007), characterized by these changing patterns of global mobilities developing in the 1990s, was spreading into and transforming the social sciences, transcending the dichotomy between transport research and social research, putting social relations into travel, and connecting different forms of transport with complex patterns of social experience. Indeed, social science had largely ignored or trivialized the importance of the daily mobility, especially systematic one. The new paradigm challenged the ways in which much social science research had been a-mobile. Hence, the new mobilities paradigm represents a way of seeing the world that is sensitive to the role of movement in ordering social relations. It serves to legitimize questions about the practical, discursive, technological, and organizational ways in which societies deal with distance and the appropriate methods for their study.

Within this perspective, mobility is no longer conceived merely as a means of overcoming spatial separation, but as a constitutive element of social life, deeply intertwined with power relations, inequalities, and access to services. The NMP therefore shifts analytical attention from transport services and infrastructures alone to the broader assemblages of actors, technologies, institutions, and practices that enable, constrain, or shape movement (Sheller & Urry, 2006). This shift is particularly relevant for understanding contemporary mobility systems, where patterns of movement are increasingly differentiated across social groups and territories, generating uneven distributions of accessibility and mobility-related benefits and burdens. By foregrounding these dimensions, the paradigm opens space for normative questions concerning the social and environmental sustainability of prevailing mobility regimes.

Regarding the transformative ambition of the NMP, Sheller and Urry (2006) argue that it seeks a “fundamental recasting of social science” (p. 207). In doing so, the paradigm explicitly problematises two sets of extant theoretical assumptions.

First, it undermines what the authors define as *sedentarist theories* widely present in geography, anthropology and sociology (Sheller & Urry, 2006, pp. 208–209). Sedentarist approaches treat stability, dwelling and bounded place as the normal condition of social life, while construing movement, distance and change as secondary or anomalous phenomena. Within such perspectives, social relations are assumed to be primarily anchored in fixed spatial containers, and mobility is relegated to a residual or technical domain rather than recognised as a constitutive dimension of social organisation.

On this basis, Sheller and Urry criticise large strands of industrial sociology, consumption studies, transport research and urban analysis for having remained fundamentally static, failing to account for

the profound role of mobility, and particularly automobility, in reshaping time–space relations, everyday practices and urban life (Sheller & Urry, 2006; Urry, 2007).

Second, the new mobilities paradigm challenges container-based conceptions of space by emphasising that all places are embedded in networks of movement and connection that extend beyond their apparent territorial boundaries (Sheller & Urry, 2006, p. 214). From this standpoint, the critique of sedentarism also implies a rethinking of how transport systems and mobility demand are conceptualised within policy and planning frameworks. If social relations, economic activities and everyday practices are intrinsically mobile, then treating travel demand as static or exogenous becomes analytically insufficient. Mobility must instead be understood as dynamically produced through the interaction between spatial organisation, technological systems, institutional arrangements and situated practices.

This insight anticipates later developments in transport and mobility research that emphasise the endogenous nature of travel demand and the limits of infrastructure-centred policy models. Within this perspective, mobility demand is no longer treated as an exogenous quantity to be accommodated, but as a socially and institutionally produced outcome shaped by spatial organisation, technological systems, informational environments and everyday practices. From a policy standpoint, this implies a shift from supply-oriented approaches toward demand-oriented and behaviour-sensitive strategies, in which transport policy intervenes not only on infrastructure and technology but also on the behavioural, informational and contextual determinants that structure mobility choices and routines (cf. Banister, 2008; Cervero, 2013). In this sense, the critique advanced by the new mobilities paradigm foreshadows the contemporary emphasis on governing mobility through the shaping of choice contexts rather than through the mere expansion of capacity.

Second, the critique of static social science developed by the new mobilities paradigm also departs from approaches that focus primarily on post-national deterritorialisation and the erosion of states as containers of social life. In this respect, the work of Bauman on *liquid modernity* provides an important conceptual bridge. Bauman (2000) redirected attention away from heavy, solid and territorially bounded structures of modernity toward a social order characterised by fluidity, circulation and speed, in which the movement of people, capital, images and information becomes a central organising principle. Modernity is thus reconceptualised as “light” and mobile rather than “heavy” and fixed, and social life is increasingly understood through the dynamics of flows rather than through stable institutional containers.

However, as Sheller (2004) and Sheller and Urry (2006) explicitly argue, deterritorialisation does not entail the disappearance of place, attachment or material anchoring. On the contrary, the new mobilities paradigm insists on the co-presence of movement and fixity. Mobilities are always supported by highly specific, often immobile infrastructures and institutional arrangements. Mobility is therefore never purely fluid: it is located, materialised and selectively enabled through the

mobilisation of locality and the reorganisation of place-based materialities (Sheller, 2004, pp. 47–49; Sheller & Urry, 2006, pp. 213–215).

In this sense, the apparent fluidity of liquid modernity rests on dense systems of “moorings” (airports, roads, stations, digital platforms, regulatory frameworks) that stabilise and channel flows. The complexity of contemporary mobility systems thus derives precisely from the coexistence of multiple mobilities and multiple fixities. Far from dissolving space, mobilities continuously rework spatial organisation by articulating flows with infrastructures, territories and institutional constraints. This insight provides a crucial conceptual foundation for rethinking transport systems not as neutral conduits for pre-given demand, but as socio-technical assemblages that actively produce, enable and constrain everyday mobility practices.

This emphasis on the coexistence of mobility and fixity is particularly relevant for transport and sustainability debates. While contemporary mobility appears increasingly fluid and flexible, it remains heavily dependent on material infrastructures, energy systems, land-use patterns, and institutional frameworks that are often carbon-intensive and spatially rigid. As a result, the expansion of mobility does not automatically translate into greater sustainability but may instead reinforce environmentally and socially problematic trajectories. The NMP thus provides a critical lens for questioning not only how much mobility occurs, but also which forms of mobility are promoted, for whom, and at what social and environmental cost.

Limits of the New mobilities paradigm for transport policy and behavioural intervention

Despite its substantial contribution to rethinking mobility as a socio-economical and technical phenomenon, the New Mobilities Paradigm presents important limitations when it comes to informing concrete transport policy design and behavioural intervention. While the paradigm effectively deconstructs sedentarist assumptions and highlights the embeddedness of mobility in social relations, infrastructures and power dynamics (Sheller & Urry, 2006; Urry, 2007; Sheller & Urry, 2016), it remains largely descriptive in orientation and comparatively weak in terms of analytical precision and operational guidance.

Beyond its well-established critique of static social theory and its emphasis on the dynamism of social interactions, the paradigm offers only a limited and often fragmented theoretical account of how contemporary mobility systems are actually organised, governed and reproduced. As several authors have noted, mobilities research has generated rich interpretative insights into meanings, representations and experiences of movement, but has remained relatively thin in its theorisation of transport systems as structured socio-technical configurations (Cresswell, 2010; Adey et al., 2014; Shaw & Hesse, 2010). With few exceptions, the paradigm provides little systematic analysis of institutional architectures, decision-making processes, demand formation mechanisms or the organisational logics through which everyday mobility is stabilised over time.

In this sense, the NMP often says more about *how* social life is mobile than about *how mobility systems work*. Its central claim that social relations are dynamic, relational and networked, while analytically valuable, remains at a relatively high level of abstraction and contributes only indirectly to the understanding of concrete transport dynamics. As a result, the paradigm produces limited cumulative knowledge about the functioning, transformation and governance of contemporary mobility systems beyond the general observation that they are complex, heterogeneous and socially embedded.

This theoretical under-specification becomes particularly problematic when the focus shifts from interpretation to intervention. Mobilities research offers few analytical tools for identifying where, how and under which conditions policy actors can intentionally intervene to reshape mobility demand and everyday travel behaviour in practice. The paradigm's emphasis on multiplicity, fluidity and contingency, although conceptually productive, tends to privilege interpretation over steering. As noted by several authors, this orientation risks marginalising questions of governance, policy effectiveness and behavioural regulation, which are central to transport planning and sustainability-oriented policymaking (Banister, 2008; Ison & Rye, 2008; Shaw & Docherty, 2014).

By concentrating primarily on how mobilities are produced, experienced and represented, the NMP under-specifies the mechanisms through which dominant, and often unsustainable, mobility practices can be destabilised and redirected toward more sustainable trajectories. It provides limited guidance on how choice contexts are structured, how routines are stabilised, how habits are formed, and how institutional and infrastructural constraints shape feasible behaviour over time.

From a transport policy perspective, this limitation is particularly consequential. Achieving sustainable mobility requires not only understanding the social meanings and inequalities associated with movement, but also developing instruments capable of influencing choice contexts, behavioural routines and demand formation processes over time (Banister, 2008; Holden et al., 2020). Consequently, the New Mobilities Paradigm alone is insufficient to support the design of demand-side and behaviour-oriented transport policies, especially in contexts where incremental behavioural change rather than radical systemic disruption is required.

For this reason, this thesis argues that insights from mobilities research must be complemented by theoretical frameworks explicitly concerned with system steering, behavioural change and policy intervention. The transition from mobilities as an analytical lens to sustainable mobility as a policy-oriented paradigm requires moving beyond critique toward approaches that integrate socio-technical transition theory, governance perspectives and behavioural models of action (Urry, 2011; Geels, 2014). Together, these frameworks provide a more operational foundation for governing mobility demand and for designing behaviour-sensitive transport policies, such as Travel Demand Management and Voluntary Travel Behaviour Change programs, which are examined in the following sections.

Mobilities, complexity, and sustainability transitions

This chapter discusses what the New Mobilities Paradigm can offer to the growing body of work within the field of sustainable transport. Although developed from different disciplinary traditions, the New Mobilities Paradigm and sustainable transport research converge in their critique of conventional transport planning, particularly its focus on traffic growth, infrastructure expansion, and efficiency-oriented performance indicators (Banister, 2008; Sheller & Urry, 2006; Urry, 2007; Geels, 2012; Cresswell, 2010). Both perspectives challenge the assumption that increasing mobility is inherently beneficial and instead emphasize the need to critically assess the social, environmental, and behavioural implications of prevailing mobility patterns. Their integration therefore provides a richer analytical framework for addressing sustainability challenges in transport, combining attention to material systems with insights into social practices and behavioural change.

While converging in their critique of conventional transport planning, these two bodies of literature have developed largely in parallel, drawing on different disciplinary traditions and analytical priorities. For this reason, the discussion begins by outlining key contributions from the New Mobilities Paradigm, particularly John Urry's reflections on sustainable mobility, before introducing Banister's Sustainable Mobility Paradigm as a more explicitly policy-oriented framework within transport studies.

As emphasized by Sheller and Urry (2016), the NMP draws on three major theoretical strands (complexity theory, socio-technical transitions theory, and social practice theory) which together provide a powerful framework for analysing sustainability transitions in mobility systems.

Within this perspective, complexity theory plays a significant role in conceptualizing mobility systems as complex adaptive systems evolving over time and space. From the mid-1990s onward, complexity-oriented approaches in the social sciences have highlighted how such systems are characterized by non-linearity, feedback loops, path dependency, and periods of relative stability punctuated by moments of rapid and often unpredictable change (Urry, 2011). Long phases of stabilization through technological, institutional, and behavioural lock-ins coexist with critical junctures in which small disturbances may trigger substantial system reconfigurations (Sheller & Urry, 2016). Importantly, this perspective underscores the decisive role of social institutions, governance arrangements, and collective practices in shaping long-term system trajectories.

When applied to urban and transport policy, this understanding challenges the traditional *predict and provide* paradigm, under which transport planning focused on expanding infrastructure to accommodate forecasted demand. From a complexity perspective, such an approach risks reinforcing unsustainable lock-ins by treating mobility demand as an exogenous variable. Instead, complexity theory supports a shift toward *predict and prevent* strategies, in which policy actively seeks to shape mobility demand in line with long-term sustainability objectives (Ison & Rye, 2008). This implies recognizing travel demand as co-produced by land-use patterns, transport supply, pricing

mechanisms, and behavioural norms, thereby reinforcing the relevance of demand-side approaches such as Travel Demand Management, which aim to influence when, how, and why people travel.

The second theoretical perspective informing the New Mobilities Paradigm is socio-technical transitions theory, which provides a framework for understanding how complex socio-technical systems such as mobility evolve over time through the interaction between technologies, infrastructures, institutions, markets and users' practices. This approach has significantly influenced how sustainable mobility transitions are conceptualized, analysed, and governed, both in retrospective analyses and future-oriented scenarios.

Central to this theory is the multi-level perspective, which conceptualizes transitions as the outcome of interactions between niches, socio-technical regimes, and socio-technical landscapes (Geels, 2006; Geels, 2014). Socio-technical regimes denote the dominant and stabilized configurations through which mobility systems are reproduced, encompassing not only prevailing technologies and infrastructures, but also institutional arrangements, regulatory frameworks, market structures, user practices, and shared cognitive and normative rules that coordinate and stabilise everyday mobility. Niches, by contrast, constitute protected spaces in which alternative technologies, organisational models, and behavioural patterns can emerge and be experimented with outside the selection pressures of the dominant regime. Landscapes refer to the broader and relatively exogenous socio-economic, political and cultural environment, including macro-trends, long-term structural changes and external shocks, that shapes the conditions under which regimes and niches evolve and interact, while remaining largely beyond the direct influence of individual actors.

Beyond its structural components, socio-technical transitions theory increasingly emphasizes the role of social and psychological dimensions in driving mobility transitions. Changes in technologies and infrastructures alone are insufficient to destabilize entrenched mobility regimes if users' preferences, habits, meanings, and normative expectations remain aligned with existing practices. As highlighted by Sheller and Urry (2016), transitions toward sustainable mobility therefore depend critically on shifts in attitudes, beliefs, social norms, and everyday practices, which influence both the uptake of niche innovations and the erosion of dominant regimes.

From this perspective, behavioural change is not a peripheral outcome of socio-technical transitions, but a central mechanism through which transitions unfold. Individual and collective mobility behaviours act as the interface between structural change and system-level transformation, mediating how new mobility options are perceived, adopted, routinized, or rejected. This insight directly anticipates the focus of the subsequent chapters, which examine how behavioural theories, behaviour-oriented policy instruments, and context-enabling solutions can support the diffusion of sustainable mobility practices and contribute to broader transition processes.

The third theoretical contribution underpinning the NMP is social practice theory, which shifts analytical attention from individual choices or technological systems to the practices through which mobility is routinely performed and reproduced. Social practices are understood as configurations of material elements (such as infrastructures and technologies), competences (skills, know-how, and

embodied routines), and meanings (social norms, values, and symbolic interpretations) that are dynamically interconnected (Shove, Pantzar, & Watson, 2012).

Applied to mobility, a practice-oriented perspective emphasizes that travel behaviour is embedded in everyday routines and social contexts rather than resulting from isolated, rational decisions. Mobilities emerge from the continuous interaction between people, places, technologies, and institutional arrangements, producing patterns of movement that are simultaneously stabilized and open to change. From this viewpoint, unsustainable mobility patterns persist not simply because of individual preferences, but because car-based practices are deeply anchored in existing material infrastructures, cultural meanings, and competences.

In the context of sustainability transitions, social practice theory suggests that achieving lower-carbon mobility requires the transformation or replacement of dominant mobility practices rather than marginal adjustments to individual behaviour. This entails reconfiguring the material and organizational conditions of mobility, redefining social meanings associated with travel, and supporting the development of new competences related to alternative modes and multimodal travel. These insights strongly resonate with behaviour-oriented and context-enabling policy approaches discussed later in this thesis, including Travel Demand Management, Voluntary Travel Behaviour Change programs, and Mobility as a Service, all of which can be interpreted as attempts to reshape mobility practices rather than merely influencing isolated travel choices.

The Sustainable mobility paradigm and policy implications

What Banister (2008) has termed the *Sustainable Mobility Paradigm* builds on a critical reflection on the environmentally and socially problematic implications of contemporary transport systems, a debate that gained momentum in the 1970s following the oil crisis. This critique, initially environmental and moral in nature, questioned the cultural, social, and territorial consequences of mass motorization. Importantly, the Sustainable Mobility Paradigm does not reject mobility per se, but redefines its role by shifting the analytical focus from movement to accessibility, quality of life, and environmental limits.

By foregrounding accessibility rather than mobility volumes, this paradigm implicitly challenges the assumption that travel demand should be treated as exogenous and accommodated through infrastructure expansion. Instead, it opens the conceptual space for policies that actively shape mobility demand and travel behaviour through spatial organization, digital substitution, and behavioural change, rather than relying exclusively on technological efficiency gains. In doing so, the paradigm aligns with broader sustainability discourses that emphasize sufficiency, equity, and well-being over growth-oriented performance metrics, with significant implications for transport policy and planning.

Presented in his article *The Sustainable Mobility Paradigm* (Banister 2008), this approach primarily questioned two of the underlying principles of conventional transport planning: that travel is a derived

demand, and that travel time is a cost minimization. In relation to the first point, Banister claimed that for work-home commuting time is important, but since travel patterns changed and leisure-based movement increased, travel time may become more of a positively valued activity (Mokhtarian, Salomon 2001). Furthermore, the escape theory proposed by Heinze (2000) hypothesizes that leisure mobility is an attempt to get away from one's everyday environment to do something completely different. Hence, a substantial amount of leisure-based travel could be undertaken for its own sake and then the activity of travelling is valued. This reconsideration of travel as not exclusively instrumental has important implications for transport policy, as it challenges purely efficiency-driven approaches and calls for a broader understanding of mobility practices and their social meanings.

Regarding the second point, Banister states that there is some kind of contradiction between the users' desire to travel faster saving in travel time and the decision-makers' effort actually going into to slow traffic down for environmental and safety reasons. Consequently, the policy objective shifts from minimizing travel time to ensuring reasonable and reliable travel times, emphasizing system quality, predictability, and user experience rather than speed alone.

Taken together, these critiques highlight a fundamental shift in the rationale of transport analysis and planning: from accommodating mobility demand through infrastructure expansion toward actively shaping mobility patterns in line with social, environmental, and behavioural objectives.

Then, Banister adapts a table from Marshall's *The challenge of sustainable transport* (2001) to compare the conventional approach of Transport Planning and Engineering and the alternative approach of Sustainable Mobility. The primary concepts of both approaches are illustrated in Table 1.

Table 1 Contrasting approaches to transport planning

The conventional approach — transport planning and engineering	An alternative approach — Sustainable mobility planning
Physical dimensions	Social dimensions
Mobility	Accessibility
Traffic focus, particularly on the car	People focus, either in (or on) a vehicle or on foot
Large in scale	Local in scale
Street as a road	Street as a space
Motorized transport	All modes of transport often in a hierarchy with pedestrian and cyclist at the top and car users at the bottom
Forecasting traffic	Visioning on cities
Modelling approaches	Scenario development and modelling
Economic evaluation	Multicriteria analysis to take account of environmental and social concerns
Travel as a derived demand	Travel as a valued activity as well as a derived demand
Demand based	Management based
Speeding up traffic	Slowing movement down
Travel time minimization	Reasonable travel times and travel time reliability
Segregation of people and traffic	Integration of people and traffic

Source 1 Banister (2008), adapted from Marshall (2001)

The contrast illustrated in Table 1 reflects more than a conceptual reorientation of transport planning; it implies a fundamental transformation in the nature of policy instruments required to achieve sustainable mobility. By shifting the analytical focus from mobility volumes to accessibility, and from traffic growth to demand management, the Sustainable Mobility Paradigm explicitly challenges the assumption that mobility outcomes can be governed primarily through infrastructure provision and technological efficiency (Banister, 2008). Instead, it foregrounds the role of travel demand as a policy-relevant variable, shaped by behavioural choices, spatial organization, and institutional contexts rather than treated as an exogenous constraint.

Consistent with the New Mobilities Paradigm, the Sustainable Mobility approach treats transport as embedded within broader social, economic, and spatial systems (Banister, 2008). Travel is therefore understood not only as movement between locations, but as a practice interconnected with everyday activities, spatial organization, and institutional arrangements. This systemic perspective reinforces the idea that travel behaviour is shaped by the interaction between transport systems, land use, and social practices, and can thus be influenced through coordinated policy interventions that extend beyond infrastructure provision alone.

In summary, the Sustainable Mobility approach requires actions to reduce the need to travel (less trips), to encourage modal shift, to reduce trip lengths, and to encourage greater efficiency in the transport system. Within this framework, logically, mobility can become more sustainable if we travel more efficiently, travel differently, and/or travel less.

This implication becomes particularly evident when considering the Avoid–Shift–Improve (ASI) framework, which has emerged as a central operationalization of sustainable mobility strategies (Holden et al., 2020; GIZ, 2011). The first one, the Reduction or Avoid strategy encourages efforts to reduce motorized travel (except for those whose basic transport needs are not yet met) by travelling less and making shorter trips. The Alteration or Shift strategy attempts to change existing transport patterns currently dominated by automobiles through a modal shift towards more sustainable forms of transport. The last one, Efficiency or Improve, suggests that environmental performance and accessibility can be improved through more efficient novel technologies implemented in all parts of the transport system, including motorized transport vehicles, transport infrastructure, and the energy system.

Within the ASI framework, the Avoid and Shift strategies are particularly dependent on changes in travel behaviour and decision-making processes. While Improve strategies primarily rely on technological and infrastructural interventions, Avoid and Shift require individuals to reconsider established mobility practices, routines, and preferences. This behavioural dimension highlights the limitations of purely supply-oriented approaches and underscores the need for policy instruments capable of influencing how, when, and why people travel. This includes instruments that act on the choice context, information environment, and behavioural routines underpinning everyday mobility practices, rather than solely on network capacity or vehicle performance. From this perspective, Travel Demand Management and Voluntary Travel Behaviour Change programs emerge not as complementary or “soft” measures, but as structurally necessary components of sustainable mobility policy, providing the means through which the normative objectives of the paradigm can be translated into effective and socially embedded interventions.

Concluding synthesis: mobility and sustainability as an analytical reorientation

This chapter has framed the relationship between mobility and sustainability as a fundamental analytical reorientation rather than as a purely normative objective of transport policy. By reviewing the evolution of sustainability concepts and their application to the mobility domain, the chapter has shown that sustainable mobility cannot be understood as the simple optimization of transport systems, nor as the technological decarbonization of existing mobility patterns. Instead, sustainability introduces a set of systemic constraints that fundamentally reshape how mobility demand, behaviour, and policy interventions must be conceptualized.

A central insight emerging from this chapter is that mobility is not an end in itself, but a derived demand whose social value lies in enabling access to activities, opportunities, and services. From a

sustainability perspective, this implies a shift away from maximizing movement toward optimizing accessibility, equity, and environmental performance. These reframing challenges long-standing assumptions in transport planning that equate increased mobility with social and economic progress, and instead foregrounds questions of necessity, efficiency, and distribution.

By situating mobility within the broader sustainability discourse, the chapter has highlighted the inherent limitations of supply-oriented and technology-centric approaches. While technological innovation plays a key role in reducing environmental impacts, it is insufficient to address the social, spatial, and behavioural dimensions of unsustainable mobility patterns. Sustainability thus emerges not as a sector-specific goal, but as a cross-cutting criterion that requires coordinated interventions across land use, transport systems, and individual behaviour.

At the same time, the chapter has shown that the two paradigms that have most strongly contributed to rethinking mobility in recent decades also display important analytical limitations when considered from a policy and intervention perspective. The New Mobilities Paradigm has provided a powerful critique of sedentarist assumptions and a rich understanding of mobility as a socio-technical and socio-cultural phenomenon, but remains largely descriptive and offers limited guidance for the design of concrete policy instruments and behavioural interventions. Conversely, the Sustainable Mobility Paradigm has introduced a strong normative orientation toward environmental performance and system efficiency, but has often remained anchored in aggregate indicators and technology-led strategies, paying comparatively little attention to the micro-foundations of travel demand, everyday practices, and behavioural change processes.

Within this landscape, the chapter has highlighted the continued relevance of the Avoid–Shift–Improve (ASI) framework as a pragmatic and integrative analytical device. By explicitly distinguishing between demand reduction (avoid), modal reallocation (shift), and technological efficiency (improve), the ASI model provides a simple but conceptually robust structure for linking sustainability objectives with concrete policy levers across infrastructure, services, and behaviour. Importantly, ASI offers a bridge between systemic transition perspectives and behaviour-oriented interventions, making it possible to locate travel demand management and voluntary behavioural change within a coherent sustainability strategy rather than treating them as marginal or auxiliary instruments.

This analytical perspective provides the conceptual foundation for the subsequent chapters of the thesis. By redefining sustainable mobility as a systemic outcome generated through the interaction between activity patterns, transport systems, and behavioural processes, the chapter prepares the ground for a demand-oriented and behaviour-sensitive analysis of travel. In particular, it establishes the rationale for focusing on travel demand management and voluntary behavioural change as key policy domains in which sustainability objectives can be operationalized.

More broadly, the chapter positions sustainability as a lens through which mobility policies must be evaluated not only in terms of efficiency and performance, but also in terms of their capacity to reshape demand, influence behaviour, and support long-term transitions toward less resource-

intensive mobility practices. In doing so, it bridges normative sustainability goals with the analytical and empirical focus of the thesis, setting the stage for the examination of travel behaviour, demand management strategies, and context-enabling solutions developed in the following chapters.

Transportation systems: conceptual framework and system characterization

This chapter introduces the conceptual framework of transportation systems, which constitute the structural, institutional, and operational context within which travel demand and travel behaviour emerge, evolve, and can be influenced through policy intervention. Rather than focusing on mobility outcomes in isolation, the chapter situates travel demand and behaviour within the broader system that shapes available opportunities, constraints, and incentives for movement.

Building on the sustainability-oriented mobility paradigms discussed in the previous chapter, this chapter adopts a systemic view of transportation, moving beyond a purely technical interpretation of transport infrastructure, services and energy. Transportation systems are conceptualized as complex socio-technical systems, in which physical networks, technological components, regulatory frameworks, governance arrangements, and human behaviour are deeply interdependent. Within such systems, mobility outcomes are not the result of isolated decisions or single interventions, but emerge from the interaction between transport supply, spatial organization, institutional settings, and users' behavioural responses over time.

The chapter takes transportation systems engineering as an analytical starting point, drawing in particular on the definition proposed by Cascetta, while progressively extending the analysis to incorporate behavioural, institutional, and contextual dimensions. This integrated perspective allows transportation systems to be framed as Complex Large-Scale Integrated Open System (CLIOS), characterized by non-linear interactions, feedback mechanisms, multiple actors, and different temporal scales of change. Such characterization is especially relevant for understanding why transport systems often display path dependency, resistance to change, and unintended consequences of policy interventions.

By clarifying the structure, components, and dynamics of transportation systems, this chapter establishes the system-level context within which travel demand is generated, and behavioural choices are made. It highlights why policies aimed at influencing mobility outcomes cannot operate solely at the level of individual behaviour or infrastructure provision but must account for the systemic interactions that shape accessibility, performance, and choice environments. In doing so, the chapter provides the conceptual foundation for the subsequent analysis of travel demand, travel behaviour, and behaviour-oriented demand-side policies developed in the following chapters.

Concept and definition of transportation system

Having established the broader sustainability-oriented and behavioural perspective adopted in this thesis, it is necessary to clarify the concept of transportation system as the analytical foundation for

the study of travel demand and travel behaviour. Over the past decades, a substantial body of literature has developed around the definition and characterization of transportation systems, drawing on different disciplinary traditions, including transportation engineering, economics, geography, and the social sciences. Among these, the transportation systems engineering perspective has played a significant role in formalizing the system-level understanding of transport phenomena.

Within this tradition, a transportation system is defined as a set of interconnected physical, organizational, and institutional elements whose interactions generate both the demand for travel within a given area and the provision of transport services to satisfy that demand (Cascetta, 2001; Cascetta, 2009). This definition is particularly relevant for the purposes of this thesis, as it explicitly conceptualizes travel demand not as an exogenous input to the system, but as an endogenous outcome of the interactions between transport supply, spatial organization, and users' activity patterns and behavioural decisions. In this sense, demand and supply are co-produced within the same system rather than treated as separate or sequential components.

By framing travel demand as an internal component of the transportation system, this definition moves beyond simplified representations in which mobility demand is assumed to be fixed or given. Instead, it highlights that demand emerges from the need to access activities and opportunities distributed in space and time, and is continuously shaped by changes in infrastructure, service provision, pricing, regulation, and individual behaviour (Cascetta, 2009; Rodrigue, Comtois, & Slack, 2016). This systemic view provides a crucial conceptual bridge between transport system analysis and behavioural approaches to mobility, anticipating later discussions on how demand can be influenced through policy intervention.

Transportation systems are also embedded within broader economic, social, and territorial contexts. They enable and constrain economic exchanges, social interactions, and everyday practices, and are therefore integral components of societal organization. Although the notion of a "system" may suggest a coherent structure operating at national or metropolitan scale, both travel demand and transport supply exhibit significant spatial heterogeneity, reflecting demographic characteristics, land-use patterns, institutional arrangements, and cultural contexts (Colleoni, 2019). As a result, transportation systems display highly differentiated configurations and performance outcomes across territories.

The generality and flexibility of Cascetta's definition allows it to be adapted to different analytical purposes and spatial scales. Depending on the research question, the system boundary can be defined narrowly, focusing on specific modes, networks, or services, or more broadly, incorporating land-use systems, governance structures, and behavioural responses. This adaptability is particularly important for the present research, which progressively extends the analysis from a system-level characterization toward a deeper examination of travel demand, travel behaviour, and behaviour-oriented policy instruments. By adopting this systemic definition as a starting point, the chapter establishes the analytical conditions for understanding how mobility outcomes emerge from the

interaction between technical components and human behaviour, and why effective policy interventions must address both dimensions simultaneously.

Transportation as a Complex Large-Scale Integrated Open System (CLIOS)

To characterize transportation systems and to identify their main components and interrelations, a growing body of literature suggests adopting the conceptual framework of Complex Large-Scale Integrated Open System (CLIOS). Originally developed by Sussman (2000, 2002), the CLIOS framework has proven particularly useful for analysing transportation systems, as it captures their inherently socio-technical nature and the complex interactions between physical infrastructures, organizational arrangements, institutional settings, and human behaviour. In the context of sustainable mobility, this perspective allows transportation systems to be examined not merely as technical artefacts, but as dynamic systems in which behavioural responses and policy decisions interact with material networks through multiple feedback mechanisms (Sussman, 2000).

The acronym of CLIOS refers to complex, large-scale, integrated, and open systems. According to Sussman (2000), a system can be defined as complex when it is composed of multiple interrelated components and subsystems whose interactions are characterized by uncertainty with respect to directionality, magnitude, and temporal scale. Even when the behaviour of individual subsystems is relatively well understood, the aggregate behaviour of the system as a whole may be difficult to predict and often counterintuitive, particularly in the presence of human decision-making and adaptive responses. This property makes the CLIOS framework especially well suited to the analysis of transportation systems, where user behaviour, institutional choices, and technological configurations continuously co-evolve.

Sussman (2000, 2002) identifies four interrelated dimensions of complexity that are particularly relevant for transportation systems.

1. *Internal complexity*: the first dimension is internal complexity, which refers to the multiplicity of physical and organizational components that constitute the system, including infrastructure networks, vehicles, control systems, pricing mechanisms, regulatory frameworks, and travel demand itself. These elements are interconnected through dense networks of interactions, such that changes in one component can propagate throughout the system. Importantly, within this perspective, travel demand and supply are not separate entities, but mutually interdependent components whose interaction shapes system performance over time (Cascetta, 2001; Cascetta, 2009).
2. *Behavioural complexity*: the second dimension is behavioural complexity, which arises from the adaptive and often non-linear interactions between system components and users' behaviour. Travel choices influence congestion levels, service performance, and costs, which in turn feed back into future travel decisions, generating multiple feedback loops operating at

different temporal scales. Behavioural complexity is particularly pronounced in transportation systems because users continuously adjust their decisions in response to both experienced and anticipated system conditions, often under conditions of bounded rationality and habit formation. This dimension highlights why behavioural responses cannot be treated as static or exogenous but must be considered an integral part of system dynamics (Sussman, 2000; Cascetta, 2009).

3. *Evaluative complexity*: a third dimension concerns evaluative complexity, which stems from the presence of multiple stakeholders and decision-makers with divergent objectives, values, and criteria for assessing system performance. Public authorities, transport operators, users, private firms, and civil society actors may prioritize efficiency, accessibility, equity, environmental quality, or economic competitiveness in different ways. As a result, there is no single, unambiguous definition of optimal system performance, and policy interventions are often the outcome of negotiation and trade-offs among competing perspectives. This evaluative complexity is particularly relevant for sustainable mobility policies, which require balancing environmental goals with social inclusion and economic viability.
4. *Nested complexity*: the fourth dimension is nested complexity, which refers to the embedding of transportation systems within broader institutional, economic, social, and political systems. Decisions made within the policy system, such as land-use regulation, pricing policies, or investment priorities, interact with the physical transportation system and influence behavioural responses over time. Conversely, observed mobility patterns and behavioural outcomes can trigger institutional learning and policy adjustment. This nested structure highlights why interventions targeting travel behaviour must operate simultaneously at multiple levels, addressing not only individual choices but also the institutional and regulatory contexts that shape them (Sussman, 2000).

Taken together, these dimensions indicate that transportation systems cannot be adequately understood or governed through linear cause–effect relationships. Instead, they require analytical frameworks capable of capturing feedback mechanisms, behavioural adaptation, institutional dynamics, and long-term structural change. Transportation systems are also characterized by large spatial extent and long temporal horizons, as their impacts unfold across regions and over extended periods. Through their interaction with land-use patterns, economic activities, and social practices, transportation systems exert considerable influence on environmental conditions, urban form, quality of life, and social cohesion (Cascetta, 2001; Cascetta, 2009; Colleoni, 2019).

Given this complexity, transportation systems engineering traditionally adopts an analysis system approach, which involves isolating those elements and interactions that are most relevant to the problem under investigation, while treating the remaining elements as part of the external environment. However, even within such simplified representations, travel demand and user behaviour cannot be treated as exogenous inputs. Rather, they constitute endogenous components that actively interact with infrastructure, services, pricing, and regulatory arrangements. This has

important implications for policy design: interventions aimed at improving system performance or sustainability must anticipate behavioural responses and feedback effects, rather than relying solely on technical or infrastructural solutions.

Finally, transportation systems qualify as open systems, as they are continuously influenced by external social, economic, political, and technological developments, such as demographic change, energy transitions, digitalization, and shifts in societal values. This openness reinforces the need for adaptive, behaviour-sensitive, and context-aware policy approaches, anticipating the later discussion on Travel Demand Management, Voluntary Travel Behaviour Change programs, and context-enabling solutions such as Mobility as a Service.

Internal structure and components of transportation systems

Considering transportation systems as a specific instance of Complex Large-Scale Integrated Open System (CLIOS), and adopting the analysis system approach outlined above, it is possible to identify the main internal components of transportation systems and the network of interactions that connect them. This internal perspective is essential for understanding how mobility outcomes emerge from the interplay between physical infrastructure, services, institutional arrangements, and user behaviour.

According to Cascetta (2001, 2009), transportation systems consist of two fundamental and interdependent components: demand and supply (Figure 1). Travel demand derives from the need to access urban functions and services, conceptualized as opportunities in Hansen's (1959) accessibility framework, distributed across space. These opportunities act as attractors of mobility flows and are shaped by the spatial organization of households, employment, education, retail, and other activities.

The diagram illustrates a conceptual model of the transportation system, organized into three main functional areas: **SUPPLY**, **DEMAND**, and the **ACTIVITY SYSTEM**.

SUPPLY (Top Left): This section focuses on the provision of transportation services. It includes:

- TRANSPORTATION FACILITIES AND SERVICES** and **SUPPLY ELEMENT CAPACITIES**, which both influence **TRANSPORTATION SERVICE PERFORMANCE**.
- CONGESTION** is a critical factor that arises from the interaction of supply capacities and demand, directly impacting **TRANSPORTATION SERVICE PERFORMANCE**.

DEMAND (Bottom Left): This section represents the need for transportation. It includes:

- LEVEL AND SPATIAL DISTRIBUTION OF TRAVEL DEMAND**, which determines the **TRAVEL DEMAND BY TRANSPORTATION MODE**.
- The travel demand then flows into the **FLOWS ON MODAL NETWORKS**, which in turn contributes to the overall **CONGESTION** within the system.

ACTIVITY SYSTEM (Right): This system governs the spatial and economic activities that generate and are affected by transportation. It includes:

- ACCESSIBILITY** (comprising active and passive components) is a central concept that is influenced by the **NUMBER AND LOCATION OF HOUSEHOLDS BY TYPE** and **SPACE AVAILABILITY BY AREA AND TYPE**.
- The **LEVEL AND LOCATION OF ECONOMIC ACTIVITIES** is also shaped by these factors and, in turn, influences the **ACCESSIBILITY**.
- The **ACTIVITY SYSTEM** as a whole has a direct impact on the **TRANSPORTATION SERVICE PERFORMANCE** and the resulting **CONGESTION**.

Interactions and Feedback Loops: The model shows a complex web of interactions. For instance, **TRANSPORTATION SERVICE PERFORMANCE** affects **CONGESTION**, which then feeds back into the **DEMAND** side through the modal networks. Similarly, the **ACTIVITY SYSTEM** influences the **DEMAND** by determining where and how people live and work, which then affects the transportation system's performance and congestion levels.

transportation system users respond to this spatial distribution through a combination of long-term mobility choices (such as car ownership, residential location, and subscription to mobility services) and short-term travel choices (such as destination, mode, route, and departure time). These decisions give rise to observed travel demand flows, namely the trips made between different zones, for different purposes and at different times of day, often involving the sequential use of multiple facilities and modes (Sussman, 2000).

Crucially, these choices cannot be interpreted as purely technical or automatic responses to system conditions. Rather, they reflect behavioural decision-making processes shaped by preferences, habits, constraints, perceptions, and available information. As emphasized in travel behaviour and demand modelling literature, observed travel demand represents the aggregate outcome of individual behavioural processes mediated by the structure, performance, and organization of the transportation system (Ortúzar & Willumsen, 1994; Ben-Akiva et al., 2002; Cascetta, 2009; Banister, 2008). This behavioural interpretation is particularly relevant for sustainable mobility, as it implies that changes in infrastructure or service provision alone may be insufficient to alter travel demand if users' perceptions, routines, and decision-making processes remain unchanged.

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systems, regulations, and pricing mechanisms. Infrastructure, typically the fixed component of the system, can be further distinguished into guideways (such as roads and railways), terminals regulating departures and arrivals, and stations facilitating passenger access. Vehicles represent the mobile components of the system and are intrinsically linked to propulsion or power systems, which determine energy use and environmental impacts.

Additional key components include control, communication, and location systems, which govern traffic management, service coordination, and network operation. Increasingly, these functions are performed through automated and digital technologies rather than direct human control, reinforcing the socio-technical character of transportation systems. Supply is further shaped by regulatory frameworks that define service levels, safety standards, market access, and public obligations, as well as by pricing mechanisms that influence both provider behaviour and user choices.

From a conventional economic perspective, prices are often interpreted as the outcome of an equilibrium between transportation supply and demand. However, transport systems exhibit several structural characteristics that complicate this relationship (Rodrigue, Comtois & Slack, 2016). High entry costs (such as capital investments and fixed costs) in many transport modes limit the capacity of supply to adjust rapidly to demand fluctuations and tend to produce oligopolistic market structures. Moreover, the strong involvement of public authorities in transport provision and regulation frequently disrupts market-based pricing mechanisms, resulting in subsidized fares and non-marginal cost pricing. Finally, demand elasticities vary significantly across modes and trip purposes, further complicating the relationship between costs and observed travel behaviour.

Within this complex structure, transportation systems are characterized by multiple feedback cycles linking demand, supply, and system performance (Cascetta, 2001; 2009). The innermost feedback loop involves the interaction between traffic flows, congestion, and generalized travel costs: increased flows reduce service performance, which in turn affects users' route and departure time choices. Outer feedback cycles operate over longer time horizons, influencing modal split and destination choice. At an even broader temporal scale, interactions between travel demand, accessibility, and land-use patterns shape residential and activity location decisions, thereby modifying the spatial structure that generates future travel demand.

These feedback mechanisms highlight that travel demand and user behaviour are not only shaped by system performance, but also actively contribute to shaping it over time. Transportation systems therefore evolve through a continuous co-evolution of infrastructure, services, spatial organization, and behavioural responses. System performance directly affects active and passive accessibility, defined as the generalized cost of reaching other zones or being reached from them, which in turn influences land values, activity location, and long-term mobility patterns.

Taken together, this analysis confirms that transportation systems are characterized by non-linear interactions, multiple temporal scales, and strong interdependencies between technical and behavioural components. While some elements of the system, such as infrastructure and vehicles,

are governed primarily by physical laws and engineering principles, overall system performance critically depends on how users interact with these elements through their travel behaviour. Consequently, travel demand cannot be treated as an exogenous input but must be understood as an endogenous component of the system.

Conceptualizing transportation systems as Complex Large-Scale Integrated Open System has important implications that extend beyond analytical modelling and system description to the domain of policy design and governance. If transportation systems are characterized by non-linearity, feedback loops, behavioural adaptation, and path dependency, then policy interventions cannot be expected to produce proportional, linear, or fully predictable outcomes (Sussman, 2000; Sussman, 2002; Cascetta, 2009). From a CLIOS perspective, transport policies that focus exclusively on infrastructure expansion or technological optimization risk reinforcing existing system lock-ins rather than steering mobility systems toward more sustainable configurations.

Crucially, the behavioural complexity inherent in transportation systems implies that users' responses are not passive reactions to system changes, but active and adaptive processes that shape system performance over time (Cascetta, 2001; Ben-Akiva et al., 2002). Travel behaviour therefore constitutes a central mechanism through which policy interventions propagate within the system, generating intended and unintended effects through multiple feedback cycles. Ignoring behavioural responses or treating them as exogenous variables undermines the effectiveness of policy measures and contributes to well-documented phenomena such as induced demand, rebound effects, and policy resistance (Banister, 2008; Ison & Rye, 2008).

From this perspective, CLIOS provides a strong theoretical justification for behaviour-oriented and adaptive transport policies that explicitly account for learning processes, habit formation, and context-dependent decision-making. Rather than relying on one-off, static interventions, effective policy design requires instruments capable of influencing choice environments, monitoring behavioural responses, and adjusting over time in response to observed system dynamics (Sussman, 2000; Urry, 2011). This interpretation positions demand-side measures and behaviour-sensitive approaches not as marginal complements to conventional transport policy, but as rational and necessary responses to the intrinsic complexity of transportation systems, a logic that underpins the subsequent focus of this thesis on Travel Demand Management and Voluntary Travel Behaviour Change programs.

Concluding synthesis: transportation systems as the structural foundation of mobility behaviour

This chapter has conceptualized transportation systems as complex socio-technical configurations in which infrastructure, technologies, institutions, and actors interact to shape mobility opportunities and constraints. Moving beyond purely technical or supply-oriented interpretations, the analysis has

emphasized that transport systems do not merely accommodate travel demand but actively structure the conditions under which mobility practices emerge, evolve, and stabilize.

By framing transportation systems as embedded within broader economic, social, and territorial contexts, the chapter has highlighted the systemic nature of mobility outcomes. Network design, service organization, regulatory arrangements, and technological choices jointly influence accessibility patterns, modal availability, and the relative attractiveness of different travel options. In this sense, transport systems operate not only as physical infrastructures, but as enabling, or constraining, environments that shape everyday mobility decisions.

This systemic perspective has important implications for the analysis of travel demand and behaviour. If transport systems are understood as neutral backdrops, demand appears as an exogenous phenomenon to be forecasted and accommodated. Conversely, when systems are conceptualized as socially produced and institutionally governed structures, travel demand must be understood as an endogenous outcome of system configuration, accessibility conditions, and behavioural responses. This shift in perspective provides the conceptual bridge toward demand-side and behaviour-oriented approaches developed in the subsequent chapters.

By establishing transportation systems as the structural foundation of mobility behaviour, this chapter lays out the groundwork for a critical examination of travel demand as a differentiated, context-dependent, and socially constructed phenomenon. The following chapter builds on this foundation by focusing explicitly on travel demand characterization, examining how system-level conditions translate into heterogeneous mobility patterns, behavioural choices, and unequal access to opportunities.

Travel demand characterization: concepts, features, and behavioural foundations

As discussed in the previous chapter, transportation systems consist not only of physical and organizational components that interact to provide mobility opportunities, but also of the demand that makes use of these opportunities to travel from one place to another. Travel demand emerges from the interaction between transport supply and the spatial distribution of economic and social activities, such as housing, education, retail, employment, and services, which act as generators and attractors of mobility flows within a given area (Cascetta, 2009).

Travel demand characterization represents a foundational step in transport analysis, as it provides the conceptual basis for understanding how, why, and under which conditions mobility occurs. In the literature, the study of travel demand has been approached from different disciplinary perspectives, each emphasizing specific dimensions of mobility phenomena.

A first, well-established tradition is the engineering and transport economics approach, which conceptualizes travel demand as the aggregate outcome of individual trips generated by the spatial distribution of activities and constrained by the performance of transport systems. Within this framework, travel demand is treated as a measurable flow, typically expressed in terms of trips, passengers, or vehicle-kilometers, and analyzed through formal models aimed at forecasting demand and supporting infrastructure and service planning (Cascetta, 2009; Ortúzar & Willumsen, 1994). This approach has been central to the development of transport system modelling and remains essential for operational and policy-oriented analysis.

Alongside this perspective, a second and complementary tradition has emerged from transport geography, urban studies, and the social sciences, which conceptualizes mobility not only as aggregate outcome of individual trips, but also as a socially embedded practice. Alongside this perspective, a second and complementary tradition has emerged from transport geography, urban studies, and the social sciences, which conceptualizes mobility not only as an aggregate outcome of individual trips, but also as a socially embedded practice of mobile individuals, shaped by their socio-demographic and territorial characteristics. From this viewpoint, travel demand is understood as part of broader mobility systems that reflect social structures, accessibility conditions, and individual capabilities to move, as shaped by the aforementioned characteristics. (Rodrigue, Comtois, & Slack, 2016; Kaufmann, 2002). This approach highlights the differentiated, subjective, and context-dependent nature of mobility, drawing attention to issues of accessibility, social inclusion, and the mutual shaping of transport systems and spatial organization.

Rather than representing competing paradigms, these approaches are increasingly understood as complementary and mutually reinforcing. While engineering-based models focus on mobility flows and urban planning addresses transport planning and the spatial distribution of settlements, socio-

geographical perspectives offer critical insights into behavioural, social, and spatial processes, addressing service provision (economics), as well as individual characteristics examined in sociology and psychology.

Integrating these perspectives is particularly important in the context of sustainable mobility, where influencing travel demand requires not only infrastructural and technological interventions, but also an understanding of how individuals perceive, experience, and adapt their mobility practices.

In this integrated perspective, travel demand emerges as a complex phenomenon resulting from the interaction between activity systems, spatial structures, transport supply, and individual behaviour. The present chapter adopts this multidimensional view to characterize travel demand, combining formal definitions and measurable features with a discussion of behavioural, social, and spatial determinants. This provides a conceptual bridge toward the subsequent chapters, which focus more explicitly on travel behaviour, behavioural change processes, and policy instruments aimed at influencing mobility demand.

Definition and measurement of Travel demand

Travel demand is defined as the number of users with given characteristics consuming particular services offered by a transportation system in a given time period. It's clear that travel demand flows result from the aggregation of individual trips (Cascetta, 2009). Although travel demand is commonly represented through aggregate indicators and flows, it ultimately results from the aggregation of individual travel decisions and behaviours, which are shaped by both objective constraints and subjective preferences.

Furthermore, travel demand represents the expression of transport needs, even if those needs are satisfied fully, partially, or not at all, and is expressed in terms of number of people (or volume, or tons when it comes to freight transport) per unit of time and space (Rodrigue, Comtois, Slack, 2016).

More pointedly, it's represented by T_{ij} , which expresses the travel demand between two locations, i and j , during the reference period. Regarding the unit of measurement, the passenger-km is a common measure expressing the passenger travel demand as it compares a transported quantity of passengers by a defined mode of transport with a distance over which it gets carried.

Further concepts worth defining include trip, trip chain, and path (Cascetta 2009). The first is defined as the act of moving from one place (origin) to another (destination) using one or more modes of transportation, to carry out one or more activities. Trip chain refers to a sequence of trips, following each other in such a way that the destination of one trip coincides with the origin of the next. The last one, path, is defined as a sequence of consecutive links (of a network) without loops, characterized by a dominant trip purpose, which connects an origin and a destination of trip without activities in intermediate locations, in a reference time inside the day (Musolino 2022).

Beyond this definition, further distinction could be made. Literature, especially in the fields of engineering, architecture, and urban planning, with an essentially transport perspective, distinguishes two types of travel demand: potential travel demand and realized travel demand (Rodrigue, Comtois, Slack 2016). The first one denotes the amount of mobility flows if transport costs were negligible. The second one, the realized travel demand is a subset of the potential transport demand and represents the flows that actually takes place, namely in view of costs between the origins and the destinations.

Key features of travel demand

Having established this first overall taxonomy, it must be noted that everyday urban travel demand is an increasingly varied phenomenon, characterized by manifold forms and unprecedented pervasiveness. Indeed, in the literature several important features are found relating to the nature of travel demand, such as those following below (Ortuzar, Willumsen 1994).

These features highlight that travel demand cannot be fully understood as a homogeneous or purely quantitative phenomenon, but rather as the outcome of heterogeneous behaviours, constraints, and opportunities that differ across individuals, contexts, and spatial settings. These latent and subjective dimensions of mobility demand challenge traditional transport modelling approaches, which often struggle to capture attitudes, perceptions, habits, and lifestyles, thereby motivating the integration of behavioural theories into travel demand analysis (Ben-Akiva et al., 2002; Walker, 2001).

To begin with, the demand for mobility is inherently *subjective*. Travel demand and the underlying mobility behaviour are always the expression of individual characteristics that extend beyond socio-demographic attributes to include psycho-cognitive factors such as attitudes, values, habits, perceptions, and lifestyle orientations (Kaufmann, 2002). These unobserved factors, often referred to as latent variables, play a crucial role in shaping how individuals perceive mobility opportunities, evaluate constraints, and make travel decisions.

This emphasis on subjectivity resonates strongly with the conceptual shift introduced by the New Mobilities Paradigm, which challenged traditional, a-mobile approaches within the social sciences by foregrounding the role of movement in structuring social relations and everyday life (Sheller & Urry, 2006; Urry, 2007). From this perspective, mobility demand cannot be fully captured through observed trips alone, as it is mediated by meanings, aspirations, social norms, and embodied practices that influence how mobility is experienced and enacted.

Consequently, emerging strands of social science research sensitive to complex and plural mobilities have called for a redefinition of both the objects of inquiry and the methodological tools used to study travel demand. This has led to the integration of qualitative and mixed-method approaches alongside traditional quantitative models, aimed at capturing the subjective and behavioural dimensions underlying observed mobility patterns. As a result, travel demand is increasingly understood both as an aggregate flow, which provides information on movement intensity, and as the observable outcome of individual decision-making processes that translate opportunities, constraints, and preferences into concrete mobility practices.

Second, travel demand is *differentiated*. Mobility is not a uniform phenomenon but is composed of multiple dimensions that extend beyond the spatial act of movement, encompassing the networks that support mobility, the resources required to move, and the capacities individuals possess to access and use transport systems (Canzler et al., 2008). This understanding resonates with the New Mobilities Paradigm, which explicitly conceptualizes mobility in the plural, directing analytical attention to the heterogeneous meanings, practices, and conditions of possibility associated with movement across different social groups and territorial contexts (Sheller & Urry, 2006; Pucci & Vecchio, 2019).

From this perspective, travel demand varies not only in quantitative terms, but also in its qualitative characteristics, including propensity to travel, intensity, temporal patterns, modal choices, and spatial scale. These variations are closely linked to differences in the availability and quality of transportation resources, such as infrastructure, services, and information, as well as to individuals' social positions, lifestyles, and mobility capabilities. As emphasized within both mobilities research and sustainable mobility scholarship, such differentiation implies that mobility opportunities are unevenly distributed, producing differentiated access to activities and services (Banister, 2008; Kaufmann, 2002).

Differences in accessibility therefore translate into unequal capacities to participate in economic, social, and cultural activities, shaping not only observed travel behaviour but also the range of feasible alternatives available to individuals. In this sense, accessibility emerges as a key mediating concept between transport systems and travel demand, linking the differentiated structure of mobility opportunities to broader issues of equity, inclusion, and sustainability that are central to the mobility paradigms discussed in the first chapter.

As to the third point, and as discussed in the chapter on the Sustainable Mobility Paradigm, transportation has traditionally been conceptualized as a *derived demand*, reflecting an instrumental view of mobility as a means to access spatially distributed activities rather than as a source of utility in itself (Cascetta, 2009; Rodrigue et al., 2016). In this perspective, travel demand emerges from the organisation of economic and social activities and from the accessibility conditions provided by transport systems. More recent mobility studies have qualified this view by emphasising that travel may also carry symbolic, experiential and relational meanings (Kaufmann, 2002; Sheller & Urry, 2006; Cresswell, 2010), without abandoning the analytical core of the derived-demand concept. Within the Sustainable Mobility Paradigm, recognising travel demand as derived implies that it is neither fixed nor exogenous, but co-produced through the interaction between activity patterns, spatial organisation, transport systems and everyday practices, and therefore open to policy intervention (Banister, 2008; Cascetta, 2009; Holden et al., 2020).

In this systemic perspective, it becomes useful to distinguish between two forms of derived travel demand (Rodrigue et al., 2016). Direct derived demand refers to movements generated as an immediate consequence of participation in economic and social activities, such as commuting, shopping or education-related trips. Indirect derived demand, by contrast, refers to movements generated by the functioning of the transport system itself, including vehicle repositioning, intermodal

transfers, redistribution flows and circulation movements that arise as secondary effects of other trips.

This distinction reinforces the relational and multi-layered nature of mobility demand. Travel is produced not only by individual activity choices, but also by network organisation, operational constraints and systemic interdependencies. Behavioural change and policy interventions may therefore operate both on primary activity-related trips and on the secondary layers of demand that shape congestion, reliability and environmental performance, anticipating the need for integrated and behaviour-sensitive approaches to sustainable mobility governance.

As a final point, travel demand is heavily *governed by space*. As was seen above, transportation is concerned with movements that take place over space, but these movements are shaped by a variety of constraints. Thus, the physical features of space impose major constraints on transportation systems, in terms of what mode can be used, the extent of the service, its costs, and capacity. Transport geography, sub-discipline of geography concerned about movements, recognizes three basic spatial constraints of the terrestrial space including topography, hydrography, and climate. Furthermore, physical constraints fundamentally act as absolute and relative barriers to movements. The first one represents geographical features that entirely prevent a movement, meanwhile the relative barriers concern those features that force a degree of friction on a movement, commonly known as the friction of distance (Rodrigue et al 2016). The latter in turn influences the spatial distribution of social and economic activities which, according to what has already been illustrated in the previous paragraph, makes for travel demand.

However, the relations between these locations, the generators, and attractors of mobility flows, aren't constant but resulting from the relationships between agglomeration and accessibility at the local, regional, and global levels which in turn depend on the transportation developments (Rodrigue et al 2016). In other words, the link between travel demand and space can only be conceived as bidirectional. Since, on the one hand, the mobility behaviours of the transportation systems' users affect the evolution of structure and morphology of a given area.

This clearly occurs predominantly in a long-term perspective and at a very general level of observation. In the short term, however, these mobility behaviours are in turn influenced by the morphology of the territorial context in which they take place, which is evidently a factor in determining for individuals the distance, time, and frequency of movements, as well as the choice of mode with which to do them. This bidirectional relationship implies that travel demand is both a product of spatial structures and a driver of their evolution over time, reinforcing the need for integrated approaches that simultaneously address land use, transport supply, and individual travel behaviour.

Taken together, these defining features (subjectivity, differentiation, derived nature, and spatial embeddedness) confirm what has been discussed previously, namely that travel demand cannot be treated as a neutral or purely technical variable. Rather, it represents the observable outcome of complex behavioural processes situated within specific spatial, institutional, and socio-technical

contexts. Travel demand emerges from the interaction between individual preferences and capabilities, activity patterns, accessibility conditions and transport system structures, and evolves over time through multiple feedback mechanisms. This perspective challenges supply-oriented approaches that treat demand as fixed or exogenous and instead supports a behaviour-oriented view in which demand itself becomes a legitimate object of policy intervention. Consequently, analysing travel demand requires moving beyond aggregate flows to examine the decision-making processes through which mobility choices are formed, enacted and stabilised.

This interpretation aligns with both sustainable mobility scholarship and behavioural transport research, which increasingly emphasizes that effective policy interventions must address the processes through which travel demand is formed and stabilized over time, including habitual routines, perceptions of accessibility, and the organization of everyday activities (Ison & Rye, 2008; Shove et al., 2012). From this standpoint, travel demand becomes a legitimate and necessary target of policy action, providing the conceptual justification for demand-side and behaviour-oriented approaches that seek to influence mobility outcomes not by accommodating demand, but by governing its underlying drivers.

This shift provides the conceptual bridge to the next chapter, which focuses explicitly on travel behaviour as the generative mechanism through which mobility demand is produced and transformed over time.

From travel demand to travel behaviour: decision-making processes

Understanding travel demand also requires examining travel behaviour, taking into account its multiple dimensions. This chapter focuses on the individual decision-making processes that generate observed mobility patterns. Travel demand represents the aggregated outcome of mobility choices, while travel behaviour is the underlying micro-level mechanism through which demand is formed, structured, and evolves over time. Studying travel behaviour is therefore essential to move beyond simply describing mobility flows and toward explaining how and why individuals make specific travel choices under particular structural and contextual conditions.

Travel behaviour research provides the behavioural foundation of transport demand analysis by examining how individuals navigate constraints related to time, resources, habits, accessibility, and information when making mobility decisions. In this perspective, aggregate travel demand does not arise mechanically from infrastructure provision or activity patterns alone but emerges from a sequence of interdependent decisions taken by individuals and households within a given transportation system. This behavioural perspective aligns with the systemic approach discussed in the previous chapter, where travel demand was conceptualized as an endogenous component of transportation systems rather than an exogenous input.

Drawing on insights from transport economics, behavioural sciences, and mobility studies, this chapter situates travel behaviour as the analytical bridge between system-level conditions and

individual mobility outcomes. By clarifying the structure and temporal layering of travel-related decisions, it prepares the ground for the subsequent examination of behavioural theories and behaviour change frameworks, which provide the conceptual tools needed to understand how travel behaviour can be intentionally influenced through policy intervention.

The study of travel behaviour is largely concerned with the analysis, and modeling, of travel demand, and it's founded on theories and analytical methods from a wide range of scientific disciplines (Mwale, Luke, Pisa 2022). But before delving into theories on behaviour and on behaviour change which will represent a core of specific chapter it's useful to analyze a range of travel choices.

The behaviour of travel choices, namely what an individual carries out when every day he has to decide on multiple aspects of his journey, is a complex phenomenon as it's strongly intertwined with the characteristics of individuals and their families (Meloni 2013). Considering the full range of travel-related decisions would appear to be a daunting task because of the number of decisions and the range of alternatives. Indeed, travel choices of transportation system's users are multiple: from the choice to do a trip to the choice of the departure time from the origin; from the choice of the elementary destination to the choice of the transport modes-services (or the combination of); from the choice of the method of payments of the transport mode-service to the choice of path (or of a combination of) from the origin to the destination of the trip; from the choice of driving yourself to the choice of being accompanied and so on (de Palma, Lindsey, Picard, 2006). These decisions are not independent, but mutually interrelated, and are often made under bounded rationality, time pressure, and incomplete information, particularly in the case of routine and repeated travel.

The elements that describe and characterize mobility and travel behaviour are to be found in the choices that the individual makes over different time spans (Meloni 2017). In particular, the effects of the individual's behaviour are to be sought in short, medium, and long-term decisions. This temporal stratification is analytically relevant because different categories of travel behaviour theories are better suited to explaining decisions at different time scales, ranging from habitual daily choices to strategic life-course decisions.

Short-term decisions, so-called travel choices, are those that normally include the choice to carry out the activity outside the home and therefore to move, the departure time, the destination, the mode, and the number of paths. The results of these choices are the number of journeys per unit of time, the average distances per person and per journey, the modal share, etc. These daily choices are influenced by medium and long-term ones, defined as mobility choices.

Medium-term mobility choices are related to the so-called mobility capital such as holding a driving license, owning a car, purchasing a public transport pass, etc. (Kaufmann, Bergman, Joye, 2004). Even the choices, at first glance, not strictly related to mobility like decisions on locational behaviour such as more significant location choices e.g., residence and workplace, influence daily travel behaviour (Fried, Havens, Thall 1977). The latter choices are considered as long-term choices.

It's usually assumed that long- and medium-term mobility choices determine the available alternatives for travel choices. For example, the choice of residence determines the distance to

potential destinations, and the purchase of a car determines the possible modes of transport used. Actually, according to some authors, the structure between these choices is not so clear, in the sense that car ownership can precede the choice of residence location, or the workplace can be chosen in relation to the car purchase (Meloni 2017). This mutual influence suggests that travel behaviour should be understood as a dynamic system of interdependent decisions, rather than as a linear hierarchy, reinforcing the need for behavioural frameworks capable of capturing feedbacks and change over time.

By analysing travel behaviour as a system of interrelated decisions unfolding across different temporal scales, this chapter has clarified the mechanisms through which individual mobility choices give rise to observed travel demand patterns. Daily travel choices, medium-term mobility decisions, and long-term locational choices are not independent, but dynamically interact over time, shaping both individual mobility practices and aggregate system outcomes. This perspective highlights that travel behaviour cannot be reduced to isolated decisions but must be understood as a process embedded in structural constraints, institutional arrangements, and habitual routines.

From a policy perspective, this behavioural interpretation has important implications. If travel demand emerges from individual decision-making processes, then policies aimed at influencing mobility outcomes cannot rely solely on supply-side interventions or infrastructural adjustments. Instead, they must engage with the behavioural mechanisms that shape how individuals perceive alternatives, form intentions, and enact mobility choices in everyday contexts. This insight reinforces the need to complement system-level interventions with behaviour-oriented approaches capable of addressing both reflective and habitual dimensions of travel behaviour.

On this basis, the following chapter turns to behavioural theories and behaviour change frameworks, which provide the conceptual foundation for analysing how travel behaviour is formed, maintained, and transformed over time. These theories are essential for understanding the conditions under which behavioural change can occur and for designing demand-side policy instruments, such as Travel Demand Management and Voluntary Travel Behaviour Change programs, aimed at supporting more sustainable mobility practices.

Concluding synthesis: Travel demand as a behaviourally grounded and system-dependent phenomenon

This chapter has reconceptualized travel demand as a behaviourally grounded and system-dependent phenomenon, moving beyond traditional interpretations that treat demand as a purely derived, exogenous outcome of economic activity. By integrating insights from transport economics, activity-based approaches, and behavioural research, the chapter has shown that travel demand emerges from the interaction between individual decision-making processes, activity patterns, spatial structures, and the institutional and infrastructural configuration of transport systems.

A central contribution of the chapter lies in clarifying that travel demand is not simply a quantitative expression of mobility needs, but a dynamic outcome shaped by how activities are organized in space and time, how alternatives are perceived and evaluated, and how habitual routines and constraints structure everyday choices. From this perspective, demand is neither fully autonomous nor fully controllable through supply-side interventions alone. Instead, it is co-produced by behavioural mechanisms and contextual conditions, making it inherently responsive to policy interventions that act on both dimensions.

The discussion of travel demand features, such as variability, temporal rigidity, spatial embeddedness, and behavioural inertia, has highlighted why conventional infrastructure-based responses often fail to address the root causes of unsustainable mobility patterns. Travel demand is characterized by strong path-dependencies and habitual reinforcement, particularly in daily and mandatory travel, which limit the effectiveness of policies that assume flexible, fully rational, and context-independent users. These characteristics underscore the importance of understanding demand not only in terms of volumes and flows, but also in terms of the behavioural processes that sustain them over time.

By grounding travel demand in behavioural foundations, the chapter has also provided a conceptual bridge between demand analysis and behaviour-oriented policy approaches. The recognition that travel demand is shaped by attitudes, perceptions, norms, habits, and perceived behavioural control directly challenges the assumption that demand must be passively accommodated. Instead, it opens the analytical space for policies that aim to influence how demand is generated, structured, and expressed, rather than merely how it is served.

This behavioural interpretation of travel demand has important implications for sustainable mobility policy. It suggests that effective demand-side strategies must move beyond aggregate indicators and address the micro-level mechanisms through which demand is produced and reproduced. In particular, it highlights the relevance of interventions that act on activity organization, choice context, and behavioural routines, anticipating the role of Travel Demand Management measures and Voluntary Travel Behaviour Change programs discussed in the subsequent chapters.

In the overall structure of the thesis, this chapter plays a pivotal conceptual role. By reframing travel demand as an endogenous, behaviourally mediated, and system-dependent construct, it establishes the analytical foundation upon which the following chapters build. The transition from travel demand characterization to Travel Demand Management and behaviour-oriented policies is therefore not a thematic shift, but a logical progression: once demand is understood as behaviourally constituted, influencing travel behaviour becomes a legitimate and necessary object of transport policy. This perspective ultimately supports a more integrated and policy-relevant understanding of sustainable mobility transitions, in which demand, behaviour, and system design are treated as mutually reinforcing components of change.

Travel behaviour theories and behaviour change frameworks

Travel behaviour has been examined through multiple disciplinary lenses, yet there is still no unified general theory of human behaviour and behavioural change capable of fully explaining how and why individuals make mobility choices and how such choices evolve over time (Darnton, 2008; Meloni, 2017). This plurality of perspectives is particularly evident in the transport domain, where decisions are frequently repeated, embedded in daily routines, and shaped by structural constraints such as time availability, accessibility, and the presence of viable alternatives.

Consequently, different theoretical traditions have emerged to explain travel behaviour by focusing on (i) intra-individual determinants, such as attitudes, values, norms, and habits, and/or (ii) contextual determinants, including incentives, social influence, institutional arrangements, and characteristics of the built environment. In line with the argument advanced by Stern (2000), a comprehensive understanding of environmentally significant behaviour, including sustainable mobility, requires acknowledging the joint influence of both individual and contextual factors.

This chapter reviews the main behavioural theories and socio-psychological models that have informed transport research and, more specifically, the conceptual foundations of policies aimed at promoting travel behaviour change. Following a widely adopted distinction in the literature, the reviewed frameworks are organized into two complementary categories: models of behaviour, which explain the determinants of choice and behaviour at a given point in time, and theories of behavioural change, which conceptualize change as a dynamic process unfolding over time through stages, feedback mechanisms, and implementation processes (Meloni, 2017; Darnton, 2008).

This distinction is particularly relevant for policy design and evaluation, as models of behaviour are primarily suited to explaining and predicting choices under given conditions, whereas behavioural change theories inform the design, sequencing, and assessment of interventions across time. In this sense, behavioural models primarily inform baseline understanding and ex ante analysis, while theories of behavioural change provide guidance for intervention sequencing, monitoring, and the selection of outcome indicators across different stages of change.

This perspective is also especially relevant in the transport domain, where mobility choices are rarely made under unconstrained conditions. Daily travel decisions are often embedded in routine contexts and shaped by structural, spatial, and temporal constraints that limit individuals' ability to translate intentions into actual behaviour. These characteristics help explain why intention-based models alone have proven insufficient to account for observed mobility patterns.

In response to these limitations, later theoretical developments in transport research have progressively incorporated concepts such as actual behavioural control, habitual processes, and contextual constraints into behavioural models. These advances, exemplified by extensions of the

Theory of Planned Behaviour and dual-process approaches (Ajzen, 1991;; Haustein, 2012), provide the conceptual foundations for analysing behaviour-oriented mobility policies and are therefore central to the discussion developed in the remainder of this chapter.

Despite these differences, there are significant overlaps between the two bodies of theories, which should be regarded as complementary rather than mutually exclusive. While both categories are essential for understanding travel behaviour, theories of behavioural change and habit-oriented models are particularly relevant for the design of behaviour-oriented transport policies, as they explicitly address the processes through which behavioural change can be initiated, supported, and maintained over time. Taken together, these perspectives provide a comprehensive basis for analysing and promoting behavioural change (Darnton, 2008).

Beyond their explanatory value, the theories reviewed in this chapter also provide the conceptual foundations for policy instruments aimed at influencing mobility choices. In transport planning, behavioural and behavioural change theories have progressively informed the shift from supply-oriented approaches toward demand-side strategies, supporting the design of interventions that seek to influence how, when, and why individuals travel. In this sense, these theories constitute not only analytical frameworks, but also operational references for behaviour-oriented transport policies.

Table 2 provides a synthetic overview of the main behavioural frameworks discussed in this chapter, highlighting their complementary roles in baseline analysis, intervention design, and evaluation.

Table 2 Behavioural frameworks and their relevance for policy design and evaluation

Type	Main focus	Relevance for policy
<i>Behaviour models</i>	Determinants of choice	Baseline understanding
<i>Habit-based models</i>	Automaticity	Habit disruption
<i>Theories of behavioural change</i>	Process over time	Intervention design & evaluation

Source 3 Author's elaboration based on Ajzen (1991), Triandis (1977), Verplanken et al. (1994), Prochaska and DiClemente (1982), Darnton (2008), and Haustein (2012).

Accordingly, this theoretical overview provides the conceptual basis for the subsequent chapters on Travel Demand Management and Voluntary Travel Behaviour Change programs, where these theories are explicitly operationalized into intervention design, implementation strategies, and evaluation frameworks.

Models of travel behaviour

This section reviews the main models of human behaviour that have been applied to the analysis of travel behaviour, following an analytical progression that reflects the evolving understanding of how mobility choices are made. Rather than providing an exhaustive inventory, the section focuses on those models that have most strongly influenced transport research and the development of behaviour-oriented mobility policies.

The discussion begins with rational and cognitive models of choice, which conceptualize travel behaviour as the outcome of deliberate utility maximization. It then moves toward socio-psychological models, such as the Theory of Reasoned Action and the Theory of Planned Behavior, which introduce attitudes, norms, and perceived control as key determinants of intention. Subsequently, habit-oriented and script-based approaches are examined, reflecting growing recognition of the automatic and routinized nature of everyday travel behaviour. The section concludes with theories of pro-environmental behaviour, which are particularly relevant for understanding sustainable mobility choices and the moral and normative dimensions of behaviour.

Rational and cognitive models of choice

The earliest behavioural models applied to travel behaviour are rooted in standard economic theory, which conceptualizes choice as the outcome of a rational evaluation of alternatives based on utility maximization. Within this framework, individuals are assumed to possess comprehensive knowledge of all available alternatives and their attributes, and to be capable of systematically comparing costs and benefits in order to select the option that maximizes their utility (Domencich & McFadden, 1975; Ben-Akiva & Lerman, 1985). Travel behaviour is thus interpreted as the result of deliberate and individualistic decision-making processes, largely independent of habits, social influence, or contextual constraints.

These assumptions, however, have been widely criticized for their limited realism when applied to everyday travel behaviour. In particular, Herbert Simon (1955, 1957) challenged the notion of full rationality by introducing the concept of bounded rationality, arguing that individuals face cognitive, informational, and temporal constraints that prevent them from optimizing in the strict economic sense. According to Simon, decision-makers operate with simplified representations of reality and rely on heuristics, seeking solutions that are *satisficing* rather than optimal. In the context of travel behaviour, this implies that individuals may choose options that are “good enough” given limited information, habitual routines, and time pressure, rather than those that maximize utility in an abstract sense.

Further critiques emphasized that the cognitive effort required for fully rational decision-making is itself costly and often unjustified in routine choice situations. Winston (1989) argued that maximal rationality is rarely rational, as the resources required to collect and process information may outweigh the benefits of marginally improved decisions. Similarly, de Palma (1998) highlighted that transport choices are frequently made under uncertainty and incomplete information, further undermining the assumptions of classical rational choice models.

While rational choice theory and its extensions provided a foundational analytical framework for transport modelling, these critiques paved the way for behavioural approaches that incorporate cognitive limitations, heuristics, and non-deliberative processes. This shift is particularly relevant for travel behaviour, which is often repetitive, habitual, and embedded in stable contexts. As later

sections of this chapter demonstrate, these limitations of rational choice theory motivated the development of socio-psychological models, such as the Theory of Reasoned Action and the Theory of Planned Behavior, as well as habit-oriented and dual-process theories that more explicitly account for the realities of everyday mobility decision-making.

The Theory of reasoned action (TRA) is the first example (Fishbein, Ajzen 1975). Developed to explain and predict volitional behaviours, TRA is still based on the assumption that the individual makes reasoned choices, i.e., he is aware of the consequences, and that the behaviour stems from the intention to act, intention is the immediate determinant of action (Ajzen 1985, Fishbein, Ajzen 1975, Ajzen 1991). Intentions are in turn determined by attitudes, which are a function of behavioural beliefs, toward behaviour and by subjective norms which are a function of normative beliefs. The attitudes reflect the degree to which the implementation of a behaviour is evaluated positively or negatively whereas the subjective norm concerns the importance that an individual gives to the approval of others of his behaviour (Meloni 2017). Furthermore, Ajzen (1985, 1991) argued most behaviours depend, to some degree at least, on factors such as time, money, skills, and the cooperation of others (collectively representing actual behavioural control), and these factors may not always be under the individual's control. This implies that TRA cannot be used to predict behaviours that are only partially volitional, including resource-constrained actions, opportunity-dependent choices, habit-driven routines, and behaviours requiring external enabling conditions. In such case, intentions alone are insufficient to account for behavioural performance.

In this regard, as an extension to TRA, the Theory of planned behaviour (TPB) was introduced by Ajzen (1985) to account for non-volitional behaviour perceived behavioural control as a third determinant of intention, in addition to attitude and subjective norm. Perceived behavioural control refers to the perceived difficulty or ease of performing a given behaviour and reflects the individual's assessment of available resources and constraints. This extension is motivated by the recognition that intentions, in the strict sense, can only predict a person's attempt to perform behaviour and not necessarily its actual execution. The limited power of intention with respect to realised behaviour implies that external constraints and enabling conditions may intervene between intention and action. Subsequent developments further extended the TPB framework by incorporating additional dimensions drawn from related behavioural theories. In particular, the distinction between perceived and actual behavioural control was introduced to capture the role of objective constraints and opportunities (Ajzen and Fishbein, 2005).

Some other criticism has been leveled against theories of expected utility. In particular, Kahneman and Tversky (1979) raised the issue of their uselessness when it comes to making decisions in which the outcome is uncertain advancing Prospect theory (PT) as an alternative model for explaining how decisions are made which involve some degree of uncertainty. According to this theory, individuals avoid outcomes which they are uncertain about when making decisions by giving more weight and subjective values to alternatives with greater certainty of outcome. Furthermore, the authors showed

that when gains and losses associated with choice alternatives are made more explicit, loss aversion is triggered, due to the stronger emotion ascribable to loss rather than gains.

Script-based theories and the role of habits in travel behaviour

Script-based choice theories represent an alternative line of thought to rational and intention-based models by emphasizing the role of habit and automaticity in behavioural performance. According to this perspective, proposed by Gärling et al. (2001), repeated behaviour in stable contexts leads to a gradual shift from conscious deliberation to automatic repetition.

Thus, the main difference between the two groups of theories lies in the relative importance attributed to the level of consciousness to explain and predict a given social behaviour. While for the proponents of the first the social behaviour is rational and under the control of the individual, the Script-based choice theories propose that the level of consciousness decreases when the level of habit increases in the performance of a behaviour (Meloni 2017). Habit formation theories have received increasing attention in travel behaviour studies over the past decade. Some authors argue habits developed in past behaviour are a better predictor of behaviour than attitudes (Triandis 1977, Ouellette, Wood 1998).

Furthermore, Script-based theories represent a prominent aspect within the broader framework of behavioural theories, seeking to explain how individuals acquire and perform complex behaviours using pre-structured mental scripts. According to Gärling and Axhausen (2003), if the situation remains unchanged, repeating choice after first time deliberation may be more rational or more appropriate than the maximal rationality of RCT.

In particular, the proponents of these theories advance that individuals create mental representations of common scenarios, organizing them into scripts consisting of a sequence of actions, events, and expected outcomes which serve then as cognitive frameworks that guide behaviour, enabling individuals to anticipate and respond to situational cues effectively (Gärling, Axhausen 2003). Hence, according to the Script-based theories, only when faced with a choice decision for the first time the individual engage in rational deliberation to locate a preference among a set of alternatives. Once that the repeated sequences of behaviour proved to be effective become codified as a script which the individual can retrieve in future when confronted with the same decision situation. Simply put, under the same conditions, the same choice is therefore repeated, forming habit.

However, while scripts provide a default behavioural pattern, individuals can deviate from them when faced with novel situations or when alternative actions are deemed more appropriate. This flexibility allows individuals to adjust their behaviour based on contextual factors and personal goals. Nevertheless, where the choice may be considered as strongly habitual it cannot be changed easily by minor changes in circumstances ascribed to the advantage in terms of saving time and effort in confront to the research and re-elaboration of information.

Another theory that falls into a scripts-based theory framework is a Theory of interpersonal behaviour (TIB) proposed in the late 1970s by Harry C. Triandis (1977). Likewise to TRA and TPB, TIB also defines intention, and behavioural control conceptualized as an element that facilitates the understanding of objective conditions, as one of the influential factors of behaviour. But Triandis's Theory also takes into consideration habit as an additional element in the interpretation of how behaviour occurs within social contexts. Therefore, TIB is based on the premise that human behaviour is influenced by both dispositional factors (habits and intentions) and situational factors (environmental influences). The interaction between these two factors is considered the core aspect of Triandis's theory. It suggests that habits and intentions interplay with environmental (situational) factors that either facilitate or inhibit behaviour. Thus, the theory proposes that individuals adapt and adjust their behaviour based on the demands of the situation, and their cognitive and affective processes mediate this interaction. To put it simply, the theory emphasizes the dynamic nature of interpersonal behaviour, highlighting the reciprocal influence between the person and the situation. For example, in daily commuting, a strong habit of car use may prevail over pro-environmental intentions when situational conditions continue to favour private transport. More generally, Triandis emphasized that the stronger the habit, the weaker the influence of intentions on behaviour, and vice versa. Behaviour is therefore not solely the outcome of deliberate choice, but the result of a dynamic interplay between routinised action and situational opportunities and constraints.

To summarise, this line of thought points out that past behaviour is a strong predictor of future behaviour: in the absence of external changes, individuals tend to reproduce the same choices repeatedly. Such behavioural persistence has an important cognitive advantage, as relying on habitual responses allows individuals to avoid the effort of repeatedly making complex decisions based on detailed cost–benefit comparisons. However, this efficiency comes at the cost of reduced attention to new information and to potentially superior alternatives, thereby increasing the risk of foregone benefits.

On the other hand, presenting the choice context in ways that help individuals overcome their own preconceptions, highlights the potential benefits of alternative options and support informed decision-making opens the field to policies aimed at modifying human behaviour, including mobility behaviour.

Theories of pro-environmental behaviour

When sustainable mobility is conceptualized as a form of pro-environmental behaviour, understanding the psychological mechanisms underlying such behaviour becomes essential for addressing environmental challenges and achieving sustainability objectives. Several theories have been developed to explain why individuals engage in environmentally responsible actions. This section focuses on two influential frameworks: the Norm Activation Theory (NAT) (Schwartz, 1977; Schwartz & Howard, 1981) and the Value–Belief–Norm (VBN) theory of environmentalism (Stern, 2000).

The first theory NAT proposes personal norms as the determinant of pro-social behaviour which are formed through an adaptation of societal norms (Klöckner, Matthies 2004) as well as activated only when the person becomes aware of the consequences of his or her behaviour and takes responsibility for them (Wall et al., 2008). In this perspective, the pro-environmental actions follow the activation of personal norms and reflect the moral obligation to perform or refrain from specific actions. The moral norms in turn depend on four factors (Meloni 2017) defined by Schwartz and Howard (1981) as situational because their influence can vary in relation to different contexts as well as vary over time: *i)* awareness of the problem, i.e. of the negative consequences of non-environmental behaviour; *ii)* the attribution of responsibility, in not acting in a pro-environmental way; *iii)* the effectiveness of the result, in the sense of identifying what reduces the environmental problems; *iv)* ability, i.e. the acknowledgment of one's ability to achieve the target of reducing environmental problems.

Furthermore, since in many cases the realization of a pro-environmental behaviour requires other costs, and personal efforts the pro-environmental behaviour occurs when people associate morality with a higher value than perceived costs derived from this behaviour. Therefore, the basic element is that these norms to be activated require a strong awareness of the problems caused by individual behaviour and of the individual's ability to contribute to solving them.

The Value–Belief–Norm theory of environmentalism (VBN) (Stern, 2000) represents an extension of the Norm Activation Theory and provides a conceptual framework to explain environmentally significant individual behaviour. According to VBN, pro-environmental behaviours stem from the endorsement of specific personal values, from beliefs that objects important to those values are under threat, and from beliefs that individual actions can help alleviate such threats and restore the underlying values (Stern et al., 1999).

In line with Ajzen's (1991) notion that beliefs antecede behavioural intentions, which in turn antecede actual behaviour, Stern et al. identify a causal process in which environmental beliefs activate personal norms, which subsequently motivate pro-environmental behaviour. VBN extends Ajzen's causal chain by showing that environmental beliefs are themselves anteceded by personal values and by replacing attitudinal and intentional determinants with moral obligation as the central motivational mechanism. In this perspective, behaviour is driven less by instrumental evaluations of outcomes and more by internalised normative commitments.

Moreover, some of the studies went further and proposed a more complete model of pro-environmental behaviour considering, beyond intra-individual processes, also the social context within which the social-psychological processes occur. For instance, Stern, Dietz, Kalof, et al. (1995) stressed the importance of considering the social structure (individuals' concrete positions within socio-economic, institutional and territorial contexts) within which individuals are embedded, based on the belief that social structures systematically shape their lived experiences, material constraints and opportunities, and, through these channels, their values, beliefs and behavioural orientations. The hierarchical model presented by Stern, Dietz, Kalof, et al. (1995) extends Ajzen's TPB models according to which attitudes guide intentions, which in turn guide behaviour, and adds the other two

dimensions. The authors suggest that individuals' worldviews precede their attitudes, that their personal values precede their worldviews, and that their position within the social structure precedes their values (i.e., position → values → worldviews → attitudes → intentions → behaviour).

The main criticism leveled against this theory regards the level at which the variables are measured or rather all the variables remain at the individual's level. Hence, Oreg and Katz-Gerro (2006) went beyond extant models by extending on Ajzen's TPB (Ajzen 1985) and on Stern et al.'s (1999) VBN theory incorporating, parallel to individual-level values, cultural value dimension (Schwartz's country-level harmony dimension (1994) and Inglehart's postmaterialism index (1977)) as a broad contextual antecedent. According to the authors, the culture within which individuals behave, representing the higher-level and external-to-individual variable, constitutes a meaningful context for the creation of the attitudes and beliefs that ultimately guide behaviour.

In general, according to some studies, these theories are particularly effective in explaining low-cost environmental behaviours (Steg, Nordlund 2012), while they are less effective in situations characterized by high behavioural costs (Abrahamse, Steg 2009).

Limitations of behavioural models and the need for change-oriented frameworks

In conclusion, while models of behaviour provide valuable insights into the determinants of travel choices at a given point in time, their explanatory power is limited when the objective is to actively promote behavioural change. In particular, they offer limited guidance on how individuals move from intention to action, how habits can be disrupted, and how new behaviours can be stabilized. These limitations underscore the need to complement explanatory models with change-oriented frameworks capable of addressing how behaviour evolves over time and how policy interventions can actively support transitions from intention to sustained behavioural change.

Theories of behavioural change

Understanding travel behaviour at a given point in time is a necessary but insufficient condition for designing policies aimed at producing lasting change. While behavioural models help explain how choices are formed under existing conditions, they offer limited guidance on how individuals move from established routines toward new mobility practices, how resistance to change can be overcome, and how behavioural shifts can be sustained over time. For these purposes, theories of behavioural change provide a more appropriate analytical lens, as they explicitly conceptualize change as a dynamic, processual phenomenon unfolding through stages, feedback mechanisms, and interactions between individuals and their contexts.

In the domain of mobility, where behaviour is often habitual, embedded in daily routines, and constrained by structural conditions, understanding the temporal and procedural dimensions of change is particularly important. Behavioural change theories focus not only on why individuals intend

to change, but also on when, how, and under which conditions intentions are translated into action and consolidated into new routines. This perspective aligns closely with the demand-side and behaviour-oriented policy approaches discussed in the previous chapters, which seek to influence mobility choices without coercion by acting on motivation, habits, and enabling conditions.

The following sections therefore review key theories of behavioural change that have informed both behavioural research and policy design, starting from Lewin's Foundational Theory of change and its field-theoretical approach, through stage-based models such as the Transtheoretical Model, and culminating in more action-oriented frameworks such as Self-Regulation Theory and Implementation Intention Theory. Together, these theories provide essential conceptual tools for understanding how behavioural change can be initiated, supported, and maintained over time, and form the theoretical basis for the analysis of voluntary and context-enabling mobility policies developed in the subsequent chapters.

Lewin's Foundational Theory of change

As a beginning, Lewin's Field Theory represents the general framework through which Lewin explains human behaviour. Indeed, the Field Theory depicted well the territory of human beings in their contexts, namely, of people in relationships, in community. The core of Lewin's Field theory is that a holistic perspective towards the person extends to include the environment, the social world, organizations, and culture. In this sense, a field represents an individual's psychological and social environment, which consists of various forces and influences that shape human behaviour. Another concept introduced by Lewin is that about of life space (Lewin, Lorsch 1939) that refers to an individual's subjective representation of their current situation, encompassing their needs, goals, perceptions, and experiences and in which the behaviour takes place (Lewin, 1942). It then represents the psychological reality of the individual within their field.

Lewin's field theory states that behaviour is derived from the totality of coexisting and interdependent internal (thoughts, needs, and personality) and external (social norms, physical environment, and situational factors) forces that impinge on a person or group in their immediate environment or field that drive the individual to change behaviour or vice versa (Meloni, 2017). Thus, it's possible to understand, predict and provide the basis for changing the behaviour of individuals and groups by constructing a life space comprising the psychological forces influencing their behaviour at a given point in time (Back 1992; Diamond 1992). Therefore, it is a question of understanding the forces that sustained undesired behaviours, and identifying those forces that would need to be either strengthened or weakened in order to bring about desired behaviours (Lewin, 1998).

Stage-based models of behavioural change

Therefore, while the Field Theory represents the framework through which Lewin explains human behaviour because of the interaction between external and internal factors, the Theory of change (Lewin, 1947) is explicitly centered on the processes underlying behavioural change.

Regarded by some scholars as one of the most important theories of change, Lewin's theory of change developed by pioneer in the field of social psychology Kurt Lewin (1947) have provided valuable insights into the process of behavioural change as well as formed the basis for many of the approaches to describing behavioural change.

Focusing on the procedural aspect, Lewin's theory (1947) posits a three-stage model of change articulating it in Unfreezing, Changing, and Refreezing. The stage construct is the key organizing construct of the model representing a temporal dimension. Indeed, according to this line of theories, behavioural change implies phenomena occurring over time rather than construed as an event. Lewin's theory construes change as a process involving progress through a series of stages.

The first stage is Unfreezing, where the individual becomes aware of the need for change and is motivated to let go of existing behaviour or beliefs. In particular, in this phase it comes to free people from their mental patterns and to prepare them to accept new information or concepts to review the situation with new eyes, that is, to make individuals aware of carrying out a cognitive restructuring (Meloni 2017). The second phase concerns the change stage, where new behaviour or belief is adopted and implemented. It comes to identify a model in which to identify and to be helped to open the mind to new perspectives, or to stimulate research activity to broaden one's views, to have new ideas and concepts. The third stage is refreezing, where the new behaviour becomes the norm and is integrated into the individual's identity. There is the consolidation of new behaviour, in the sense of integrating the new points of view into the world that surrounds the individual. Moreover, Lewin's theory of change underlines that only what is accepted and chosen by those who have to change has the highest probability of lasting, thus referring to a voluntary change process.

A more recent and updated version of this Lewin's theory of change is Transtheoretical Model (TTS) developed by Prochaska and DiClemente (Prochaska, DiClemente 1982, Prochaska, Velicer 1997), representing a widely recognized and influential theory that provides a framework for understanding and promoting behaviour change across various domains.

The aforementioned model proposes that individuals progress through five stages of change: precontemplation, contemplation, preparation, action, and maintenance. These stages represent different levels of readiness to modify and reflect the individual's engagement with the change process. The first stage is precontemplation characterized by a lack of awareness or intention to reshape actual behaviour due to the unawareness of the negative consequences of current behaviour or because of the failure of previous attempts to change individual has lost confidence in his own real ability to progress. Subjects in this phase are described as unmotivated or resistant to change when

confronted with the need for break an established behavioural pattern. Afterwards, in the contemplation stage, individuals acknowledge the need to change and consider the pros and cons (e.g., weighing the benefits of change against the perceived barriers and challenges) of making a shift, process that sometimes causes a situation of great ambivalence which can keep person in this phase even for long periods of time. During the preparation stage, individuals are actively preparing to act shortly, making a commitment to change, and formulating a plan of action. This stage regards setting specific goals, gathering necessary resources, and developing useful strategies to overcome potential barriers. The next stage, denominated action, is characterized by the implementation of specific strategies and actions to achieve the desired shift, often with external support and resources. This stage requires ongoing effort to understand, analyze and emphasize failures and unsuccessful attempts as opportunities for further learning to bring about change in one's behavioural pattern. The last phase of change is about maintaining and stabilizing the changed behaviour over time, resulting in incorporation of the new behaviour into one's lifestyle. Since the TTS is cyclical, a relapse into old patterns is always possible.

The Prochaska and DiClemente's Transtheoretical model has then provided a general basis for more advanced models also used in the field of transport. The Self-regulation theory (SRT) proposed by Carver and Scheier (2001) is an example. The SRT represents indeed a prominent framework that explores how individuals engage in self-control and self-regulation to achieve their goals.

The SRT model assumes that the individual's behaviour is oriented towards the pursuit of personal objectives and regulated by retroactive control processes, namely that the behaviour is guided and regulated in line with the motivated action. Thus, the self-regulation theory emphasizes the presence, as in Lewin's theory of change, of an intention to change in relation to the achievement of an important personal goal in performing behaviour. Indeed, goals provide individuals with a sense of direction and purpose, motivating them to regulate their actions and make progress towards desired outcomes. Put simply, the SRT is constructed as a dynamic goal-achieving motivational system, which develops and issues strategies to activate these goals, evaluating progress and revisiting goals and strategies accordingly. The reference to the dynamism of the model leads to a centrality of feedback loops of self-monitoring, self-evaluation, self-control, and adjustment to stay on track towards goal attainment (Meloni 2017). For example, a commuter who sets the goal of limiting car use to two days per week may monitor daily travel behaviour through a tracking application, compare actual choices with the intended target, and progressively adjust departure times, routes or modes when deviations occur, in order to restore consistency between behaviour and personal objective.

Action-oriented approach and the role of implementation intentions

However, intentions are not always directly related to the accomplishment of the action, and the path between goal setting, definition of a pre-established goal and goal attainment is often bumpy and long (Gollwitzer 1990). The importance of taking concrete steps in implementing behaviour change strategies represents the core of an action-oriented approach in behavioural change theories.

An example of a model that aims to explain how to overcome the difficulties that people encounter in translating their goals into actions is proposed by Gollwitzer (1990). The Gollwitzer's Implementation intention theory represents a framework that explores the role of implementation intentions in facilitating goal-directed behaviour (Gollwitzer 1993, Gollwitzer 1996, Gollwitzer 1999). Precisely, unlike the Carver and Scheier's SRT goal intentions which focus on the desired outcome¹, implementation intentions refer to specific plans, the so-called action steps typically taking form of If-Then statements that link situational cues or triggers to specific behavioural responses, that individuals make regarding when, where, and how they will act to achieve their goals which allows, in advance, to highlight the critical factors that may be encountered in obtaining the objective.

According to Gollwitzer, by forming such cue-response associations in memory, individuals are more likely to initiate the intended behaviour automatically and with reduced cognitive effort when the relevant situational cues are encountered. For example, a commuter who intends to reduce car use may form the plan "If it is a weekday morning and the weather is dry, then I will cycle to work instead of driving," thereby increasing the likelihood that the alternative mode is enacted when the situation arises.

In short, the Gollwitzer's implementation intention theory offers a practical and action-oriented approach to behaviour change by focusing on specific plans and cues for action which, when integrated with other behaviour change frameworks, can enhance our understanding in how promoting behavioural change.

Concluding synthesis: From explanatory models to policy-relevant behavioural frameworks

This chapter has reviewed the main theoretical approaches used to explain travel behaviour and behavioural change, with the explicit objective of identifying those elements that are most relevant for the design and evaluation of behaviour-oriented transport policies. Rather than providing a purely descriptive overview of competing theories, the chapter has progressively reframed behavioural models as analytical tools whose value lies in their capacity to explain why and under which conditions behavioural change may or may not occur in everyday mobility practices.

The discussion has shown that traditional economic and rational-choice models, while foundational for transport analysis, offer a limited account of travel behaviour when applied to routine, habitual, and context-dependent decisions. Their emphasis on stable preferences and utility maximisation underestimates the role of habits, cognitive constraints, and situational factors that systematically shape daily mobility choices. Behavioural economics and psychologically grounded models address

¹ Also the other theories, Theory of reasoned action, Theory of planned behaviour, Theory of interpersonal behaviour Norm Activation theory, Value-Belief-Norm theory of environmentalism, described in this chapter represent goal-directed behaviour theories or rather accord goal intentions a central role in their theorizing about action

part of this limitation by introducing bounded rationality, heuristics, and motivational factors, yet they remain largely static and insufficient to explain how behaviour evolves over time.

Behavioural change theories provide a critical complement by explicitly conceptualising change as a dynamic and process-oriented phenomenon. Stage-based models such as the Transtheoretical Model highlight that individuals differ in their readiness to change, and that behavioural transitions unfold through sequential phases characterised by distinct cognitive and motivational states. These insights are particularly relevant for transport policy, where interventions often target heterogeneous populations and where the timing and sequencing of measures can be as important as their content.

At the same time, habit-oriented and dual-process approaches fundamentally challenge the assumption that increased awareness or stronger intentions are sufficient to induce behavioural change. By distinguishing between automatic, habit-driven processes and reflective, intention-based decision-making, these theories explain why an intention–behaviour gap systematically emerges in domains such as daily travel, where choices are repeated under stable contextual conditions. From this perspective, behavioural change becomes possible primarily when habitual scripts are disrupted and when contextual cues are modified in ways that activate reflective evaluation.

Taken together, the chapter has demonstrated that no single theoretical framework is capable of fully capturing the complexity of travel behaviour and behavioural change. However, by combining intention-based models, stage-based theories, and dual-process approaches, it is possible to construct a more comprehensive and policy-relevant understanding of mobility behaviour. Such an integrated perspective explicitly acknowledges that travel behaviour is shaped by the interaction between motivation, cognition, habits, and context, and that effective interventions must address multiple behavioural mechanisms simultaneously.

This synthesis provides the conceptual foundation for the subsequent chapters of the thesis. First, it directly informs the analysis of Travel Demand Management and Voluntary Travel Behaviour Change programs, which are explicitly designed to intervene in motivational, cognitive, and habitual determinants of travel behaviour. Second, it establishes the theoretical basis for examining context-enabling solutions, such as Mobility as a Service, that operate on the structural conditions under which behavioural change is enacted and stabilised. By moving from explanatory models toward integrated behavioural frameworks, this chapter positions behavioural theory as a central component of sustainable mobility policy design rather than as a purely descriptive analytical exercise.

Travel Demand Management within the sustainable mobility framework

Travel Demand Management (TDM) has progressively gained prominence within the broader framework of sustainable mobility, as transport policy has progressively shifted from a predominant focus on infrastructure expansion toward strategies aimed at managing travel demand and influencing individual mobility behaviour (Banister, 2008; Cairns et al., 2008). This evolution reflects the growing recognition that technological improvements and supply-side interventions alone are insufficient to address the environmental, social, and economic challenges associated with contemporary mobility systems (Holden et al., 2020). This shift is fully consistent with the mobility paradigms discussed in the first chapter, which critically question the assumption of ever-increasing mobility demand and emphasize the need to address sustainability challenges through demand-side and behaviour-oriented policy approaches rather than through infrastructure expansion alone.

Within the Sustainable Mobility Paradigm, the objective of reducing negative externalities while maintaining acceptable levels of accessibility cannot be achieved through infrastructural and technological measures alone but requires policy instruments that explicitly address travel behaviour and the mechanisms through which mobility demand is generated (Banister, 2008). From the perspective of the New Mobilities Paradigm, this behavioural turn in transport policy reflects a broader reorientation toward understanding mobility as a socially embedded practice shaped by routines, meanings, and contextual constraints, rather than as a purely technical problem of traffic management (Sheller & Urry, 2006; Urry, 2007). In this context, TDM encompasses a wide range of policies and instruments designed to influence when, how, how much, and why people travel, with the objective of reducing car dependency, encouraging modal shift toward more sustainable alternatives, and containing the growth of travel demand (Meyer, 1997; Meloni, 2017). By focusing on the demand side of mobility, TDM directly contributes to key sustainability goals such as emissions reduction, energy efficiency, congestion mitigation, and improved quality of urban environments.

The development of TDM is closely linked to advances in behavioural research, which have increasingly challenged the assumption that mobility choices are solely the outcome of rational utility maximization. Instead, travel behavior is understood as the result of complex interactions between individual preferences, social norms, habits, and contextual constraints (Steg & Tertoolen, 1997; Steg & Vlek, 2009). Consequently, TDM integrates both structural measures that modify the objective conditions of choice and informational or voluntary measures that target the cognitive and motivational determinants of behaviour (Bamberg et al., 2011).

This chapter provides a conceptual overview of Travel Demand Management within the framework of sustainable mobility. It first clarifies the definition and scope of TDM and reviews the main classifications of demand management measures proposed in the literature (Litman, 2003; May et

al., 2003). It then distinguishes between structural (hard) and informational (soft) strategies, highlighting their respective roles and limitations (Steg & Tertoolen, 1997; Gärling & Schuitema, 2007). Particular attention is given to Voluntary Travel Behaviour Change programs as a specific category of soft TDM measures that operationalize behavioural insights through information, persuasion, and engagement rather than coercion (Ampt & Gleave, 2003; Cairns et al., 2008). Finally, the chapter situates TDM within the Avoid–Shift–Improve (ASI) framework, illustrating how demand management measures contribute to the broader objectives of sustainable mobility (GIZ, 2011; Holden et al., 2020).

By framing Travel Demand Management as an integral component of sustainable mobility strategies, this chapter establishes the policy and conceptual foundation for the subsequent analysis of Voluntary Travel Behaviour Change programs. The following chapter builds on this foundation by examining in detail the behavioural theories that underpin VTBC interventions and explain the mechanisms through which voluntary measures can support long-term and sustainable changes in travel behavior.

Travel Demand Management: definition and scope

In the field of transportation planning and policy, a wide range of behavioural models and theories of behavioural change has been developed to understand how individuals make mobility choices and how such choices can be influenced over time. As discussed in the previous chapter, models of behaviour primarily aim to explain travel decisions under given conditions, while theories of behavioural change focus on the dynamic processes through which intentions, habits, and practices evolve in response to cognitive, motivational, and contextual factors (Meloni, 2017; Meloni et al., 2013).

Building on these theoretical foundations, transport policy has progressively moved toward the development of demand-side instruments that explicitly seek to influence travel behaviour rather than merely accommodate projected demand. Travel Demand Management emerges in this context as a policy framework that translates behavioural insights into concrete intervention strategies, operationalizing concepts such as behavioural control, habit disruption, and intention–action translation within the domain of mobility (Cairns et al., 2008).

In this sense, TDM represents the practical interface between behavioural theory and transport policy, providing a structured set of measures through which insights from behavioural and behavioural change theories are applied to shape when, how, and why people travel.

In the field of transportation planning and policy, the development of Travel Demand Management has been closely intertwined with advances in behavioural research. As discussed in the previous chapters, models of travel behaviour and theories of behavioural change have progressively challenged the assumption that mobility choices are purely technical or economically rational outcomes, highlighting instead the role of cognitive processes, habits, social norms, and contextual constraints (Meloni, 2017; Meloni et al., 2013).

These theoretical developments have provided the conceptual foundations for a shift in transport policy from supply-oriented approaches toward interventions explicitly designed to influence how travel decisions are formed and enacted. In this context, behavioural theories have not remained purely analytical tools but have increasingly informed the design of policy instruments aimed at promoting more sustainable mobility patterns. Travel Demand Management can therefore be understood as the policy translation of behavioural insights into practical strategies intended to influence travel demand by acting on decision-making processes, choice contexts, and everyday mobility practices (Cairns et al., 2008).

In general terms, TDM can be defined as any action, strategy, or policy, implemented individually or as part of a coordinated package, aimed at influencing people's mobility behaviour so that travel demand is reduced, redistributed in space or time, or modified through changes in travel mode choice (Meyer, 1997). From this perspective, TDM seeks to reduce reliance on private motorized vehicles and to promote more sustainable alternatives such as walking, cycling, public transport, and shared mobility services (Meloni, 2017; Cairns et al., 2008). Importantly, the objective of TDM is not to suppress mobility, but to improve the efficiency, sustainability, and equity of mobility systems while maintaining adequate levels of accessibility to activities and services (Banister, 2008).

The scope of TDM is therefore inherently broad and multi-dimensional. On the one hand, TDM measures operate by reshaping the context in which travel choices are made, acting on structural factors such as the availability, cost, convenience, and performance of transport options. By modifying these contextual conditions, TDM interventions alter the objective opportunity set faced by individuals, thereby influencing travel behaviour indirectly (Steg & Tertoolen, 1997; Bamberg et al., 2011). On the other hand, TDM also encompasses measures that act directly on individual-level determinants of behaviour, such as preferences, values, attitudes, perceptions, and decision-making processes. These interventions aim to stimulate a shift from habitual or automatic travel choices toward more deliberate and reflective decision-making (Steg & Vlek, 2009; Meloni, 2017).

This dual nature distinguishes TDM from more traditional transport policies and highlights its strong connection with behavioural research. By explicitly acknowledging that mobility behaviour is shaped by both contextual constraints and psychological factors, TDM provides an overarching framework capable of integrating diverse policy instruments, ranging from regulatory and economic measures to informational and voluntary interventions (Bamberg et al., 2011; Gärling & Schuitema, 2007). As such, TDM constitutes a flexible and adaptive policy approach that can be tailored to different spatial, social, and institutional contexts, and that lends itself to integration with broader sustainable mobility strategies.

In summary, Travel Demand Management represents a comprehensive policy framework aimed at influencing travel behaviour through a combination of structural and behavioural measures. Its scope extends beyond isolated interventions to include coordinated packages of actions designed to reduce car dependency, promote modal shift, and manage travel demand in ways that support environmental sustainability, social equity, and urban liveability (Cairns et al., 2008; Banister, 2008). This

conceptualization of TDM provides the foundation for the subsequent sections of this chapter, which examine in greater detail the classification of TDM measures and their role within the sustainable mobility paradigm.

Classifications of Travel Demand Management measures

The literature offers several classifications of TDM measures, reflecting the multifaceted nature of travel behavior and the diversity of policy instruments available. One of the most widely cited is Litman's (2003) classification, which groups TDM measures into four categories: supply management measures, travel pricing measures, land-use planning measures, and information and persuasion measures. This framework emphasizes the diversity of policy levers through which travel demand can be influenced, highlighting the multidimensional nature of demand management.

May et al.'s classification system (2003) concerns an even more articulated categorization of TDM measures highlighting the multi-faceted nature of sustainable transportation planning. It includes six key groups such as Supply-Side Strategies, Demand Management Strategies, Pricing Strategies, Land Use and Transportation Planning Strategies, Information and Marketing Strategies, Institutional Strategies. This approach highlights the need for integrated and coordinated policy packages to effectively address sustainable mobility goals.

Moreover, among many different categorizations of TDM measures, then there is a traditional classification, with reference to psychological and motivational aspects (Steg & Vlek, 2009), that makes distinction between structural strategies and informational strategies defined as cognitive-motivational (Steg & Tertoolen, 1997).

The first category of structural measures, also referred to as Hard policies (Bamberg et al 2011), act primarily on the physical, economic, and regulatory context in which travel choices are made. These measures modify the availability, attractiveness, costs, and benefits of different transport options, thereby altering the objective conditions of choice. Structural policies typically aim to reduce the attractiveness of private motorized vehicle use (push measures) and/or enhance the attractiveness of more sustainable alternatives (pull measures) (Steg & Tertoolen, 1997).

Examples of this type of policy include interventions acting on:

- the *transport supply system* (such as reduction of road capacity, adding a new transport service, increases in service frequency etc.);
- the *economic system*, through pricing policies, monetary incentives and disincentives, subsidies, discounts, taxes, tolls, etc. aiming to change the perceived utility;
- the *regulatory and legislative framework*, through regulations, measures, and administrative provisions to regulate some aspects of individual and collective choices;

- the *territorial and land-use system*, through densification policies and the spatial reorganization of activities integrated with public transport provision.

By reshaping the choice context, these measures prompt individuals to re-evaluate their travel options and may lead to changes in behavior. However, empirical evidence suggests that hard policies, when implemented in isolation, often produce limited or short-term effects and may face issues of public acceptability, limiting their effectiveness in achieving sustained reductions in car use (Gärling & Schuitema, 2007).

In contrast, informational strategies, also known as soft measures (Bamberg et al., 2011) focus on influencing travel behaviour through non-regulatory and non-infrastructure-based approaches. These measures are commonly referred to as Voluntary Travel Behaviour Change (VTBC) programs (Ampt & Gleave, 2003). The defining feature of VTBC programs is their reliance on voluntariness, meaning that individuals make mobility choices autonomously and for personal satisfaction, without a top-down mechanism or regulation of any kind, without external coercion such as regulations or infrastructural constraints (Meloni, 2017). Voluntariness therefore alludes the policies that don't involve intervention on transport infrastructure but rather the techniques of information dissemination and persuasion to influence transportation systems' users to reshape their own mobility behaviour (Ampt & Gleave, 2003; Gärling & Fujii, 2009; Taniguchi et al. 2007; Taylor, 2007; Taylor & Ampt 2003).

These measures directly target the cognitive and motivational mechanisms underlying travel behavior, particularly car use, by altering perceptions of the objective environment, increasing awareness of unsustainable practices, attributing responsibility, highlighting the consequences of different travel options, and improving knowledge of available sustainable alternatives (Möser & Bamberg, 2008; Steg & Vlek, 1997).

Rather than relying on physical changes to the transport system, soft measures focus on community engagement strategies, including public events, workshops, and campaigns, to raise awareness, generate interest, and foster a sense of collective responsibility for sustainable travel choices. Within this framework, social marketing represents a valuable approach offering a systematic and strategic method to influence individuals' travel choices towards more environmentally friendly and efficient modes of travel. By applying audience segmentation, behaviour change techniques, effective messaging, and partnerships, social marketing can drive behaviour change, promote sustainable transportation as the social norm, and contribute to a more sustainable and efficient transportation system (Meloni, 2017).

Taken together, these classifications underline that Travel Demand Management encompasses a heterogeneous set of policy instruments that differ not only in their operational mechanisms, but also in the behavioural processes they activate. Structural and informational measures act on distinct, though interrelated, dimensions of travel behaviour, modifying either the objective conditions of choice or the cognitive and motivational determinants that guide individual decision-making. This

distinction is analytically valuable, as it clarifies why no single category of measures can be expected to produce sustained behavioural change in isolation.

At the same time, behavioural research suggests that the effectiveness of TDM measures cannot be fully understood by considering policy instruments alone. The impact of both hard and soft measures is strongly mediated by users' behavioural dispositions, levels of awareness, habitual routines, and readiness to change, as well as by the broader temporal and situational context in which interventions are implemented. This insight points to the limitations of generic, one-size-fits-all demand management strategies and highlights the need for approaches that explicitly engage with behavioural dynamics.

In this perspective, Voluntary Travel Behaviour Change programs emerge as a particularly relevant subset of TDM measures, as they are explicitly designed to translate behavioural theory into practice by targeting cognitive, motivational, and habitual mechanisms of travel behaviour. The following chapter therefore focuses specifically on VTBC programs, examining their conceptual foundations, intervention logic, and empirical effectiveness as behaviour-oriented policy instruments within the broader framework of Travel Demand Management.

Behavioural plasticity, life events, and windows of opportunity for VTBC interventions

A central assumption underlying Voluntary Travel Behaviour Change (VTBC) programs is that behavioural change unfolds over time and is inherently uneven across individuals and contexts. Behavioural change cannot be effectively induced through generic, short-term interventions aimed at the general population, but rather requires targeted, time-sensitive actions directed at individuals who are more receptive and available to change (Colleoni, 2019). This assumption is consistent with behavioural change theories reviewed in the previous chapter, which emphasize that individuals move through different stages of readiness and engagement in the change process (Prochaska & DiClemente, 1982; Darnton, 2008).

Behavioural research has repeatedly shown that individuals are not equally open to modifying established behaviours at all times. Instead, changes in habitual behaviour are more likely to occur during specific "key transition points" or moments of change, often associated with major or minor life events that disrupt existing routines and weaken the automaticity of behaviour (Verplanken et al., 2008; DfT, 2011). These moments create conditions of heightened behavioural plasticity, in which individuals are more likely to re-evaluate existing practices, reconsider alternatives, and engage in reflective decision-making processes.

From a theoretical perspective, this insight resonates with both stage-based models of behavioural change and habit-oriented approaches. Within the Transtheoretical Model, life transitions can facilitate movement from precontemplation or contemplation toward preparation and action by increasing awareness, motivation, and perceived relevance of change (Prochaska & Velicer, 1997). From a habit theory perspective, life events represent disruptions to stable contexts that normally

sustain habitual behaviour, thereby reducing the strength of automatic responses and opening space for deliberate choice (Verplanken & Wood, 2006; Gardner, 2009). In this sense, key transition points function as natural “unfreezing” moments, in Lewin’s terminology, in which established behavioural patterns become more malleable.

Moreover, Haustein’s (2012) dual-process adaptation of the Theory of Planned Behaviour provides a particularly useful interpretative framework. By explicitly distinguishing between automatic, habit-driven processes (System 1) and reflective, intention-based processes (System 2), Haustein emphasizes that behaviour change is most likely when contextual conditions reduce the dominance of automatic responses and activate reflective evaluation. Key life events can be interpreted precisely as moments in which this balance shifts: established habits are temporarily destabilized, perceived behavioural control is reassessed, and individuals become more attentive to alternative courses of action. Within this framework, VTBC interventions are most effective when they are timed to coincide with such moments, as the relative influence of intentions, information, and motivational cues is significantly amplified.

Empirical studies support this theoretical interpretation. Several contributions have shown that individuals are more open to changing habitual travel behaviours during periods of transition, often referred to as major or minor life events, which alter daily routines, social roles, or spatial contexts (DfT, 2011; Connidis, 2010). These events may include residential relocation, entering or leaving the labour market, changes in employment conditions, obtaining a driving license, acquiring or losing access to a car, or starting a new educational path (Van der Waerden et al., 2003; Klöckner, 2004). Such transitions disrupt the situational cues that sustain habitual behaviour and create a window of opportunity in which alternative mobility practices can be considered, tested, and potentially adopted.

From an analytical perspective, these findings reinforce the idea that behavioural change within Travel Demand Management cannot be conceived as an instantaneous or universal process. Behavioural change is inherently temporally differentiated and context-dependent, shaped by the interaction between individual motivation, habit strength, and situational constraints. As emphasized by both behavioural theory and empirical evidence, interventions that fail to account for timing and target population characteristics risk limited effectiveness, particularly in contexts where mobility behaviour is strongly routinized.

These insights have important implications for Travel Demand Management and VTBC program design. Rather than treating behavioural change as a uniform process applicable to all individuals, behaviour-oriented demand management strategies must account for temporal dynamics and target interventions at moments when individuals are more receptive to change. This temporal sensitivity enhances both the effectiveness and the efficiency of VTBC measures, as interventions delivered during key transition points are more likely to translate into meaningful and sustained changes in travel behaviour (Bamberg et al., 2011; Meloni, 2017).

From a policy perspective, this approach moves beyond one-size-fits-all information campaigns and supports the design of targeted, time-limited interventions aligned with life-course dynamics. By focusing on population groups experiencing heightened behavioural openness, VTBC programs can leverage reduced habit strength and increased cognitive engagement to support the adoption of more sustainable mobility practices, thereby increasing the likelihood of long-term behaviour stabilization.

This insight is particularly relevant for the empirical focus of this thesis, which examines university students as a population group undergoing significant life transitions. Entering higher education is typically associated with changes in residence, daily schedules, social networks, and mobility resources, all of which contribute to destabilizing previously established travel habits. These conditions make students especially receptive to interventions aimed at reshaping mobility behaviour, providing a strong theoretical and analytical justification for their selection as the target group of analysis.

By situating VTBC interventions within moments of heightened behavioural plasticity, Travel Demand Management strategies can more effectively translate behavioural insights into sustained changes in travel demand. This temporal and process-oriented understanding of behavioural change directly informs the design, targeting, and evaluation of VTBC programs and anticipates the role of context-enabling solutions, such as Mobility as a Service, examined in the subsequent chapters, which further support the consolidation of new mobility practices once behavioural change has been initiated.

In this sense, behavioural plasticity constitutes the critical analytical hinge between behavioural theory and policy design, linking individual readiness to change with the strategic timing and targeting of demand-side mobility interventions.

Travel Demand Management and Avoid–Shift–Improve (ASI) framework

The conceptual foundations of Travel Demand Management (TDM) are closely aligned with the broader sustainable mobility paradigm, which seeks to reduce the environmental, social, and economic impacts of transport while ensuring adequate levels of accessibility. As discussed in Chapter Mobility and Sustainability, sustainable mobility requires coordinated actions aimed at reducing the need to travel, encouraging modal shift toward more sustainable transport options, shortening trip lengths, and improving the efficiency of transport systems (Banister, 2008; Holden et al., 2020). Within this perspective, mobility becomes more sustainable when individuals and societies travel more efficiently, travel differently, and/or travel less.

These objectives are commonly articulated through the Avoid–Shift–Improve (ASI) framework, originally proposed in the context of international transport policy, and subsequently refined and systematized in the academic literature (GIZ, 2011; Holden et al., 2020). The ASI framework provides a hierarchical and integrative structure for transport policy by distinguishing, as already summarized

in chapter The Sustainable mobility paradigm and policy implications, between three complementary strategic directions that address different dimensions of mobility-related impacts.

The Avoid (or Reduction) strategy represents the most transformative dimension of the ASI framework, as it seeks to reduce the overall volume of motorized travel by encouraging fewer trips, shorter distances, and alternative forms of access to activities. This includes measures such as land-use planning aimed at proximity, teleworking, digitalization of services, and travel demand reduction initiatives. Avoid-oriented strategies challenge deeply embedded mobility practices and are therefore strongly dependent on behavioral change as well as on broader spatial, institutional, and socio-economic conditions (Holden et al., 2020).

The Shift (or Alteration) strategy addresses travel behavior more directly by promoting a transition away from private motorized transport toward more sustainable modes such as public transport, walking, cycling, and shared mobility services. The aim of this strategy is to reduce the environmental footprint of mobility by changing how trips are made, rather than their frequency or length. Shift-oriented policies therefore combine structural interventions, such as the provision of high-quality public transport and active mobility infrastructure, with measures that influence users' preferences, perceptions, and routines (Cairns et al., 2008; Meloni, 2017).

The Improve (or Efficiency) strategy focuses on enhancing the environmental performance of transport systems through technological and operational innovation. Improve-oriented measures are central to contemporary transport policy and can deliver substantial reductions in emissions per vehicle-kilometer travelled. However, they typically leave overall travel demand levels and underlying behavioural patterns largely unchanged (Banister, 2008; Holden et al., 2020).

While the Improve and Shift strategies are necessary components of sustainable mobility policy, growing evidence suggests that they are insufficient on their own to achieve long-term sustainability targets, particularly in the context of continuous growth in travel demand and potential rebound effects. Efficiency gains may be offset by increased travel volumes, while modal shifts alone may not deliver substantial reductions in overall energy consumption and emissions if total mobility demand continues to rise (Banister, 2008; Holden et al., 2020). Consequently, the Avoid and Shift strategies, both of which explicitly require modifications in established travel behavior, are of central relevance to TDM and, more specifically, to Voluntary Travel Behaviour Change (VTBC) programs.

Within the TDM framework, VTBC programs play a key role in operationalizing the behavioral dimensions of the ASI approach. Informational and voluntary measures contribute to the Shift strategy by increasing awareness of sustainable transport alternatives, reshaping attitudes and social norms related to car use, and facilitating experimentation with non-car modes (Ampt & Gleave, 2003; Cairns et al., 2008). At the same time, VTBC programs support the Avoid strategy by encouraging reflection on travel necessity, promoting trip reduction and consolidation, and fostering lifestyle changes that reduce dependence on frequent motorized travel (Möser & Bamberg, 2008; Meloni, 2017).

By acting on cognitive, motivational, and habitual determinants of travel behavior, VTBC programs complement structural TDM measures and help translate the strategic objectives of the ASI framework into individual-level behavioral change. In this integrated perspective, VTBC programs can therefore be understood as a key policy instrument situated at the intersection of TDM and the ASI framework, particularly regarding the Avoid and Shift dimensions. This positioning underscores their strategic relevance for reducing car dependency and fostering long-term transitions toward more sustainable mobility patterns.

Concluding synthesis: Travel Demand Management as a behavioural policy framework: from demand regulation to voluntary change

This chapter has positioned Travel Demand Management as a core component of contemporary sustainable mobility policy, reframing it not merely as a collection of demand-side measures but as an explicitly behaviour-oriented policy framework. By integrating insights from travel behaviour theory with policy-oriented classifications of TDM instruments, the chapter has shown that managing travel demand fundamentally implies managing the behavioural processes through which mobility demand is generated, reproduced, and potentially transformed over time.

The review of definitions and classifications has highlighted that TDM encompasses a wide spectrum of interventions, ranging from regulatory and pricing measures to voluntary, information-based approaches. While structural (“hard”) measures remain essential for shaping the objective conditions of choice, the analysis has shown that their effectiveness is often limited when implemented in isolation. In contrast, voluntary and informational measures explicitly target cognitive, motivational, and habitual mechanisms underlying travel behaviour, thereby addressing dimensions of mobility decision-making that cannot be reached through infrastructural or economic instruments alone.

By situating TDM within a behavioural perspective, the chapter has clarified why Voluntary Travel Behaviour Change programs represent a critical evolution of demand management policy, rather than a marginal or auxiliary tool. VTBC programs operationalize behavioural theory within transport policy by translating insights on intentions formation, habit disruption, and behavioural maintenance into concrete intervention strategies. In this sense, TDM emerges not simply as a means of reducing traffic volumes, but as a framework for supporting gradual, voluntary, and potentially durable transformations of everyday mobility practices.

The chapter has further emphasized that the effectiveness of behaviour-oriented demand management depends on recognising the temporal and contextual nature of behavioural change. Travel behaviour is deeply embedded in routines and stable contexts, and change is more likely when interventions are aligned with moments of heightened behavioural openness and supported by enabling conditions. This insight reinforces the need to move beyond one-off measures and toward integrated policy packages that combine structural changes with behavioural support mechanisms.

Overall, this chapter establishes the conceptual bridge between sustainable mobility objectives and the behavioural processes through which these objectives can be achieved in practice. By framing TDM as a behavioural policy framework and by identifying VTBC programs as a key operational component, it provides the analytical foundation for the subsequent chapters, which examine how behavioural insights can be translated into effective, voluntary, and context-sensitive mobility interventions.

Voluntary Travel Behaviour Change programs: conceptual and theoretical foundations

Building on the Travel Demand Management framework previously discussed, this chapter focuses on Voluntary Travel Behaviour Change (VTBC) programs as a specific category of demand-side interventions explicitly designed to influence individual mobility choices through non-coercive, information-based, and motivational strategies. By translating behavioural insights into concrete policy instruments, VTBC programs represent a key operational link between behavioural theory and sustainable mobility practice, addressing the cognitive, motivational, and habitual mechanisms that underpin everyday travel behaviour.

The effectiveness of VTBC programs is grounded in the assumption that travel behaviour is not solely the outcome of rational utility maximization, but rather the result of complex interactions between individual cognition, social norms, habitual routines, and contextual constraints. Accordingly, information, when carefully designed, framed, personalized, and delivered, can play a significant role in influencing the psychological and motivational factors that underpin behavioural change. This perspective challenges traditional economic approaches to transport behaviour and calls for the systematic integration of insights from behavioural science, cognitive psychology, and theories of behavioural change collected and discussed in the previous chapters.

On this basis, here the theoretical foundations, methodological approaches, and design principles that characterize VTBC programs will be examined. The chapter first reviews the behavioural theories that inform voluntary change interventions, then discusses methods for evaluating their effectiveness, and finally identifies the key methodological requirements for successful implementation. In doing so, the chapter aims to clarify how VTBC programs can contribute to sustained and voluntary transitions toward more sustainable mobility patterns.

Behavioural foundations of VTBC programs

Behavioural models and behavioural change theories relevant to VTBC programs

Voluntary Travel Behaviour Change (VTBC) programs are grounded in the assumption that mobility behaviour can be influenced without coercion by acting on the cognitive, motivational, and contextual mechanisms that underlie individual travel choices. Their core hypothesis is that information, when appropriately selected, framed, personalized, and delivered, can activate reflective decision-making processes, weaken habitual responses, and support the adoption of more sustainable mobility practices (Ampt & Gleave, 2003; Meloni, 2017). In this sense, VTBC programs represent the practical translation of behavioural theories into policy instruments aimed at reshaping travel demand through voluntary engagement rather than regulatory constraint.

The relevance of behavioural theories for VTBC programs must be understood in relation to the broader conceptual framework developed in the previous chapters. As discussed within the Sustainable Mobility Paradigm and the New Mobilities Paradigm, travel demand is not an exogenous or purely technical phenomenon, but the outcome of socially embedded practices, routines, meanings, and decision-making processes. VTBC programs operationalize this perspective by explicitly targeting the behavioural foundations of mobility demand, thereby complementing structural Travel Demand Management measures that modify the objective conditions of choice.

From an analytical standpoint, behavioural theories contribute to VTBC programs in three fundamental ways. First, they clarify which determinants of behaviour can be influenced through non-coercive interventions. Second, they explain why information alone is often insufficient unless it is aligned with individuals' motivations, norms, habits, and perceived constraints. Third, they provide guidance for designing, sequencing, and targeting interventions in ways that increase the likelihood of sustained behavioural change.

Within transport research, the theoretical foundations of VTBC programs can be broadly traced to two complementary bodies of literature: behavioural models and theories of behavioural change (Meloni, 2017; Meloni et al., 2013). As already discussed, behavioural models focus on identifying the determinants of travel choices at a given point in time, whereas theories of behavioural change conceptualize behaviour as a dynamic process unfolding over time. VTBC programs require both perspectives: the former to understand *why* individuals behave as they do, and the latter to explain *how* behaviour can be modified and stabilized.

Classical economic models of travel behaviour, based on utility maximization and rational choice, have played a foundational role in transport analysis (Domencich & McFadden, 1975; Ben-Akiva & Lerman, 1985). However, their explanatory power is limited in the context of VTBC programs, as voluntary interventions do not alter prices, infrastructure, or regulations, but rather rely on persuasion, awareness, and motivation. Insights from behavioural economics and cognitive psychology, such as bounded rationality, heuristics, and systematic biases, are therefore particularly relevant, as they explain why individuals often rely on simplified decision rules and habitual choices in everyday travel (Simon, 1955, 1957; Tversky & Kahneman, 1974).

Socio-psychological models such as the Theory of Planned Behavior (Ajzen, 1991), the Norm Activation Model (Schwartz, 1977), the Value–Belief–Norm theory (Stern, 2000), and the Theory of Interpersonal Behavior (Triandis, 1977) are especially central to VTBC programs because they identify modifiable psychological mechanisms, attitudes, norms, moral obligations, perceived control, that can be activated through information and communication strategies. These models make it explicit why increasing knowledge alone is insufficient unless it is accompanied by changes in perceived responsibility, social expectations, and confidence in one's ability to act. In this sense, VTBC programs draw directly on these theories to design messages that resonate with individuals' values and social contexts, rather than relying on purely informational appeals.

A critical contribution of behavioural theory to VTBC programs concerns the role of habit. As discussed in the previous chapter, mobility behaviour is often characterized by strong habitual components that limit conscious deliberation and reduce sensitivity to new information (Gärling et al., 2001; Verplanken & Wood, 2006). Script-based theories highlight that individuals rely on learned behavioural scripts in stable contexts, particularly for routine travel such as commuting. For VTBC programs, this implies that information-based interventions are unlikely to be effective unless they are delivered in contexts where habitual responses are weakened or disrupted.

Theories of behavioural change address precisely this limitation by conceptualizing change as a temporal and processual phenomenon. Lewin's theory of change (1947) and the Transtheoretical Model (Prochaska & DiClemente, 1982) are particularly relevant because they emphasize that behaviour change requires phases of awareness, motivation, experimentation, and consolidation. VTBC programs implicitly rely on this logic when they aim first to raise awareness, then to support trial behaviour, and finally to reinforce new routines.

Among these frameworks, the Transtheoretical Model plays a pivotal role in VTBC program design, as it allows interventions to be tailored to individuals' readiness to change. This is analytically crucial for voluntary measures, which cannot impose behavioural change but must instead accompany individuals along a gradual process. In practice, this means that VTBC programs may combine different communication strategies for individuals at different stages, from awareness-raising for those in precontemplation to action support and feedback for those already experimenting with alternative travel modes.

The integration of behavioural models and behavioural change theories thus provides VTBC programs with a coherent analytical foundation. Behavioural models explain *what* drives travel choices, while behavioural change theories explain *how* these drivers can be activated, weakened, or reconfigured over time. Together, they justify the focus of VTBC programs on personalization, timing, and voluntariness, distinguishing them from both traditional information campaigns and coercive regulatory measures.

By embedding behavioural theory within the broader framework of Travel Demand Management, VTBC programs emerge not as isolated soft measures, but as theoretically grounded policy instruments capable of addressing the behavioural roots of travel demand. This analytical perspective reinforces the role of VTBC programs as a key component of sustainable mobility strategies and prepares the ground for the subsequent chapter, which examines in detail the design, implementation, and evaluation of VTBC interventions in practice.

Integrating habit and reflection: Haustein's dual-process adaptation of the theory of planned behaviour

The previous sections have shown that travel behaviour cannot be adequately explained by models that focus exclusively on deliberate, intention-based decision-making, nor by approaches that reduce

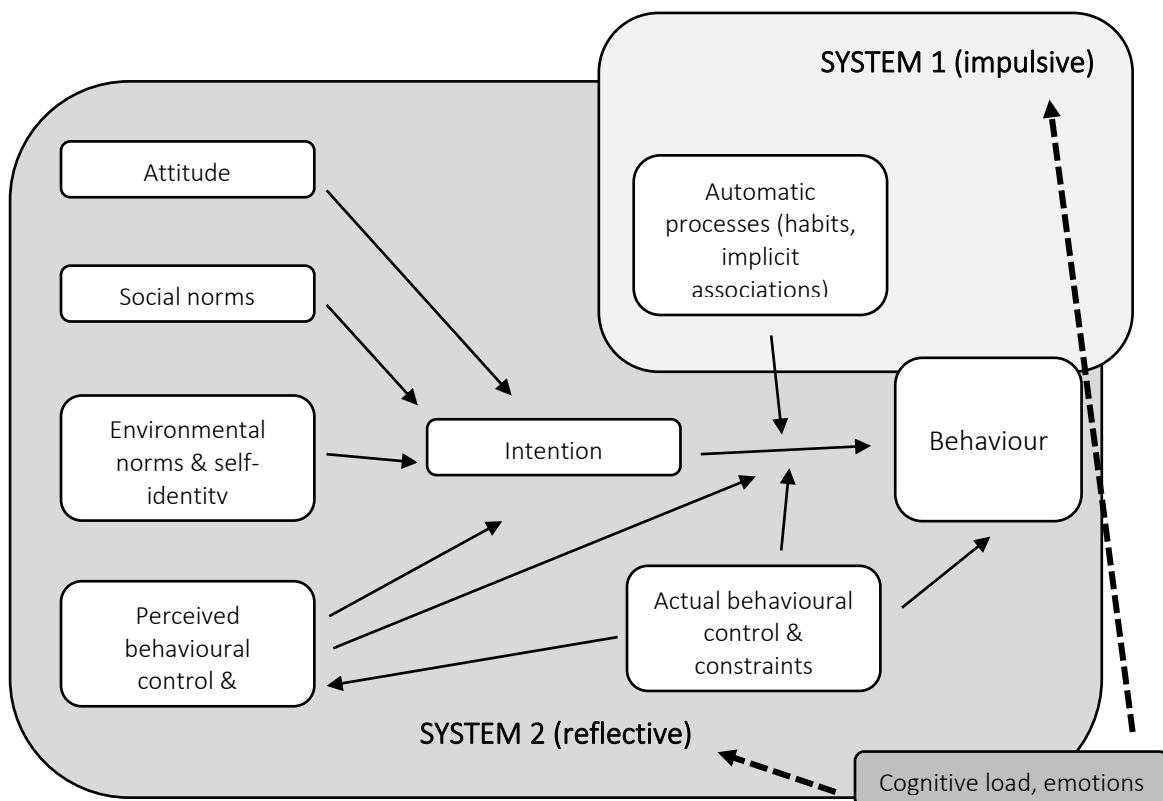
behaviour to automatic habit alone. Rather, mobility behaviour emerges from the continuous interaction between reflective evaluation, habitual routines, and contextual constraints embedded in the transport system.

Within this theoretical landscape, Haustein's model offers a particularly valuable integrative perspective, as it explicitly combines intention-based explanations of behaviour with habit-oriented and context-sensitive accounts. By doing so, it responds directly to the limitations identified in both traditional behavioural models and stage-based change theories, and provides a coherent framework for understanding when, how, and under which conditions Voluntary Travel Behaviour Change (VTBC) interventions are likely to be effective.

Both script-based theories and behavioral change theories converge in highlighting the pivotal role of habit in shaping travel behavior and in limiting the effectiveness of purely rational, information-based interventions. Habitual behaviors frequently bypass reflective decision-making, thereby reducing the impact of traditional policy measures that rely on conscious deliberation.

To address these limitations, particularly the strong influence of habit in routine travel, this research incorporates Haustein's dual-process adaptation of the Theory of Planned Behavior (Figure 2). By integrating dual-process accounts of cognition, this framework explicitly captures the interaction between automatic, habitual processes and reflective, intention-driven decision-making, thereby providing a conceptual bridge between behavioural models, theories of change, and the practical design and evaluation of VTBC programs (Haustein, 2012).

Figure 2 Haustein's dual-process adaptation of the theory of planned behaviour



Source 4 Haustein 2012

Indeed, the study of Voluntary travel behavior change (VTBC) programs has increasingly emphasized the need to move beyond purely rational-choice frameworks in order to better capture the complexity of everyday mobility decisions. In this context, Haustein's adaptation of the Theory of Planned Behavior (TPB) represents a significant theoretical advancement, as it integrates insights from cognitive psychology and behavioral economics to account for both reflective and habitual dimensions of travel behavior (Haustein, 2012). This framework is particularly relevant for evaluating the effectiveness of VTBC programs, which aim to encourage sustainable travel choices without coercive measures.

The traditional TPB, developed by Ajzen (1991), conceptualizes behavior as the outcome of intentional processes shaped by attitudes, subjective norms, and perceived behavioral control. While this model has been widely applied in transport research, its explanatory power has been criticized for underestimating the role of habits and automatic decision-making, especially in routine behaviors such as daily travel (Bamberg, Fujii, Friman, & Gärling, 2011). Travel mode choice often occurs under conditions of time pressure and cognitive load, limiting the extent to which individuals engage in deliberate evaluation of alternatives.

Haustein addresses these limitations by drawing on the Reflective–Impulsive Model (RIM) proposed by Strack and Deutsch (2004), which distinguishes between two interacting cognitive systems governing behavior. This dual-process perspective aligns with broader developments in behavioral economics and psychology, notably Kahneman's (2011) distinction between fast, automatic thinking and slow, effortful reasoning. By embedding TPB constructs within a dual-system architecture, Haustein provides a more comprehensive explanation of how travel behaviors are formed, maintained, and potentially changed.

In Haustein's framework, System 1 corresponds to automatic, impulsive processes that operate with minimal cognitive effort and are strongly shaped by habits, emotions, and situational cues (Haustein, 2012). These processes are particularly influential in daily mobility patterns, where repeated choices, such as commuting routes or mode selection, become routinized over time, and, as discussed, empirical studies have shown that habitual behavior is one of the strongest predictors of travel mode choice, often overriding attitudes and intentions (Verplanken, Aarts, van Knippenberg, & van Knippenberg, 1994; Gardner, 2009).

From the perspective of VTBC programs, the dominance of System 1 implies that information-based interventions alone are insufficient to induce lasting behavior change. Instead, effective interventions must disrupt existing habits and create opportunities for new routines to emerge. Haustein and Hunecke (2007) argue that this can be achieved through contextual changes, such as temporary incentives, personalized travel feedback, or exposure to alternative mobility options, which reduce reliance on automatic responses and trigger reconsideration of established behaviors.

System 2 encompasses reflective, deliberate decision-making processes in which individuals consciously evaluate their behavior in light of personal attitudes, social norms, and perceived control

(Haustein, 2012). This system closely corresponds to the original TPB structure and becomes particularly salient when individuals face novel situations or when habitual patterns are disrupted. Under these conditions, travelers are more likely to assess the environmental, social, and personal consequences of their mobility choices.

VTBC programs often seek to activate System 2 by increasing awareness of the negative externalities of car use and the benefits of sustainable alternatives. Personalized travel planning, goal setting, and social norm feedback have been shown to enhance reflective engagement and strengthen pro-environmental intentions (Bamberg, 2013; Fujii & Taniguchi, 2006). However, Haustein emphasizes that reflective motivation alone does not guarantee behavior change, especially when structural constraints limit feasible alternatives.

One of the key innovations in Haustein's adaptation of TPB is the explicit distinction between perceived behavioral control (PBC) and actual behavioral control (ABC). While PBC refers to an individual's subjective assessment of their ability to perform a behavior, ABC captures objective, real-world constraints that may facilitate or inhibit change (Haustein, 2012). This distinction is particularly important in transport contexts, where infrastructure availability, service quality, spatial configuration, and time constraints play a decisive role.

Empirical evidence suggests that discrepancies between perceived and actual control can significantly affect the outcomes of VTBC programs. Individuals may express strong intentions to adopt sustainable travel modes, yet fail to do so due to inadequate public transport, unsafe cycling infrastructure, or inflexible work schedules (Gaker & Walker, 2011). By incorporating ABC into the analytical framework, Haustein's model provides a more realistic assessment of behavioral feasibility and highlights the importance of aligning soft policy measures with supportive structural conditions.

Haustein's integrated framework has important implications for the design and evaluation of VTBC programs. First, it underscores the need to address both cognitive systems simultaneously by combining informational strategies with interventions targeting habitual behavior. Second, it calls for greater attention to contextual and structural factors that shape actual behavioral control, thereby bridging the gap between individual-level interventions and broader urban mobility policies.

From an evaluation perspective, this approach suggests that program effectiveness should not be assessed solely on changes in attitudes or intentions, but also on the extent to which interventions successfully disrupt habits and reduce objective barriers to change. In this sense, Haustein's adaptation of TPB offers a robust conceptual foundation for understanding why some VTBC programs achieve only short-term effects, while others contribute to sustained shifts toward more sustainable travel behavior.

In analytical terms, the adoption of Haustein's dual-process adaptation of the Theory of Planned Behaviour represents a decisive step toward a more realistic and policy-relevant understanding of travel behaviour change. By explicitly distinguishing between automatic, habit-driven processes and reflective, intention-based decision-making, the model overcomes the limitations of approaches that

rely exclusively on rational deliberation or motivational change. This distinction is particularly crucial in the context of VTBC programs, which operate without coercion and therefore depend on their ability to activate reflective processes while simultaneously weakening the dominance of habitual responses.

Moreover, the explicit differentiation between perceived and actual behavioural control allows the model to bridge individual-level behavioural explanations with system-level conditions, such as infrastructure availability, service quality, spatial constraints, and institutional settings. This feature aligns closely with the systemic perspective on mobility developed in the earlier chapters and reinforces the argument that behavioural change cannot be achieved through information alone but requires supportive contextual conditions that make alternative behaviours feasible.

Importantly, the dual-process perspective also provides a strong theoretical justification for the temporal and target-oriented design of VTBC interventions. As discussed in the previous chapter, moments of heightened behavioural plasticity, such as life transitions or contextual disruptions, reduce the strength of habitual responses and increase the salience of reflective evaluation. Haustein's framework precisely captures these dynamics, explaining why voluntary, information-based measures are more likely to succeed when interventions are aligned with such windows of opportunity.

By integrating habit, reflection, and contextual feasibility within a single analytical framework, Haustein's model ensures theoretical coherence across the thesis and provides a robust conceptual foundation for the empirical analysis that follows. In the subsequent chapters, this framework is used to interpret VTBC programs not merely as information campaigns, but as context-sensitive interventions capable of supporting sustained changes in travel behaviour when appropriately designed, timed, and embedded within the broader mobility system.

Toward an integrated theoretical framework for VTBC programs

By combining the Transtheoretical Model (TTM), the Theory of Planned Behavior (TPB), and Haustein's dual-process adaptation of TPB, this research advances an integrated and theoretically coherent framework for analysing Voluntary Travel Behaviour Change (VTBC) programs. This integration responds directly to the limitations identified in the previous chapters, namely the fragmentation of behavioural explanations across models that privilege either motivation, cognition, habit, or context in isolation.

Rather than treating VTBC interventions as generic information-based initiatives, the proposed framework conceptualizes them as multi-dimensional and temporally structured processes, in which behavioural change emerges from the interaction between individual readiness, motivational drivers, habitual mechanisms, and enabling or constraining system conditions.

Crucially, this integrated perspective aligns with the broader paradigmatic shift discussed earlier in the thesis, whereby travel demand is understood as endogenous, behaviourally mediated, and socially embedded, rather than as a fixed outcome to be accommodated through supply expansion. In this sense, the framework provides the analytical link between behavioural theory, Travel Demand

Management, and the design of voluntary policy instruments capable of supporting sustainable mobility transitions.

Each of the three theoretical perspectives contributes a distinct analytical layer: the Transtheoretical Model introduces a temporal and process-oriented understanding of change; the Theory of Planned Behavior specifies the cognitive and motivational determinants of intention formation; and Hausteins dual-process adaptation explicitly incorporates habitual and contextual dynamics, explaining why intentions often fail to translate into action. Their integration allows VTBC programs to be analysed not only in terms of whether they work, but also when, for whom, and through which mechanisms behavioural change is likely to occur.

Table 3 Integrated conceptual framework for the analysis of VTBC programs

Analytical dimension	Transtheoretical Model (TTM)	Theory of Planned Behavior (TPB)	Haustein's Dual-Process Adaptation of TPB	Implications for VTBC programs
<i>Temporal nature of change</i>	Behavior change unfolds through sequential stages (precontemplation, contemplation, preparation, action, maintenance)	Largely static, focused on intention at a given point in time	Continuous interaction between automatic and reflective processes	VTBC interventions should be tailored to individuals' stage of change
<i>Motivation formation</i>	Motivation increases progressively across stages	Intention shaped by attitudes, social norms, and perceived behavioral control	Reflective motivation may be weakened by strong habits	VTBC programs must both strengthen motivation and reduce behavioral inertia
<i>Role of cognition</i>	Cognitive engagement evolves across stages	Central role of deliberative, rational evaluation	Coexistence of automatic (System 1) and reflective (System 2) processes	Combination of information, persuasion, and contextual stimuli is required
<i>Role of habits</i>	Recognized mainly as a challenge in the maintenance phase	Implicitly treated as barriers to intentional change	Explicitly central within automatic decision-making	VTBC measures must disrupt established travel routines
<i>Behavioral control</i>	Barriers and facilitators influence transitions between stages	Perceived Behavioral Control as determinant of intention	Distinction between perceived and actual behavioral control	Soft measures must be supported by enabling structural conditions
<i>Intention–action translation</i>	Critical transition between preparation and action	Intention–behavior gap acknowledged	Gap explained by habit strength and contextual constraints	Action planning, feedback, and incentives support implementation
<i>Behavior stabilization</i>	Maintenance phase vulnerable to relapse	Not explicitly addressed	Habits as key mechanism for behavioral stabilization	VTBC programs aim to foster new, sustainable habits

Source 5 Author's elaboration based on Ajzen (1991), Prochaska and DiClemente (1982) and Haustein (2012)

The integrated logic of this framework is summarized in Table 3, which functions as an analytical map linking theoretical constructs to concrete implications for the design and evaluation of VTBC programs. Rather than presenting the theories as parallel or competing explanations, the table highlights how each contributes to different but complementary dimensions of behavioural change.

In particular, the Transtheoretical Model provides the temporal and process-oriented backbone of the framework by conceptualizing behavioral change as a gradual progression through successive stages characterized by different levels of awareness, motivation, and readiness to act. As illustrated in Table 3, this perspective is particularly relevant for VTBC programs, which typically address heterogeneous populations positioned at different stages of change. Individuals are therefore not uniformly receptive to change-oriented messages or interventions; rather, the effectiveness of VTBC measures depends on their alignment with the individual's current stage of change. VTBC interventions can thus be designed to support movement from precontemplation to contemplation by raising awareness of unsustainable travel practices, from contemplation to preparation by strengthening motivation and perceived feasibility, and from action to maintenance by reinforcing newly adopted routines and reducing the risk of relapse.

The Theory of Planned Behavior complements this process-based perspective by specifying the key cognitive and motivational determinants underlying intention formation at each stage of change. As reflected in Table 3, attitudes toward travel modes, perceived social norms, and perceived behavioral control shape individuals' readiness to modify their travel behavior, particularly during the critical transition from contemplation to action. Within VTBC programs, TPB-informed interventions, such as personalized feedback, informational campaigns, and tailored support throughout the phases of change, aim to positively influence these constructs, thereby increasing the likelihood that motivational shifts translate into concrete behavioral attempts.

However, as extensively documented in transport research, the presence of strong intentions does not necessarily result in sustained behavioral change, especially in the context of routine and habitual travel behavior. Haustein's dual-process adaptation of TPB addresses this limitation by explicitly integrating automatic, habitual processes alongside reflective, intention-driven decision-making. As highlighted in Table 3, this framework acknowledges that a substantial share of daily mobility behavior is governed by automatic responses to contextual cues rather than conscious deliberation and explains why changes in attitudes or intentions do not necessarily result in immediate or sustained behavioral change. Habitual travel behavior frequently bypasses reflective cognition, particularly in stable contexts where choices are repeatedly enacted under similar conditions. Consequently, VTBC programs must be conceptualized as interventions that simultaneously target both cognitive systems: disrupting automatic, habit-driven behavior through contextual changes and stimuli, while activating reflective reasoning through motivational, informational, and planning-oriented components.

In practical terms, this dual focus enables VTBC programs to operate on multiple leverage points within the decision-making process, as summarized in Table 3. Contextual interventions, such as

temporary incentives, changes in accessibility, or exposure to alternative travel options, can weaken existing habits and reduce reliance on automatic decision-making. At the same time, reflective mechanisms are strengthened by enhancing perceived behavioral control, clarifying available action possibilities, and supporting concrete action planning, including the formation of implementation intentions. Through this combined approach, VTBC programs facilitate the transition from intention to action and increase the likelihood that newly adopted behaviors are stabilized and maintained over time.

The distinction between perceived behavioral control and actual behavioral control further strengthens the explanatory power of the framework. While TPB emphasizes individuals' subjective assessment of their ability to perform a behavior, Haustein's adaptation explicitly acknowledges the role of objective constraints, such as infrastructure quality, service availability, spatial structure, and time limitations. The table therefore underscores that VTBC programs are most effective when soft, voluntary measures are aligned with supportive structural conditions, and when interventions explicitly address both perceived and real barriers to change.

Finally, the framework emphasizes that the stabilization of new travel behaviors is a critical and often underestimated component of VTBC programs. The maintenance phase identified in the TTM, combined with the role of habit formation highlighted in dual-process theories, points to the need for interventions that extend beyond initial behavior change. VTBC programs should therefore aim not only to trigger behavioral experimentation, but also to support the consolidation of new, sustainable routines and to prevent relapsing into previous, less sustainable travel patterns.

More broadly, the integration of these theoretical perspectives reflects the recognition that no single, unified theory of behavior and behavioral change currently exists, particularly with regard to complex, routine, and context-dependent behaviors such as travel (Anable et al., 2006). Each theoretical approach captures specific dimensions of decision-making and change, cognitive, motivational, habitual, and contextual, while remaining insufficient on its own to fully explain mobility behavior. As synthesized in Table 3, the strength of this framework lies not in the individual explanatory power of each theory, but in their integration. By jointly accounting for temporal dynamics, motivational processes, habitual behaviour, and structural constraints, the framework provides a robust analytical foundation for understanding why VTBC programs may succeed or fail under different conditions. This integrative approach moves beyond single-theory explanations and supports the design of context-sensitive, stage-appropriate, and system-aware interventions capable of fostering sustained and voluntary changes in travel behaviour.

Method to evaluate the effectiveness of VTBC programs

Building on the integrated theoretical framework presented in the previous section and summarized in Table 3, the evaluation of Voluntary Travel Behaviour Change (VTBC) programs must be conceived as an explicitly theory-driven process. Since VTBC interventions are designed to activate multiple

behavioural mechanisms, including intention formation, habit disruption, the translation of intentions into action, and the stabilization of new routines, their evaluation cannot be limited to the observation of short-term behavioural outcomes or aggregate indicators alone (Ajzen, 1991; Prochaska & DiClemente, 1982; Haustein, 2012).

From an analytical perspective, evaluating VTBC effectiveness requires acknowledging that behavioural change is dynamic, heterogeneous across individuals, and strongly conditioned by context. Changes in travel behaviour may occur gradually, may differ in magnitude across population groups, and may be reversible if supportive conditions are not maintained. Consequently, evaluation frameworks must be capable of capturing temporal dynamics, individual-level variability, and the persistence of change over time, rather than relying solely on static before–after comparisons at the aggregate level.

This implies a methodological shift away from purely outcome-oriented evaluation approaches toward designs that explicitly reflect the behavioural logic underlying VTBC programs. In particular, evaluation methods should allow researchers to: (i) distinguish short-term reactions from stable behavioural change, (ii) assess the extent to which intentions are translated into actual behaviour, (iii) identify whether changes reflect genuine habit disruption or merely temporary adaptations, and (iv) control for contextual factors that may confound observed outcomes. As such, the evaluation of VTBC programs becomes an integral component of behavioural policy design, rather than a purely technical ex post assessment exercise.

Within this perspective in fact, evaluation serves not only as a tool for accountability, but also as a mechanism for learning and refinement, enabling policymakers and researchers to better understand *how, for whom, and under which conditions* voluntary interventions can effectively contribute to sustainable mobility transitions.

Moreover, their evaluation then (understood as the systematic monitoring and reporting of results in order to demonstrate the short- and long-term impacts of such measures) represents one of the most complex and delicate phases in the implementation of VTBC programs (Stopher, 2005).

Evaluation serves a dual purpose. On the one hand, it provides empirical evidence to inform policymakers about whether a VTBC program constitutes a cost-effective intervention compared to alternative transport policies. On the other hand, it supports learning processes by identifying strengths, weaknesses, and the conditions under which behavioural change occurs.

Table 4 summarizes the key components of the evaluation method and illustrates how the theoretical dimensions underlying VTBC programs are operationalized into empirical evaluation strategies.

Table 4 Methodological framework for the evaluation of VTBC programs

Analytical dimension	Theoretical reference	Evaluation method	Type of data	Purpose
<i>Behavioural change</i>	TTM, TPB	Before–after comparison	Travel surveys	Measure changes in mode choice, trip frequency, distances
<i>Temporal dynamics</i>	TTM	Longitudinal design	Panel data	Capture progression and maintenance of change
<i>Habit disruption</i>	Dual-process models	Repeated observations	Individual travel diaries / surveys	Distinguish stable change from short-term fluctuation
<i>Intention–action gap</i>	TPB	Individual-level analysis	Panel data	Identify translation of intention into behaviour
<i>Causal attribution</i>	Behavioural evaluation theory	Control group comparison	Participant vs non-participant data	Isolate program effects
<i>Behavioural persistence</i>	TTM, habit theory	Follow-up monitoring	Post-program surveys	Assess stabilization and relapse
<i>Contextual influence</i>	ABC vs PBC (Haustein)	Comparative analysis over time	Mobility + contextual data	Control for external changes

Source 6 Author's elaboration based on Stopher (2005), Meloni (2017), Parker et al. (2007), Richardson et al. (2004), and Haustein (2012).

Among these objectives, the most problematic aspect concerns the quantification of behavioural change attributable to VTBC interventions. Travel behaviour is inherently variable and influenced by multiple external factors, making it difficult to isolate program's effects. To address this challenge, the literature emphasizes the need to adopt clear and transparent evaluation procedures capable of determining the effects of VTBC measures on users' travel behaviour (Stopher, 2005; Meloni, 2017). In line with this approach, behavioural change is typically assessed by comparing individuals' travel behaviour at two distinct moments: before the implementation of the VTBC program, in order to capture baseline or "typical" travel patterns in terms of modes used and distances travelled, and after implementation, in order to establish whether more sustainable travel behaviours have been adopted and whether these changes persist over time (Meloni, 2017). The primary aim of this analysis is therefore to quantitatively evaluate the effects produced on mobility behaviour following VTBC program implementation.

Before–after measurements can be carried out using either repeated cross-sectional surveys or panel surveys. In the former case, data are collected through mobility surveys administered to different samples at different points in time, which are assumed to be representative of the same reference

population. In the latter case, panel surveys involve repeated observations of the same individuals across multiple time phases, often over an extended period.

In the context of VTBC programs, panel data are generally considered preferable for two main reasons (Meloni, 2017), both of which are directly linked to the behavioural dimensions highlighted in Table 4, which summarizes the methodological framework adopted in this research. The first reason concerns behavioural variability: travel behaviour is non-static and may vary from day to day, across seasons, or in response to life circumstances. Observing the same individuals before and after program implementation allows researchers to capture intra-individual variability and to distinguish genuine behavioural change from short-term fluctuations (Stopher, 2005). The second reason relates to the level of analysis. While repeated cross-sectional surveys allow only aggregate-level comparisons, panel surveys enable disaggregation at the individual level, making it possible to identify how and to what extent specific individuals modify their travel behaviour through a sequence of repeated choices over time.

As illustrated in Table 4, the evaluation framework explicitly incorporates dimensions related to habit disruption and the intention–action gap, which are central to dual-process and cognitive behavioural theories (Haustein, 2012; Bamberg et al., 2011). Repeated individual-level observations allow evaluators to assess whether observed behavioural changes reflect stable modifications of routines or merely temporary responses to contextual stimuli. This distinction is particularly relevant for daily mobility behaviour, where habits often dominate decision-making and may reassert themselves once the intervention ends (Verplanken et al., 1994; Gardner, 2009).

In addition to longitudinal observation, a further critical element of VTBC evaluation concerns causal attribution. As emphasized by Stopher (2005), it is essential to determine whether observed behavioural changes are genuinely attributable to the VTBC program rather than to external contextual factors. For this reason, the literature strongly recommends comparing behavioural changes observed among program participants with those recorded among a control or comparison group consisting of individuals with similar socio-demographic and mobility characteristics who did not participate in the program. As indicated in Table 4, this comparison strengthens causal inference by allowing evaluators to distinguish program effects from broader contextual influences such as fuel price variations, changes in transport supply, or seasonal effects (Parker et al., 2007).

Finally, consistent with the emphasis on behavioural maintenance and habit formation highlighted in the theoretical framework and reflected in Table 4, several studies stress the importance of monitoring behavioural outcomes over time (Parker et al., 2007). Follow-up surveys conducted after the conclusion of the program make it possible to assess not only immediate effectiveness, but also the persistence and stabilization of behavioural change. A key methodological challenge in this phase concerns the definition of an appropriate time interval for monitoring. According to the literature, this interval should be sufficiently long to allow new behaviours to consolidate, but not so long that major contextual changes, such as significant shifts in costs or the availability of transport alternatives,

confound the evaluation (Richardson et al., 2004). Commonly adopted intervals range from three to twelve months, depending on the characteristics of the intervention and the local context.

In conclusion, the evaluation of Voluntary Travel Behaviour Change programs requires a methodological approach that is explicitly aligned with the behavioural complexity of mobility decisions and the theoretical foundations upon which VTBC interventions are built. As demonstrated throughout this section, assessing effectiveness cannot be reduced to measuring immediate behavioural outcomes, but must instead capture the processes through which behavioural change emerges, evolves, and stabilizes over time.

By integrating before–after comparisons, longitudinal panel designs, control group analysis, and medium-term follow-up, the evaluation framework outlined here directly operationalizes key constructs derived from behavioural models and behavioural change theories. In particular, it allows for the empirical examination of habit disruption, the intention–action gap, and behavioural persistence, dimensions that are central to dual-process theories and stage-based models of change (Haustein, 2012; Prochaska & DiClemente, 1982). The explicit consideration of both perceived and actual behavioural control further strengthens causal interpretation by accounting for the interaction between individual motivation and structural conditions.

From an analytical standpoint, this approach reinforces the argument that VTBC programs should be evaluated as context-sensitive, process-oriented interventions rather than as isolated informational campaigns. The effectiveness of voluntary measures depends not only on *whether* behavioural change occurs, but also on *when, for whom, and under what enabling conditions* such change is sustained. Evaluation methods that fail to capture these dimensions risk underestimating both the potential and the limitations of VTBC interventions.

By systematically linking theoretical constructs to empirical evaluation strategies, the framework adopted in this research provides a robust basis for assessing the contribution of VTBC programs to long-term sustainable mobility objectives. At the same time, it establishes the methodological foundation for the empirical analysis presented in the following chapters, in which VTBC interventions are examined within a specific population and institutional context, allowing theoretical expectations to be tested against observed behavioural outcomes.

The fundamental methodological requirements of VTBC programs

Building on the integrated behavioural framework developed in the previous sections, this subsection identifies the fundamental methodological requirements that Voluntary Travel Behaviour Change (VTBC) programs must satisfy in order to translate theoretical insights into effective policy practice. While earlier chapters have clarified *why* VTBC programs can work, by targeting cognitive, motivational, habitual, and contextual determinants of travel behaviour, and *how* their effectiveness can be evaluated, the present section addresses the crucial question of *how such programs should be designed and implemented* to maximize their impact and durability.

The literature on VTBC consistently shows that behavioural change does not emerge automatically from the provision of information, nor from isolated persuasive efforts. Rather, successful interventions are characterized by a high degree of methodological coherence between behavioural theory, program design, implementation strategies, and evaluation mechanisms (Ampt & Gleave, 2003; Cairns et al., 2008; Meloni, 2017). VTBC programs operate within complex socio-technical systems in which individual choices are shaped by habits, constraints, social norms, and institutional conditions; as a result, their effectiveness depends on the capacity to align intervention design with these multiple layers of influence.

From this perspective, VTBC programs should be understood not as generic communication campaigns, but as structured, process-oriented interventions that are context-specific, behaviour-specific, and tailored to individuals' capabilities and motivations (Ampt & Gleave, 2003; Cairns et al., 2008; Meloni, 2017).

There are studies in literature that have explored the effectiveness of VTBC programs highlighting some fundamental requirements that such measures must possess to achieve good levels of effectiveness to foster change in travel behaviour.

The main key factors identified are listed below (Meloni, 2017):

1. identification of a specific transport context (Target mobility context).

A first fundamental requirement concerns the identification of a specific transport and territorial context in which the VTBC program is implemented. VTBC interventions are most effective when they focus on a clearly defined spatial and infrastructural setting, such as a neighbourhood, workplace, school, or university campus, where travel choices are shaped by relatively stable conditions (Parker et al., 2007). This contextual focus allows program designers to identify which sustainable transport alternatives are realistically available and can be credibly promoted. Without an adequate transport context, characterized by accessible, reliable, and competitive alternatives to car use, behavioural change initiatives risk generating intentions that cannot be translated into action (Haustein, 2012; Gaker & Walker, 2011).

The identification of a specific mobility context is analytically crucial because voluntary behavioural change can only occur where sustainable alternatives are materially available and perceived as feasible, highlighting the interdependence between individual behaviour and system-level conditions.

2. identification of a specific behavior to promote (Target Behaviour).

Closely related to the definition of the mobility context is the identification of a specific target behaviour. The literature emphasizes that VTBC programs should promote behavioural changes that are concrete, well-defined, and realistically achievable by the target population (Fogg, 2009; Davies, 2012). Target behaviours should be simple to understand, easy to measure, and should not require drastic changes in daily routines, especially in the initial phases of intervention. Importantly, the selection of the target behaviour must be consistent with the characteristics of the transport context:

promoting public transport use, cycling, or walking is only feasible if the corresponding alternatives are available and meet minimum standards of quality and accessibility (Meloni, 2017).

Focusing on a clearly defined and achievable target behaviour allows VTBC programs to reduce behavioural complexity, increase perceived behavioural control, and facilitate the translation of intentions into concrete and measurable actions.

3. identification of a specific segment of the population (Target Population).

Another key requirement is the identification of a specific target population. VTBC programs are not designed to address the general public indiscriminately, but rather to engage individuals who are both able and willing to adopt promoted behaviour (Curtis & Headicar, 1997; Anable, 2005). This necessitates a segmentation of the population based on socio-demographic characteristics, travel patterns, attitudes, values, and readiness to change (Steg & Vlek, 2009; Meloni et al., 2014). Targeting individuals who are more receptive to behavioural change, such as those experiencing life transitions or already expressing pro-environmental attitudes, enhances program efficiency and effectiveness (Anable, 2005; Sanjust et al., 2014).

The effectiveness of VTBC programs depends on the strategic selection of population segments that combine behavioural feasibility with motivational readiness, reinforcing the principle that voluntary change is most likely among individuals who are both able and willing to modify their mobility practices.

4. identification of barriers and obstacles to behavioral change.

Effective VTBC programs systematically identify and address barriers to behavioural change, which can be grouped into three main categories (Seethaler & Rose, 2003):

- external barriers relate to the territorial, economic, and transport context, such as limited services availability or poor infrastructure. These barriers can sometimes be mitigated by verifying and communicating the existence of viable alternatives.
- internal psychological and motivational barriers include negative attitudes toward sustainable modes, lack of awareness of the impacts of car use, insufficient knowledge of alternatives, and low perceived behavioural control (Steg & Vlek, 2009; Bamberg et al., 2011).
- habitual barriers stem from the routinized nature of travel behaviour, which often bypasses reflective decision-making processes and resists change (Verplanken et al., 1994; Haustein, 2012).

A systematic identification of external, internal, and habitual barriers is essential to ensure that VTBC interventions are both credible and effective and address not only informational deficits but also structural constraints and automatic behavioural patterns that inhibit change.

5. Personalization.

Personalization is widely recognized as one of the most powerful methodological tools in VTBC programs (Gärling & Fujii, 2009). The effectiveness of VTBC interventions increases with the degree to which information, advice, and feedback are tailored to individual characteristics and circumstances (Abrahamse et al., 2007; Fujii & Taniguchi, 2006). Personalization requires detailed

knowledge of users' socio-economic profiles, motivational drivers, and travel patterns, allowing program designers to activate the most relevant motivational levers and persuasive strategies (Ampt, 2003).

Personalization can operate at multiple levels:

- the mode of contact and level of engagement with participants. Face-to-face interaction has repeatedly been shown to be particularly effective, as it enables dialogue, trust-building, and interactive problem-solving (McKenzie-Mohr, 2000; Fujii & Taniguchi, 2006).
- mobility solutions proposed, which should be tailored to individual needs and constraints and often require detailed activity–travel data collected through travel diaries or similar instruments (Stopher, 2005).
- quantification and framing of feedback, linking observed and target behaviours to individual and collective outcomes (Abrahamse et al., 2005; Gaker & Walker, 2011; Schwanen & Lucas, 2011). The information should include the quantitative characteristics associated with the chosen and unchosen transport alternatives by each individual and quantify the effects of user's behavior both at a personal level and at a community level (Shwanen&Lucas, 2011; Gaker & Walker, 2011, Abrahamse et al., 2005).

Personalization enhances the effectiveness of VTBC programs by aligning intervention content with individual circumstances, motivations, and constraints, thereby increasing relevance, credibility, and engagement while reducing cognitive overload.

6. Use of feedback information.

The systematic use of feedback information represents another core requirement of effective VTBC programs. Feedback influences behaviour by increasing awareness of current practices, clarifying the gap between observed and desired behaviour, and supporting informed decision-making (Kluger & DeNisi, 1996; Dahlstrand & Biel, 1997). To be effective, feedback must be accurate, credible, easy to understand, and provided repeatedly over time, while avoiding information overload (Brög, 2000; Fujii & Taniguchi, 2006; Fogg, 2003).

Therefore, feedback information improves the ability to make a decision towards the activation of the target behavior. Without feedback, behavioral change is less likely (Avineri, 2012).

In particular, the previously mentioned quantitative feedback information is aimed at:

- provide evidence of the observed behavior, through "feedback of the observed behavior";
- present the information, associated with the proposed alternative, through "feedback of the proposed behavior";
- incentivize behavioral change through the achievement of benefits on a personal level and for the community ("comparative feedback").

Feedback in VTBC programs typically includes quantitative indicators such as travel time, monetary cost, CO₂ emissions, and calories burned, and may also incorporate qualitative dimensions such as stress reduction or health benefits (Avineri, 2012). Feedback mechanisms play a pivotal role in VTBC programs by making mobility behaviour visible, comparable, and evaluable, thus supporting self-reflection, reinforcing motivation, and enabling informed behavioural adjustment over time. Furthermore, comparative feedback, highlighting both personal benefits and collective gains, has been shown to further enhance motivation and behavioural commitment (Abrahamse et al., 2005).

7. Use of communication and persuasion principles.

The literature consistently shows that feedback alone is often insufficient to induce behavioural change (Abrahamse et al., 2005). VTBC programs therefore integrate communication and persuasion principles, drawing on behavioural psychology and social marketing. Persuasion techniques based on principles such as social norms, commitment, reciprocity, and credibility play a key role in enhancing message effectiveness (Cialdini, 2001). Social marketing approaches further contribute by applying audience segmentation, targeted messaging, and appropriate communication channels that match users' familiarity and ease of use (Cooper, 2007; Fogg, 2009). A crucial element is also fostering a sense of personal agency, making individuals aware of their active role in achieving the program's objectives (McKenzie-Mohr, 2002).

The integration of communication and persuasion principles strengthens VTBC interventions by shaping how information is processed and interpreted, leveraging social norms, commitment, and credibility to support voluntary and self-motivated behavioural change.

8. Integration within a behavioural change process model.

A further and crucial requirement for the effectiveness of VTBC programs is the adoption of an integrated behavioural change process model. As discussed in the previous theoretical section, travel behaviour is the outcome of a complex interaction between cognitive, motivational, habitual, and contextual factors, and cannot be adequately explained or influenced through a single theoretical lens. Effective VTBC programs therefore need to be grounded in a coherent framework that combines insights from economic models of travel behaviour, theories of behavioural change, social psychology, social marketing, and persuasion (Defra, 2008; Cialdini, 2001; Anable et al., 2006).

The integrated model proposed in this research, combining the Transtheoretical Model (TTM), the Theory of Planned Behavior (TPB), and Haustein's dual-process adaptation of TPB, provides a structured conceptual basis for such integration. This framework allows VTBC programs to explicitly address the different phases, mechanisms, and constraints involved in voluntary travel behaviour change. In particular, it clarifies how interventions can be designed to support individuals' progression through stages of change (TTM), shape motivational determinants and intention formation (TPB), and disrupt habitual decision-making while supporting behavioural implementation and maintenance (Haustein, 2012; Prochaska & DiClemente, 1982; Ajzen, 1991).

By embedding VTBC programs within an integrated behavioural change process model, interventions can be systematically aligned with the theoretical mechanisms underlying travel behaviour change and with the evaluation framework discussed in the previous section. This integration ensures internal coherence between program design, implementation, and assessment, and enhances the likelihood that voluntary measures lead not only to short-term behavioural experimentation, but also to sustained and meaningful transitions toward more sustainable mobility practices (Anable et al., 2006; Meloni, 2017).

9. Evaluation and monitoring.

Finally, and in strict coherence with the methodological discussion presented in the previous section, evaluation and monitoring constitute a fundamental requirement for the design, implementation, and effectiveness of VTBC programs, rather than a merely ancillary or ex post activity. As discussed in the Chapter Voluntary Travel Behaviour Change programs: conceptual and theoretical foundations, VTBC programs aim to influence complex behavioural mechanisms, ranging from intention formation to habit disruption and behavioural maintenance, which unfold over time and are highly sensitive to contextual conditions. Consequently, robust evaluation and monitoring techniques are essential for capturing both immediate behavioural responses and longer-term dynamics of change (Stopher, 2005; Parker et al., 2007).

From the perspective of the integrated behavioural change model adopted in this research, evaluation plays a dual role. First, it serves an analytical function, providing empirical evidence on whether and to what extent VTBC interventions activate the behavioural mechanisms identified in the theoretical framework, such as changes in attitudes, perceived behavioural control, habitual routines, and the stabilization of new practices (Ajzen, 1991; Prochaska & DiClemente, 1982; Haustein, 2012). Second, it performs a process-oriented function, feeding information back into program design and implementation and allowing interventions to be adapted and refined over time in response to observed outcomes (Meloni, 2017).

Moreover, from a policy and governance perspective, evaluation and monitoring provide essential inputs for accountability, learning, and decision-making. By systematically documenting program outcomes and processes, evaluation supports evidence-based policymaking, facilitates comparisons between alternative interventions, and strengthens the legitimacy and political acceptability of VTBC programs (Stopher, 2005; Parker et al., 2007). At the same time, continuous monitoring enables iterative improvements, allowing VTBC programs to evolve as adaptive policy instruments rather than fixed, one-off initiatives.

In sum, consistent with both the integrated behavioural change model and the evaluation methodology proposed in this research, evaluation and monitoring are integral components of VTBC programs. They ensure coherence between theoretical assumptions, intervention design, and observed outcomes, and they are indispensable for understanding not only whether VTBC programs work, but also how, for whom, and under which conditions they contribute to sustained and voluntary transitions toward more sustainable mobility patterns (Anable et al., 2006; Meloni, 2017).

In conclusion, the methodological requirements outlined in this section highlight that the effectiveness of Voluntary Travel Behaviour Change programs depends on the coherence between theoretical foundations, program design, implementation strategies, and evaluation methods. VTBC programs are most effective when they are explicitly grounded in behavioural theory, tailored to specific contexts, behaviours, and population segments, and designed as process-oriented interventions capable of addressing motivational, habitual, and contextual determinants of travel behaviour. The integration of personalization, feedback, persuasion, and social marketing techniques within an overarching behavioural change process model ensures that voluntary measures can move beyond short-term behavioural experimentation and contribute to the stabilization of new, more sustainable mobility practices. At the same time, the central role assigned to evaluation and monitoring underscores that VTBC programs must be conceived as adaptive policy instruments, continuously informed by empirical evidence and responsive to observed outcomes. Taken together, these methodological requirements provide a coherent operational framework that bridges behavioural theory and policy practice, thereby strengthening the potential of VTBC programs to support long-term transitions toward sustainable mobility (Anable et al., 2006; Cairns et al., 2008; Meloni, 2017).

These methodological principles directly inform the design of the empirical study presented in the following chapters, guiding the selection of the target population, the structure of the intervention, and the evaluation strategy adopted to assess behavioural change among university students.

Concluding synthesis: Voluntary Travel Behaviour Change as a process-oriented approach to governing mobility behaviour

This chapter has critically examined Voluntary Travel Behaviour Change (VTBC) programs as a distinct and theoretically grounded category of behaviour-oriented transport policies. Moving beyond simplistic assumptions about information provision and rational choice, the analysis has demonstrated that VTBC programs are best understood as process-based interventions that explicitly address the cognitive, motivational, habitual, and contextual mechanisms underlying everyday travel behaviour.

By systematically integrating behavioural models and theories of behavioural change, the chapter has clarified that voluntary change in mobility cannot be reduced to a single causal mechanism. Instead, it unfolds through interacting processes: the formation of motivation and intentions, the disruption of entrenched habits, the translation of intentions into action, and the stabilization of new practices over time. This perspective highlights a critical distinction between explaining travel behaviour at a given point in time and actively governing behavioural change, a distinction that lies at the core of VTBC programs.

The integrated theoretical framework developed in this chapter, combining the Transtheoretical Model, the Theory of Planned Behaviour, and Haustein's dual-process adaptation of TPB, represents

a key conceptual contribution. Rather than treating these theories as competing explanations, the framework demonstrates their complementarity in capturing different dimensions of change: temporal dynamics, motivational drivers, habit strength, and the constraints imposed by both perceived and actual behavioural control. This integration responds directly to long-standing limitations in transport research, particularly the intention–behaviour gap and the persistence of habitual car use despite favourable attitudes toward sustainable mobility.

From a policy perspective, the chapter has shown that VTBC programs cannot be conceived as isolated information campaigns or short-term awareness initiatives. Their effectiveness depends on methodological coherence between theory, program design, implementation strategies, and evaluation. Targeting specific contexts, behaviours, and population segments; addressing structural, psychological, and habitual barriers; and embedding personalization, feedback, and persuasion within a clear behavioural change process are not optional features, but necessary conditions for success.

Crucially, the analysis has emphasized that one of the most fragile phases of behavioural change concerns behaviour stabilization. While many VTBC interventions are capable of triggering initial experimentation, they often struggle to consolidate new practices and prevent relapses into established routines. This insight reinforces the importance of temporal sensitivity, repeated exposure, and supportive conditions in sustaining behavioural change, and it underscores the limits of voluntary measures when they are not aligned with enabling structural and organizational contexts.

In this sense, VTBC programs emerge as a pivotal but incomplete component of behaviour-oriented transport policy. They are uniquely positioned to activate motivation, awareness, and readiness for change, yet their long-term effectiveness depends on the extent to which individuals are subsequently supported in implementing and maintaining new mobility practices. This observation directly motivates the analytical shift developed in the following chapter, which examines how context-enabling mobility solutions, specifically Mobility as a Service, can complement VTBC programs by reducing practical barriers, reinforcing behavioural control, and supporting the stabilization of sustainable travel routines over time.

By positioning VTBC as a process-oriented policy framework rather than a set of isolated techniques, this chapter provides the conceptual foundation for understanding how voluntary behavioural interventions can contribute to sustainable mobility transitions when embedded within a broader ecosystem of demand-side and context-sensitive mobility policies.

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Mobility as a Service as context-enabling mobility solutions

The previous chapters have examined Travel Demand Management (TDM) and Voluntary Travel Behaviour Change (VTBC) programs as behaviour-oriented, demand-side policy instruments aimed at influencing individual mobility choices through non-coercive, informational, and motivational strategies. Grounded in behavioural models and theories of behavioural change, VTBC programs seek to activate reflective decision-making, disrupt habitual car use, and support the adoption of more sustainable travel practices over time (Ampt & Gleave, 2003; Cairns et al., 2008; Meloni, 2017).

However, a central insight emerging from both behavioural theory and empirical evidence is that changes in attitudes, intentions, and motivations do not automatically translate into sustained behavioural change. As highlighted by the Theory of Planned Behaviour (Ajzen, 1991) and Haustein's dual-process adaptation of TPB (Haustein, 2012), the translation of intention into action is strongly conditioned by perceived and actual behavioural control, while habit-based theories emphasize the resistance of routine travel practices to purely cognitive interventions (Verplanken et al., 1994; Bamberg et al., 2011). Even when VTBC programs successfully increase awareness and motivation, behavioural change may remain limited if individuals face fragmented information, limited accessibility of alternatives, or high cognitive and practical costs associated with multimodal travel.

This perspective directly builds on the distinction between behaviour-oriented interventions and context-shaping measures discussed in the previous chapters, positioning MaaS as the structural complement to Travel Demand Management and Voluntary Travel Behaviour Change programs.

This limitation points to the importance of the choice context in which mobility decisions are made. From a behavioural perspective, this shifts analytical attention from individual motivation alone to the interaction between behavioural processes and the structural conditions under which mobility choices are enacted. While VTBC programs primarily act on motivational and cognitive mechanisms, their effectiveness is inherently conditioned by the structure and usability of the mobility system, highlighting the need for complementary context-enabling solutions. In this perspective, Mobility as a Service (MaaS) emerges as a promising policy-relevant innovation that can support and reinforce behavioural change processes by reshaping the informational, organizational, and transactional conditions under which travel choices are enacted.

This chapter conceptualizes MaaS not as a purely technological or market-driven innovation, but as a context-enabling mobility solution that operates at the intersection of behavioural change theory, Travel Demand Management, and sustainable mobility policy. By integrating information, planning, booking, and payment across multiple transport modes, MaaS has the potential to reduce cognitive effort, increase perceived and actual behavioural control, and facilitate the translation of behavioural intentions into everyday mobility practices.

Defining Mobility as a Service: beyond a technological perspective

Before reviewing existing definitions of Mobility as a Service, it is necessary to clarify the analytical perspective adopted in this thesis. Rather than approaching MaaS primarily as a technological innovation or as a market-driven digital platform, this research conceptualizes MaaS as a context-enabling mobility solution that operates on the structural conditions under which travel choices are formed and enacted. This positioning reflects the theoretical foundations developed in the previous chapters, which have shown that behavioural change in mobility cannot be achieved through motivational and informational interventions alone, but depends critically on the configuration of the choice environment, the availability of viable alternatives, and the perceived and actual feasibility of behavioural change (Banister, 2008; Stern, 2000; Haustein, 2012).

From this perspective, MaaS is not treated as an end in itself, nor as a neutral technological layer, but as a socio-technical and institutional arrangement that reshapes the choice context by integrating information, access, coordination, and payment across transport modes. By modifying the informational, organizational, and transactional dimensions of the mobility system, MaaS potentially directly influences perceived behavioural control, reduces cognitive and practical barriers to multimodal travel, and supports the translation of pro-sustainable intentions into everyday practices (Ajzen, 1991; Gärling & Schuitema, 2007; Haustein, 2012). Conceptualizing MaaS in this way allows it to be analytically positioned as a structural complement to Travel Demand Management and Voluntary Travel Behaviour Change programs, rather than as an alternative or competing approach.

Adopting a context-oriented interpretation of MaaS is therefore essential for understanding its potential contribution to sustainable mobility transitions. It enables an analysis of MaaS that goes beyond questions of technological functionality or user uptake, and instead focuses on how MaaS interacts with behavioural mechanisms, habitual routines, and system-level constraints. This approach also aligns MaaS with the behavioural and systemic paradigms discussed in the first chapter, in which mobility outcomes are understood as emerging from the interaction between individual behaviour and the broader socio-technical context in which choices are embedded (Sheller & Urry, 2006; Urry, 2007; Geels, 2014).

Mobility as a Service is commonly defined as an integrated mobility concept in which different transport services, such as public transport, shared mobility, active modes, and on-demand services, are bundled and made accessible through a single digital interface (Hietanen, 2014; Jittrapirom et al., 2017). From an operational perspective, MaaS typically combines journey planning, real-time information, booking, ticketing, and payment functionalities within a unified platform.

While early policy and industry discussions often framed MaaS primarily as a technological innovation or a novel business model, more recent academic contributions have progressively reinterpreted MaaS as a socio-technical arrangement with direct implications for travel behaviour (Sochor, Strömberg, & Karlsson, 2015; Jittrapirom et al., 2017). Rather than acting merely as a digital layer

superimposed on existing transport systems, MaaS intervenes in the very conditions under which mobility choices are generated, evaluated, and enacted.

In line with the systemic and behavioural perspectives discussed in the previous chapters, MaaS can be conceptualized as a form of behaviourally relevant infrastructure: an enabling environment that reorganizes information, access, coordination, and payment in ways that directly affect users' perceived and actual behavioural control. In this sense, MaaS does not primarily seek to persuade users to behave differently, but to make alternative behaviours easier, more intelligible, and more practicable within everyday mobility routines.

This interpretation resonates with Jittrapirom et al. (2017), who define MaaS as a socio-technical system requiring coordination across technological infrastructures, institutional arrangements, and user practices, and with Sochor, Strömberg, and Karlsson (2015), who emphasize its ecosystem nature. From a behavioural standpoint, however, the crucial contribution of MaaS lies in its capacity to reorganize the choice architecture of mobility by altering how alternatives are presented, compared, and accessed (Thaler & Sunstein, 2008).

From a behavioural perspective, the defining feature of MaaS is not digitalization per se, but its capacity to restructure the choice context of mobility. In this sense, MaaS can be understood as an institutionalized form of context modification, operating upstream of individual choice by shaping what options are perceived as feasible, accessible, and legitimate within everyday mobility practices. By simplifying access to alternatives, reducing informational asymmetries, and lowering transaction costs, MaaS can influence how individuals perceive and evaluate different travel options. In this sense, MaaS aligns closely with behavioural theories that emphasize the role of contextual factors in shaping behaviour, including perceived behavioural control (Ajzen, 1991), habit disruption (Verplanken et al., 1994), and choice architecture (Thaler & Sunstein, 2008).

Importantly, MaaS does not aim to eliminate choice, but to reconfigure it. Rather than restricting mobility options, MaaS expands the feasible choice set by making sustainable alternatives more visible, comparable, and convenient. This characteristic distinguishes MaaS from coercive regulatory measures and positions it firmly within the family of demand-side, behaviour-oriented mobility policies.

By clarifying MaaS as a context-shaping arrangement rather than a purely technological artefact, this subsection establishes the conceptual foundation for the analyses developed in the following sections. The next subsections will therefore examine how MaaS interacts with behavioural theories and with Voluntary Travel Behaviour Change programs, and how it can support the translation of behavioural intentions into sustained mobility practices.

MaaS and behavioural theory: acting on the choice context

Building directly on the theoretical framework delineated in the previous chapters and on the conceptual positioning of Mobility as a Service adopted in this thesis, this subsection examines MaaS as a context-enabling instrument that operates on the choice environment within which travel behaviour is formed and enacted. The analysis follows as a logical continuation of the integrated framework for Voluntary Travel Behaviour Change developed earlier, which combines stage-based models of change, intention-based theories, and dual-process approaches to explain how behavioural change unfolds over time.

Thanks to its role in reshaping the informational, organisational, and transactional dimensions of the mobility system, MaaS acts on the same behavioural leverage points identified in the previous chapters, particularly perceived and actual behavioural control, habit disruption, translation of intentions into action and behaviour stabilization. As such, the role of MaaS can be understood as a direct and coherent extension of the behaviour-oriented and demand-side policy approaches discussed earlier, providing the contextual conditions necessary for voluntary behavioural change to occur and to be sustained.

As discussed in the previous chapters, VTBC programs primarily target cognitive, motivational, and habitual determinants of mobility choices through information, persuasion, and engagement strategies. Behavioural theories, however, consistently show that the effectiveness of such interventions is strongly conditioned by the structure of the choice context in which decisions are made. Even when motivation and awareness are successfully activated, behavioural change may fail to materialize if individuals face high cognitive demands, fragmented information, or limited usability of available alternatives.

To clarify how MaaS can support behavioural change, it is useful to start with the critical mechanisms identified by behavioural theory that systematically hinder the translation of pro-sustainable intentions into actual mobility behaviour. Building on the integrated theoretical framework developed earlier in this thesis, this section provides a coherent analytical lens through which these mechanisms can be interpreted, and through which MaaS can be conceptualized as a context-enabling application of behavioural change principles. Specifically, the analysis revisits the core analytical dimensions identified in the VTBC framework, such as intention–action translation, perceived and actual behavioural control, motivation, cognition, habits formation, temporal nature of change, and behaviour stabilization, and examines the specific contribution that MaaS can offer with respect to each of them. In this sense, MaaS is not interpreted through a separate or autonomous theoretical model, but is analysed using the same behavioural framework adopted to conceptualize VTBC programs, with the difference lying in the mode of intervention: rather than acting primarily on motivation and cognition, MaaS operates by reshaping the structural and contextual conditions under which behavioural change processes unfold.

A first and well-documented barrier concerns the so-called intention–behaviour gap, which is particularly pronounced in domains characterized by routine decisions, time constraints, and strong contextual influences, such as daily travel.

Behavioural change theories consistently document the existence of an intention–behaviour gap, whereby individuals may express favourable attitudes toward sustainable mobility and strong intentions to reduce car use, yet fail to enact these intentions in practice (Sheeran, 2002; Bamberg & Möser, 2007). This gap is not simply attributable to weak motivation, but rather to a combination of structural constraints, limited behavioural control, and the automaticity of established travel routines. Within the Theory of Planned Behaviour, perceived behavioural control plays a central role in shaping both intention and behaviour, reflecting individuals' subjective assessment of their capacity to perform a given action (Ajzen, 1991). In transport contexts, perceived behavioural control is closely linked to the availability, reliability, comprehensibility, and usability of mobility options.

Haustein's dual-process adaptation of TPB further refines this interpretation by distinguishing perceived behavioural control from actual behavioural control, which captures the objective enabling conditions and constraints embedded in the transport system, such as service coverage, temporal coordination, pricing structures, and information availability (Haustein, 2012). Fragmented information systems, complex fare structures, and uncertainty regarding service performance can significantly undermine both perceived and actual control, even when sustainable alternatives are objectively present. Under such conditions, VTBC interventions may successfully increase awareness and motivation while still failing to generate behavioural change, because individuals lack the practical means to implement their intentions.

From this perspective, MaaS directly addresses one of the core structural barriers underlying the intention–behaviour gap. By integrating information, journey planning, booking, and payment across multiple transport modes into a single interface, MaaS reduces cognitive effort, lowers transaction costs, and increases the usability of multimodal travel options. Empirical evidence indicates that MaaS users report higher confidence in multimodal travel, greater predictability of travel outcomes, and a stronger willingness to substitute private car use with public transport or shared mobility services (Sochor et al., 2018; Karlsson et al., 2020). In behavioural terms, MaaS strengthens the translation of intention into action by increasing actual behavioural control and aligning perceived control with objective system conditions.

Beyond intention–behaviour gap, a second critical mechanism through which MaaS interacts with behavioural theory concerns the disruption of habitual travel behaviour, the automatic, script-driven processes rather than reflective decision-making (Verplanken et al., 1994; Aarts et al., 1997), and the facilitation of new routines. In stable contexts, repeated choices such as commuting mode selection become routineized, reducing sensitivity to new information and limiting the effectiveness of purely cognitive interventions. As shown in both behavioural psychology and transport research, strong habits can override attitudes and intentions, thereby sustaining car-dependent behaviour even in the presence of pro-environmental motivation (Gardner, 2009; Bamberg et al., 2011).

In this context, MaaS can contribute to habit disruption by altering the default conditions under which travel decisions are made. By systematically presenting multimodal alternatives, simplifying their use, and reducing transaction costs, MaaS can weaken the dominance of habitual car use and prompt reconsideration of established routines. This mechanism is consistent with Haustein's dual-process framework, which highlights that habitual behaviour (System 1) can be disrupted when contextual cues change or when automatic responses are no longer the most efficient or convenient option (Haustein, 2012). MaaS platforms, by reconfiguring access to mobility services and lowering the effort associated with non-car modes, can create such contextual disruptions without relying on coercive measures. This mechanism mirrors the logic of VTBC interventions aimed at habit disruption, but extends it by embedding behavioural support directly into the everyday mobility environment rather than relying solely on episodic informational or motivational stimuli.

Repeated exposure to MaaS-supported alternatives and positive travel experiences can, over time, contribute to the gradual formation of new mobility routines and to the stabilization of more sustainable travel behaviour. From a behavioural perspective, this highlights the inherently temporal nature of change: shifts in travel behaviour do not occur instantaneously, but emerge through repeated enactment, feedback, and learning processes that unfold over time.

This dynamic is closely aligned with stage-based theories of behavioural change, and in particular with the Transtheoretical Model, which conceptualizes change as a progression from action to maintenance and emphasizes the vulnerability of these later stages to relapse (Prochaska & DiClemente, 1982; Prochaska & Velicer, 1997). While Voluntary Travel Behaviour Change programs often concentrate on triggering initial behavioural change by supporting movement from contemplation to action, they are typically less equipped to sustain new behaviours once active intervention ends.

In this respect, MaaS can be interpreted as a context-enabling mechanism that supports the post-action phases of behavioural change by embedding sustainable choices within everyday mobility practices. By reducing friction, uncertainty, and coordination effort in daily travel, MaaS facilitates repeated behavioural enactment, which is a key precondition for habit formation and behavioural stabilization. Rather than replacing behavioural interventions, MaaS extends their temporal effectiveness by providing a supportive choice environment that reinforces new practices over time and reduces the likelihood of relapse into previously established, less sustainable routines.

A further contribution of MaaS to behavioural change can be understood through the lens of behavioural economics and choice architecture, which directly relates to the processes of motivation formation, cognitive engagement, and habit disruption identified in behavioural theory. Choice architecture refers to the design of decision environments in ways that systematically influence behaviour while preserving freedom of choice (Thaler & Sunstein, 2008). Transport systems are inherently structured choice environments, in which defaults, information availability, and the salience of alternatives shape both reflective evaluations and automatic responses.

By mediating access to mobility options through digital interfaces, MaaS platforms function as behaviourally relevant choice architectures that operate simultaneously on cognitive and motivational mechanisms. The ordering, framing, and presentation of travel options within MaaS applications can influence users' preferences and decisions, for example by prioritizing public transport or active modes in default route suggestions, providing transparent comparisons of travel time and cost, or visualizing environmental impacts associated with different options (Sunio et al., 2021). These features support motivation formation by making the benefits of sustainable options more explicit and personally relevant, while also enhancing cognitive clarity and reducing decision complexity.

At the same time, choice architecture mechanisms embedded in MaaS contribute to habit disruption by altering the situational cues that normally trigger automatic, car-oriented responses. Repeated exposure to multimodal alternatives presented as convenient, intelligible, and reliable can weaken established travel scripts and encourage behavioural experimentation. In this sense, MaaS does not rely solely on persuasive messages, but reshapes the decision environment in ways that progressively shift both reflective evaluations (System 2) and automatic responses (System 1).

Importantly, these nudging mechanisms operate within a voluntary and non-coercive framework, aligning with the principles of Voluntary Travel Behaviour Change. By preserving freedom of choice while subtly steering behaviour, MaaS-based choice architectures maintain ethical acceptability and political feasibility, while reinforcing the effectiveness of VTBC interventions that target awareness, commitment, and motivation.

From an evaluation standpoint, this perspective also implies that MaaS effects may manifest incrementally and indirectly, through changes in option salience, cognitive effort, and repeated exposure, rather than through immediate and discrete modal shifts. Within the integrated behavioural framework adopted in this research, MaaS therefore complements motivational and informational interventions by acting on cognition, motivation, and habit dynamics simultaneously,

Within the integrated framework adopted in this thesis, MaaS can therefore be interpreted as a structural complement to VTBC programs, enabling the practical enactment of behaviour change processes initiated through motivational and informational interventions and reinforcing the conditions under which sustainable mobility choices can emerge and stabilize over time.

While the previous discussion examined analytically the role of MaaS in translation of pro-sustainable intentions into actual mobility behaviour, Table 5 offers a synthetic overview that illustrates how MaaS simultaneously operates across multiple behavioural dimensions identified within the integrated theoretical framework.

Table 5 Extension of the integrated conceptual framework for VTBC programs: the role of MaaS

Analytical dimension	Integrated VTBC framework	Implications for VTBC programs	Role of MaaS as context-enabling solution
<i>Temporal nature of change</i>	Behavioural change unfolds over time through stages and through interaction between reflective and automatic processes	Interventions should be staged, continuous, and adaptive	Supports later stages (action, maintenance) by stabilizing access to sustainable options over time
<i>Motivation formation</i>	Motivation emerges from attitudes, norms, and perceived control but may be weakened by habits	VTBC must activate motivation while addressing inertia	Does not create motivation directly, but sustains motivated behaviour by reducing effort and uncertainty
<i>Role of cognition</i>	Coexistence of reflective (System 2) and automatic (System 1) processes	Information alone is insufficient; contextual support is required	Reduces cognitive load through integrated information, planning, and payment
<i>Role of habits</i>	Habits dominate routine travel behaviour and resist change	VTBC must disrupt routines and support new scripts	Alters default travel scripts by making multimodal choices easy, visible, and repeatable
<i>Behavioural control</i>	Distinction between perceived and actual behavioural control	Behaviour change requires enabling structural conditions	Enhances both perceived and actual control by improving usability, reliability, and coordination of services
<i>Intention–action translation</i>	Intention–behaviour gap explained by habits and contextual constraints	Action support and implementation tools are critical	Directly supports intention enactment by lowering practical and transactional barriers
<i>Behaviour stabilization</i>	New behaviours require reinforcement to prevent relapse	Maintenance depends on routine formation	Facilitates routine consolidation through repeated, low-friction use of sustainable modes

Source 7 Author's elaboration extending the integrated VTBC framework presented in Chapter X, based on Ajzen (1991), Prochaska and DiClemente (1982), Darnton (2008), Haustein (2012), and MaaS studies (Hietanen, 2014; Jittrapirom et al., 2017; Sochor et al., 2018)

The table illustrates that MaaS primarily intervenes in the later and more fragile phases of behavioural change, intention enactment, habit disruption, and behaviour stabilization, where purely informational or motivational interventions often prove insufficient.

Taken together, these theoretical perspectives suggest that MaaS can be conceptualized as a context-enabling policy instrument that operates at the intersection of behavioural control, habit dynamics, and choice architecture. By acting on the structural and informational conditions of choice, MaaS enhances the effectiveness of Voluntary Behavioural Change strategies and supports the translation of pro-sustainable intentions into sustained mobility practices. In doing so, MaaS aligns closely with the integrated behavioural change framework developed in this thesis, reinforcing the argument that sustainable mobility transitions require coordinated interventions that simultaneously address cognitive, habitual, and contextual determinants of travel behaviour.

MaaS within Travel Demand Management, Voluntary Travel Behaviour Change program and the ASI framework

Within the sustainable mobility paradigm, the Avoid–Shift–Improve (ASI) framework provides a strategic structure for understanding how different policy instruments contribute to reducing the environmental and social impacts of transport systems (GIZ, 2011; Holden et al., 2020). While Improve strategies focus primarily on technological and operational efficiency gains, the Avoid and Shift dimensions explicitly require changes in travel behaviour, mobility practices, and patterns of demand. As discussed in the previous chapters, these strategies depend not only on the availability of alternatives, but also on individuals' capacity and willingness to modify established routines and decision-making processes. In this respect, Mobility as a Service (MaaS) can be interpreted as a policy-relevant mechanism that operationalizes the behavioural dimension of the ASI framework by acting on the context in which mobility choices are made.

From an ASI perspective, MaaS primarily supports the Shift strategy by facilitating access to public transport, shared mobility, and active modes through integrated journey planning, booking, and payment systems. By lowering informational, organizational, and transactional barriers, MaaS increases the relative attractiveness and usability of non-car alternatives, thereby enabling modal substitution away from private vehicle use (Hietanen, 2014; Sochor et al., 2018). At the same time, MaaS can also contribute to the Avoid dimension, albeit more indirectly, by supporting trip chaining, reducing redundancy in travel, and enabling more efficient combinations of activities and modes. When embedded within broader policy packages that include teleworking, digital services, and proximity-oriented land-use planning, MaaS may help reduce overall motorized travel demand by making alternative forms of access more feasible and convenient (Holden et al., 2020).

Positioned within the Travel Demand Management (TDM) framework, MaaS can be conceptualized as a hybrid demand-side instrument that integrates elements traditionally addressed by separate policy measures. In this sense, MaaS occupies an intermediate position between traditional soft TDM measures and more structural interventions, combining behavioural sensitivity with tangible modifications of the mobility system.

Unlike conventional TDM tools that act either through pricing, regulation, or information provision, MaaS combines informational, organizational, and service-based interventions within a single operational platform. In doing so, it reshapes the choice environment by modifying the availability, visibility, and ease of use of transport options, rather than directly restricting behaviour or expanding infrastructure capacity (Cairns et al., 2008). This positioning aligns MaaS with the core logic of TDM as a policy approach that seeks to influence when, how, and why people travel, rather than simply accommodating projected demand through supply-side expansion.

Crucially, the effectiveness of MaaS as a TDM instrument depends not only on its technological features, but also on its integration with behavioural and organizational dimensions of mobility

systems. As highlighted in the TDM literature, demand-side policies are most effective when structural measures are combined with interventions that address cognitive, motivational, and habitual determinants of behaviour (Bamberg et al., 2011; Gärling & Schuitema, 2007). In this sense, MaaS does not replace traditional TDM measures, but complements them by providing a concrete mechanism through which behavioural change can be enacted and sustained in everyday mobility practices.

This complementarity becomes particularly evident when MaaS is integrated with Voluntary Travel Behaviour Change (VTBC) programs. As discussed in the previous subsections, MaaS can be understood as a context-enabling infrastructure that strengthens the effectiveness of VTBC interventions by acting on multiple behavioural dimensions simultaneously. While VTBC programs primarily activate motivation, awareness, and commitment through informational and persuasive strategies, MaaS supports these processes by reshaping the choice context in which behavioural intentions are enacted.

By simplifying access to multimodal alternatives, integrating fragmented information, and lowering the cognitive and practical effort required to plan, combine, and pay for trips, MaaS enhances both perceived and actual behavioural control, one of the key determinants of behaviour within the Theory of Planned Behaviour and its extensions (Ajzen, 1991; Haustein, 2012). In doing so, MaaS directly addresses the intention–action gap that frequently limits the effectiveness of voluntary behavioural interventions.

Beyond behavioural control, MaaS also interacts with motivational and cognitive mechanisms. By increasing the visibility, comparability, and perceived feasibility of sustainable travel options, MaaS reinforces motivational activation generated by VTBC programs and supports reflective decision-making processes. At the same time, by embedding sustainable options into everyday mobility routines and reducing reliance on car-based default scripts, MaaS contributes to the disruption of habitual behaviour and facilitates the emergence of new mobility routines.

Moreover, MaaS also plays a critical role in the temporal dynamics of behavioural change, particularly in addressing one of the main limitations of Voluntary Travel Behaviour Change programs, namely their difficulty in sustaining behavioural change over time. While VTBC programs are often effective in triggering initial behavioural experimentation by activating motivation, awareness, and commitment, they frequently struggle to support the stabilization and routinization of new mobility practices once the intervention ends. MaaS intervenes precisely at this critical stage by supporting subsequent phases of action, consolidation, and maintenance. By reducing friction in repeated decision-making, ensuring continuous access to integrated mobility options, and lowering the cognitive and practical effort associated with everyday travel choices, MaaS increases the likelihood that newly adopted behaviours are repeated, routinized, and eventually internalized. In this sense, MaaS functions as a structural mechanism for behaviour stabilization, complementing VTBC programs by extending their effects beyond initial change and supporting the long-term consolidation of sustainable mobility practices

Taken together, the integration of MaaS with VTBC programs operationalizes the integrated behavioural framework developed earlier in the thesis. MaaS does not replace behavioural interventions, but complements them by providing the structural, informational, and organisational conditions necessary for motivation to translate into action, for habits to be reshaped, and for behavioural change to be sustained. While VTBC programs activate reflective processes and create readiness for change, MaaS modifies the choice context in which decisions are made, making sustainable behaviours easier to perform and more likely to be repeated.

Overall, MaaS can therefore be situated at the intersection of the ASI framework, Travel Demand Management, and Voluntary Travel Behaviour Change programs. It represents neither a purely technological solution nor a stand-alone behavioural intervention, but a demand-side policy instrument that operationalizes behavioural insights through context modification. This positioning reinforces the central argument of this thesis: that effective sustainable mobility transitions require integrated policy approaches capable of aligning behavioural motivation with enabling mobility environments. In this sense, MaaS emerges as a key mechanism for translating behaviour-oriented policy objectives into everyday mobility practices, strengthening the feasibility of Avoid and Shift strategies within contemporary transport systems.

MaaS, evaluation, and behavioural outcomes

From an evaluation perspective, the integration of Mobility as a Service into behaviour-oriented mobility policies raises a set of methodological challenges that closely mirror those already identified in the assessment of Voluntary Travel Behaviour Change programs. As discussed in the chapter on the evaluation of VTBC effectiveness, conventional transport evaluation frameworks, largely centered on aggregate indicators such as traffic volumes, modal shares, or vehicle kilometers travelled, are often ill-suited to capture the complexity, temporality, and non-linearity of behavioural change processes (Cairns et al., 2008; Darnton, 2008; Möser & Bamberg, 2008). These limitations become even more pronounced in the case of MaaS, where behavioural effects are mediated through both psychological mechanisms and changes in the choice context.

Behavioural change theories consistently emphasize that behavioural outcomes should not be interpreted as instantaneous responses to an intervention, but as the result of gradual and staged processes unfolding over time. Frameworks such as Darnton's (2008) behaviour change model and stage-based theories underline the importance of distinguishing between intermediate outcomes, such as awareness, intention formation, trial behaviour, and habit disruption, and longer-term outcomes related to routine stabilization and sustained behaviour change. Within this perspective, the effectiveness of MaaS cannot be adequately assessed through single-point measurements or short-term before–after comparisons. Instead, evaluation must adopt a longitudinal and process-oriented approach, capable of tracing behavioural trajectories and identifying how individuals move across stages of change in interaction with the mobility system.

MaaS platforms offer distinctive opportunities in this respect. Unlike many traditional VTBC interventions, which rely heavily on self-reported data collected through surveys, MaaS systems inherently generate continuous, fine-grained, and objective data on users' travel behaviour, including trip frequency, modal combinations, temporal patterns, and spatial trajectories (Sochor et al., 2018; Karlsson et al., 2020). When appropriately governed and ethically managed, these data can significantly enhance the analytical capacity of evaluation frameworks by enabling the observation of behavioural dynamics rather than isolated outcomes. In particular, MaaS data allow evaluators to examine how behavioural changes emerge, consolidate, or revert over time, thereby aligning empirical assessment more closely with the theoretical assumptions of behavioural change models discussed in the VTBC chapters.

This potential directly connects MaaS to the methodological requirements outlined for VTBC program evaluation. As argued in that chapter, effective evaluation should combine outcome indicators (e.g. modal shift, reduction in car use) with process indicators that capture intermediate behavioural mechanisms, such as experimentation with alternatives, variability in travel choices, and reductions in habitual reliance on specific modes. MaaS data can support this multi-dimensional evaluation by making it possible to identify periods of behavioural exploration, increased multimodality, or gradual stabilization of new routines. This reinforces the argument advanced in the VTBC evaluation chapter that effective assessment of behaviour-oriented policies requires moving beyond static before–after comparisons toward longitudinal designs capable of capturing behavioural dynamics and feedback effects, making MaaS an enabling tool for more robust and theory-informed assessment of behaviour-oriented policies.

At the same time, the availability of large-scale behavioural data introduces new challenges that must be explicitly addressed within evaluation frameworks. Changes detected through MaaS data may reflect not only individual learning or motivation, but also external influences such as pricing policies, service disruptions, seasonal effects, or parallel interventions implemented within the Travel Demand Management framework. Consequently, evaluation designs must remain sensitive to the systemic nature of mobility behaviour, as emphasized in the CLIOS perspective and in the TDM chapters, and avoid attributing causality to MaaS in isolation.

Furthermore, the use of MaaS-generated data raises critical ethical and governance issues that are inseparable from evaluation practice. Scholars have highlighted concerns related to data privacy, informed consent, algorithmic transparency, and the potential for surveillance or behavioural manipulation (Smith et al., 2018; Zuboff, 2019). From a behavioural policy perspective, the legitimacy and acceptability of MaaS-based interventions depend not only on their effectiveness, but also on the extent to which users retain agency, trust, and control over their data and mobility choices. These considerations echo broader debates in behavioural public policy regarding the ethical boundaries of nudging and choice architecture (Thaler & Sunstein, 2008) and reinforce the need for evaluation frameworks that incorporate governance and acceptability criteria alongside behavioural outcomes.

In light of these considerations, MaaS can be positioned as both a subject and an instrument of evaluation within behaviour-oriented mobility policy. On the one hand, its impact on travel behaviour must be assessed using theoretically grounded, longitudinal, and multi-dimensional indicators consistent with behavioural change frameworks. On the other hand, MaaS platforms provide unprecedented empirical resources to operationalize such evaluation approaches, bridging the gap between behavioural theory and observed mobility practices. When integrated with VTBC programs, MaaS thus strengthens not only the implementation of behavioural interventions, but also their evaluation, by enabling a more nuanced understanding of how intentions are translated into action and how new mobility routines are formed and sustained over time.

This dual role of MaaS reinforces its strategic relevance within the broader analytical trajectory developed in this thesis: from the characterization of travel demand to the explanation of travel behaviour, to the design and evaluation of behaviour-oriented demand-side policies. By aligning technological innovation with behavioural theory and methodological rigor, MaaS contributes to advancing both the effectiveness and the evaluability of policies aimed at supporting long-term transitions toward sustainable mobility.

Concluding synthesis: MaaS at the intersection of behaviour, context, and mobility policy

This chapter has reconceptualized Mobility as a Service through a behavioural and policy-oriented lens, positioning it not as a standalone technological innovation but as a form of behavioural infrastructure that reshapes the conditions under which mobility decisions are formed, enacted, and stabilized over time. Building on travel behaviour theory, Travel Demand Management, and Voluntary Travel Behaviour Change programs, the analysis has demonstrated that MaaS operates primarily on the choice context rather than on individual motivation alone.

The central argument developed in this chapter is that MaaS does not seek to persuade individuals to behave differently, nor does it directly aim to modify attitudes, values, or norms. Instead, its contribution lies in reorganizing the informational, organisational, and transactional dimensions of the mobility system in ways that can enhance perceived and actual behavioural control, reduce cognitive and practical barriers, and lower the effort required to enact sustainable travel choices. In doing so, MaaS addresses one of the most persistent challenges identified in behavioural theory: the gap between pro-sustainable intentions and actual behaviour.

By embedding behavioural support into everyday mobility environments, MaaS complements rather than substitutes behaviour-oriented interventions such as VTBC programs. While VTBC initiatives primarily activate reflective processes (awareness, motivation, and intention formation) MaaS contributes to the structural conditions that enable action implementation and long-term behaviour stabilization. This complementarity highlights a crucial distinction between behavioural change as a

psychological process and behaviour as a situated practice shaped by system-level constraints and affordances.

Interpreted within a demand-side policy perspective, MaaS can therefore be understood as an enabling component of behaviour-oriented mobility governance. Its contribution aligns primarily with shift-oriented strategies by facilitating multimodal practices and reducing dependence on private car use, while indirectly supporting demand reduction through changes in mobility routines and resource use. Importantly, this contribution does not rely on coercive regulation or technological efficiency gains, but on modifying the everyday context in which travel decisions are repeatedly made.

From an evaluative standpoint, the chapter has also underscored that understanding MaaS as behavioural infrastructure requires moving beyond static outcome indicators. Behavioural change supported by MaaS is inherently processual, unfolding through experimentation, repetition, and stabilization over time. This calls for evaluation approach capable of capturing behavioural trajectories, intermediate outcomes, and maintenance effects, while also engaging with emerging challenges related to data governance and user autonomy.

In the overall analytical trajectory of this thesis, MaaS represents the culmination of a progressive shift from mobility paradigms to behavioural policy instruments and, finally, to context-enabling solutions.

Part 2: Methodological design and research strategy

Introductory framework

Contribution of the thesis

This study makes three main contributions to the literature on sustainable mobility, travel behaviour change, and urban transport policy.

First, it advances a behavioural–contextual understanding of travel behaviour change by conceptualising Mobility as a Service (MaaS) as a context-enabling intervention rather than a stand-alone technological solution.

While existing research on MaaS has primarily focused on adoption rates, user segmentation, or service integration outcomes, this thesis reframes MaaS as a choice-context architecture that modifies informational, cognitive, and organisational conditions under which travel decisions are made. By embedding MaaS within a Voluntary Travel Behaviour Change (VTBC) framework, the study contributes to the theoretical integration of behavioural models (e.g. Theory of Planned Behaviour, habit-based approaches) with systemic and institutional perspectives on mobility transitions.

Second, the thesis contributes methodologically by developing and implementing a theory-driven quasi-experimental design for evaluating VTBC interventions in real-world urban contexts.

The study combines revealed preference data, stated preference experiments, psychological constructs, and longitudinal behavioural tracking within a sequential mixed-method research design. This approach addresses well-known limitations in VTBC evaluation, such as self-selection bias, short observation windows, and weak causal attribution, by explicitly articulating threats to internal and external validity and by adopting an analytical generalisation logic suited to complex urban systems.

Third, the thesis provides empirical insights into the behavioural plasticity of travel choices during life-course transitions, focusing on university students as a strategically relevant yet underexplored population in urban mobility policy.

By situating the intervention within university campuses as institutional mobility attractors, the study highlights how specific socio-spatial contexts can amplify or constrain the effectiveness of behaviour change strategies. The findings contribute to debates on the timing, targeting, and scalability of demand-side mobility policies, offering evidence relevant for urban transport authorities, universities, and MaaS providers.

Overall, the thesis bridges conceptual gaps between mobility studies, behavioural transport research, and policy-oriented evaluation, demonstrating how context-sensitive, digitally mediated interventions can support sustainable mobility transitions without relying exclusively on restrictive or coercive measures.

Conceptual framework

The conceptual framework guiding this thesis is grounded in the assumption that travel behaviour results from the dynamic interaction between individual dispositions, habitual practices, and the choice context in which decisions are made. Rather than conceptualising travel behaviour as the outcome of isolated, fully rational decisions, the framework adopts a behavioural–contextual perspective in which cognitive, motivational, and routine-based mechanisms are embedded within broader institutional and informational environments.

At the individual level, travel behaviour is shaped by a combination of attitudinal orientations, perceived behavioural control, and behavioural intentions, as well as by the degree of habitualisation of existing mobility practices. Habits and routines play a central role in stabilising travel choices over time, often limiting the effectiveness of purely informational or attitudinal interventions. However, moments of disruption in daily routines—such as life-course transitions—can temporarily increase behavioural plasticity, creating opportunities for change. In this sense, entering university represents a critical phase in which established mobility patterns may be reconsidered and reconfigured.

At the contextual level, the framework emphasises the role of choice architecture and enabling conditions in shaping behavioural outcomes. Within this perspective, Mobility as a Service (MaaS) is not treated as a technological solution in itself, but rather as a context-enabling intervention that modifies the conditions under which travel decisions are made. By integrating information on available mobility options, simplifying access to multimodal services, and reducing coordination and transaction costs, MaaS can lower cognitive and organisational barriers to sustainable travel choices. In doing so, it interacts with individual-level determinants by increasing the perceived feasibility and convenience of alternative mobility practices, without directly prescribing or constraining behaviour.

Behavioural change is therefore conceptualised as an emergent process resulting from the interaction between individual dispositions and context-level interventions, particularly when such interactions occur during periods of heightened openness to change. Within this framework, Voluntary Travel Behaviour Change programs are understood as structured interventions that combine personalised information, supportive tools, and, where applicable, incentives to facilitate experimentation with alternative travel modes. These interventions can temporarily disrupt habitual patterns, allowing individuals to reassess their mobility practices and potentially establish new routines.

Behavioural outcomes are not limited to immediate changes in mode choice, but extend to variations in travel frequency, trip organisation, and the persistence or decay of behavioural changes over time. The framework explicitly acknowledges that observed behavioural responses may be heterogeneous and contingent upon contextual factors, including institutional settings and spatial configurations. University campuses, conceptualised as institutional mobility attractors, represent particularly relevant contexts in which the interaction between individual behaviour and enabling infrastructures can be empirically examined.

This conceptual framework provides the analytical basis for the research design developed in the following sections

Methodological framework and research logic

This part of the thesis translates the theoretical framework developed in Part 1 into a coherent and empirically operational research strategy. Building on the conceptualisation of mobility behaviour as a dynamic, context-dependent and socially embedded process, the methodological framework is designed to capture behavioural change trajectories rather than static mobility outcomes. In line with the core logic of Voluntary Travel Behaviour Change (VTBC) programs, the empirical strategy follows a diagnosis–intervention–evaluation sequence. It first identifies the target mobility context, the target population and the target behaviour, as well as the main barriers constraining voluntary change; it then examines how a MaaS-enabled choice environment can reshape preferences and facilitate behavioural shifts; finally, it evaluates short-term change and early maintenance mechanisms through a quasi-experimental comparison between treated and control conditions.

Consistent with the theoretical framework, the empirical strategy is explicitly developed for a metropolitan complex urban mobility system characterised by high travel demand, a dense and heterogeneous transport supply, multiple interacting actors and institutional layers, and a wide yet unevenly accessible set of mobility alternatives. This contextual scope is analytically relevant for two main reasons. First, it reflects the socio-technical complexity and openness of contemporary urban transport systems discussed in Part 1, in which behavioural change emerges from the interaction between individual routines and system-level constraints. Second, it provides the necessary conditions for analysing MaaS-enabled choice contexts, whose behavioural relevance depends on the availability and combinability of multiple transport services. Accordingly, the methodological framework is not intended to be directly generalised to low-density or low-supply contexts, such as rural or remote areas, but rather to support analytical generalisation by identifying the mechanisms and conditions under which VTBC interventions may operate in complex metropolitan settings.

The specific operationalisation of the target population and empirical context is intentionally deferred to the implementation chapter (Part 3: empirical implementation and data collection strategy). This choice reflects the aim of developing a methodological framework that is case-

independent at the design level while remaining empirically applicable to a concrete policy setting. By separating the general methodological logic from its empirical instantiation, the research preserves the analytical generality of the proposed design and clarifies that the sequence of methods and analytical steps outlined in this part could, in principle, be implemented in other metropolitan urban contexts characterised by comparable levels of mobility demand, system complexity and service availability.

The following chapters articulate the methodological positioning of the study, specify theory-driven assumptions, formulate research questions, objectives and hypotheses, and outline the overall research design and its phase structure. Together, these elements establish a transparent bridge from theory to empirical implementation and, subsequently, to analytical modelling and interpretation of results.

Methodological foundations

Methodological positioning and research approach

This section clarifies the ontological and epistemological foundations of the study and motivates the research strategy.

The methodological approach adopted in this thesis is strictly grounded in the theoretical framework developed in the previous chapters. Consistent with the behavioural and systems-oriented perspective underpinning Voluntary Travel Behaviour Change (VTBC) programs, this research rejects purely descriptive or static representations of travel behaviour and instead adopts an analytical stance oriented toward understanding behavioural change processes and their policy-relevant drivers.

From an ontological perspective, travel behaviour is understood as the outcome of interactions between individual dispositions, habitual routines, structural constraints, and the choice environments within which mobility decisions are made. Behavioural change is therefore not treated as an isolated individual decision, but as a process unfolding over time and shaped by both cognitive and contextual factors. This perspective directly informs the methodological choices of the thesis, which are designed to capture behavioural dynamics rather than single-point observations.

In epistemological terms, the research adopts a mixed-method, sequential, quasi-experimental design, combining attitudinal, contextual and behavioural data to account for both observed mobility practices and the underlying mechanisms that influence behavioural change within a MaaS-enabled choice context.

Crucially, Mobility as a Service (MaaS) is not approached as a technological innovation in itself, but as a contextual element capable of reshaping the mobility choice environment and therefore facilitate, constrain, or reorient individual mobility decisions. This interpretation allows the research to investigate behavioural change not as a reaction to isolated stimuli, but as a response to structured modifications in the choice context within which travel decisions are embedded.

By adopting this methodological positioning, the thesis aims to ensure coherence between theoretical assumptions, research objectives, and empirical strategy. The methodological framework is therefore designed not only to observe mobility behaviour, but to explain how and under which conditions behavioural change can be initiated and sustained through policy-relevant interventions operating within complex urban mobility systems.

Theory-driven and methodological assumptions

This section consolidates the key theoretical propositions that empirical analysis is designed to test.

The formulation of the research questions and hypotheses is grounded in a set of theoretical and methodological assumptions derived from the conceptual framework discussed in the previous chapters. These assumptions reflect the behavioural, system-oriented, and policy-relevant perspective adopted in this thesis and provide the analytical foundation upon which the empirical investigation is built. The assumptions specify how behavioural change is expected to emerge from the interaction between habits, psycho-attitudinal factors, perceived behavioural control and structural constraints, and why identifying barriers and obstacles constitutes a necessary prerequisite for both intervention design and evaluation within VTBC-oriented research.

Assumption 1 – Travel behaviour is a dynamic and process-oriented phenomenon.

Consistent with behavioural transport research and the Voluntary Travel Behaviour Change (VTBC) framework, this thesis assumes that travel behaviour is not a static outcome of isolated decisions, but a dynamic process shaped by socio-psychological characteristics, habits, learning mechanisms, and repeated interactions with the mobility system over time. Behavioural change is therefore expected to unfold gradually and to be influenced by both short-term adjustments and longer-term adaptations, rather than occurring as an immediate response to single interventions.

Assumption 2 – Travel behaviour is context-dependent and embedded in socio-technical systems.

Drawing on the New Mobilities Paradigm and the conceptualization of transportation systems as Complex Large-Scale Integrated Open Systems (CLIOS), the study assumes that individual mobility choices are embedded within broader socio-technical contexts. Infrastructure, service availability, institutional arrangements, and social norms interact with individual dispositions to shape the range of feasible and perceived mobility options. As a consequence, behavioural change cannot be fully understood without considering the characteristics of the mobility choice environment within which decisions are made.

Assumption 3 – Travel demand and behaviour are endogenously shaped by policy and system characteristics.

In line with sustainable mobility scholarship, this research assumes that travel demand and travel behaviour are not exogenous constraints, but outcomes that are continuously shaped by policy decisions, system configurations, and planning paradigms. Interventions targeting the demand side of mobility are therefore considered legitimate and necessary components of sustainable transport policy, rather than supplementary measures to supply-oriented strategies.

Assumption 4 – Behavioural change is constrained by identifiable barriers and obstacles.

Following the methodological principles of VTBC programs, the study assumes that resistance to behavioural change arises from a combination of habitual practices, attitudinal dispositions, perceived and actual behavioural control, and structural constraints. These barriers are expected to vary across individuals and contexts and to play a central role in determining both the effectiveness and the persistence of behavioural change. Identifying and addressing such barriers is therefore considered a prerequisite for the design and evaluation of behaviour-oriented interventions.

Assumption 5 – Modifying the choice context can facilitate voluntary behavioural change.

Building on theories of choice architecture and behavioural steering, the research assumes that behavioural change can be supported by interventions that reshape the mobility choice environment rather than directly constraining individual decisions. In this perspective, Mobility as a Service (MaaS) is conceptualized as a context-enabling solution capable of integrating services, simplifying access, and altering the perceived trade-offs associated with different mobility options. By modifying how choices are presented and accessed, MaaS is expected to lower behavioural barriers and facilitate voluntary shifts toward more sustainable travel practices.

Assumption 6 – Sustained behavioural change requires reinforcement over time.

Finally, the study assumes that initial behavioural changes may not automatically translate into long-term behavioural maintenance. In line with behavioural change theories, sustained change is expected to depend on reinforcement mechanisms, learning processes, and the stabilization of new routines. Evaluating behavioural outcomes over time is therefore essential to assess the effectiveness of behaviour-oriented interventions beyond short-term responses.

Together, these assumptions provide the conceptual and methodological foundation for the formulation of the research questions and hypotheses presented in the following section, ensuring that the empirical analysis is explicitly grounded in the theoretical framework of the thesis.

Research questions, objectives and hypotheses

Building on the theory-driven assumptions outlined above, this section formulates the overarching research question and derives a coherent set of specific research questions, objectives, and falsifiable hypotheses. The formulation follows the VTBC methodological logic and is explicitly aligned with the conceptual framework developed in Part 1, in which behavioural change is understood as a context-dependent process shaped by the interaction between individual determinants, habitual routines, and the mobility choice environment. Together, the research questions and hypotheses provide the analytical backbone for the quasi-experimental and mixed-method research design presented in the subsequent section.

ORQ: *To what extent and through which mechanisms can a MaaS-enabled choice context support voluntary travel behaviour change toward more sustainable mobility practices in complex metropolitan urban systems?*

This overarching question is articulated into a set of specific research questions that reflect the key analytical dimensions of the theoretical framework.

RQ1. *What behavioural, attitudinal, and contextual barriers constrain voluntary changes toward more sustainable mobility behaviours among target populations?*

This question addresses the identification of obstacles to behavioural change, including habitual car use, attitudes toward alternative mobility options, perceived and actual behavioural control, and structural constraints embedded in the mobility system. In line with VTBC principles, understanding such barriers is considered a necessary prerequisite for the design and evaluation of effective behaviour-oriented interventions.

RQ2. *How do MaaS-based mobility bundles reshape mobility preferences and stated behavioural responses compared to existing single-mode alternatives?*

This question focuses on the potential of MaaS-based configurations to modify individuals' mobility preferences by altering the composition, integration, and pricing of available transport services. The analysis of stated behavioural responses allows the research to explore how changes in the choice context may influence the perceived attractiveness of more sustainable mobility options.

RQ3. *To what extent does participation in a MaaS-enabled VTBC intervention lead to short-term observable changes in travel behaviour compared to a control condition?*

This question explicitly addresses the effectiveness of a MaaS-enabled intervention in producing behavioural change under real-world conditions, emphasizing the comparison between treated and control groups as a means of assessing intervention effects beyond broader contextual dynamics.

RQ4. *Are short- to medium-term behavioural dynamics associated with differentiated readiness, perceived control and habit-related configurations under binding feasibility constraints?*

This question reflects the theoretical emphasis on behavioural maintenance, readiness and implementation processes within dual-process and stage-based frameworks. Rather than testing for longitudinal psycho-attitudinal change, it examines whether the short- to medium-term behavioural dynamics observed in the experiment are associated with differentiated readiness profiles, perceived feasibility and habit-related configurations across experimental groups.

Based on these research questions, the study pursues the following research objectives:

- O1.** To analyse mobility behaviours, attitudes, and constraints among target population within a metropolitan mobility context characterized by high car availability and multimodal transport supply.
- O2.** To identify key behavioural, attitudinal, and contextual barriers that constrain voluntary changes toward more sustainable mobility practices.
- O3.** To assess the potential of MaaS-based mobility bundles to reshape mobility preferences and reduce reliance on private car use.
- O4.** To evaluate the effectiveness of a MaaS-enabled VTBC intervention in modifying travel behaviour and reducing key behavioural barriers under real-world conditions.
- O5.** To investigate whether behavioural changes are maintained in the short to medium term and how they are associated with psycho-attitudinal factors.

In order to operationalize these objectives, the research tests a set of hypotheses derived from the theoretical framework and the assumptions discussed in the previous section. Specifically, the study hypothesizes that:

- H1.** Strong habitual car use and low perceived behavioural control are negatively associated with voluntary changes toward more sustainable mobility behaviours.
- H2.** MaaS-based mobility bundles increase the perceived attractiveness of sustainable mobility options compared to existing single-mode alternatives.
- H3.** Participants exposed to a MaaS-enabled VTBC intervention exhibit greater short-term reductions in car use and higher adoption of sustainable mobility options than participants in the control group.
- H4.** Behavioural dynamics among treated participants are positively associated with post-intervention levels of psycho-attitudinal factors, particularly intention and perceived behavioural control.
- H5.** Behavioural changes supported by MaaS-enabled choice contexts show higher short- to medium-term persistence compared to changes observed in the control group.

Although hypotheses H3–H5 are formulated in terms of conventional outcome variables (e.g., changes in car use persistence and modal shares), their role within the present study is explicitly instrumental rather than primary.

The core analytical objective of the thesis is not to estimate average treatment effects in a standard evaluation framework, but to investigate whether and under which conditions the MaaS intervention is capable of altering individual feasibility regimes and inducing threshold crossings in modal behaviour.

Accordingly, hypotheses H3–H5 are used as secondary probes to triangulate the main interpretative claim concerning regime stability, bounded internal rebalancing, and the existence of upper bounds to behavioural reconfiguration within the first phase of intervention. Their function is to provide complementary evidence on observable behavioural reallocations, rather than to constitute the primary test of causal effectiveness.

In this perspective, the absence of significant average effects on car use does not constitute a failure of the intervention per se, but rather an informative boundary condition on the feasibility of regime-level reconfiguration under the given experimental scope conditions.

Together, these research questions, objectives, and hypotheses provide a coherent analytical framework that bridges the theoretical foundations of the thesis with its empirical strategy. They ensure that the methodological approach is explicitly designed to test theory-informed assumptions about behavioural change, policy intervention, and the role of MaaS in shaping sustainable mobility practices within complex urban contexts.

Research design and study protocol

Research design: conceptual overview

This section provides a conceptual overview of the research design explicitly derived from the theoretical framework developed in the previous chapters and from the research questions, objectives, and hypotheses outlined above. Consistent with the behavioural, systems-oriented, and policy-relevant perspective underpinning the study, the research design is conceived as a structured process aimed at analysing behavioural change within a complex and evolving mobility context, rather than as a simple sequence of data collection techniques. It specifies how the combination of methods supports triangulation across observed behaviour, stated choice responses and psycho-attitudinal mechanisms, while maintaining coherence with the theoretical emphasis on processual change and contextual embeddedness.

Mixed-method and sequential logic

From a methodological standpoint, the research adopts a mixed-method and sequential design, combining different sources of empirical evidence to capture complementary dimensions of mobility behaviour. The mixed-method approach is justified by the complexity of the research object: while quantitative behavioural data are necessary to observe changes in mobility practices, additional contextual, revealed and stated behavioural and psycho-attitudinal information is required to understand the mechanisms underlying such changes. The integration of different data sources reflects the assumption that no single method is sufficient to fully capture the complexity of mobility

behaviour, particularly when the objective is to assess the effectiveness of behaviour-oriented policy interventions and therefore considered sufficient to address the research questions independently; rather, the integration of multiple data sources allows for a more comprehensive and theory-consistent analysis.

The sequential nature of the research design reflects both the processual character of behavioural change and the methodological requirements of VTBC programs. Early analytical steps are oriented toward understanding the mobility context, the target population, and the behavioural barriers that constrain voluntary change. Subsequent steps focus on evaluating how modifications in the mobility choice environment influence behavioural responses and, ultimately, observable travel behaviour. This sequencing enables the research to progressively refine its analytical focus, moving from contextual and behavioural diagnosis toward intervention assessment.

MaaS as a context-enabling component of behavioural intervention

A central element of the research design is the conceptualization of Mobility as a Service (MaaS) as a context-enabling component of behavioural intervention rather than as a stand-alone technological solution. In line with the theoretical discussion on choice architecture and behavioural steering, MaaS is integrated into the research design as a mechanism capable of reshaping the mobility choice environment within which individual travel decisions are made.

From a methodological perspective, this positioning reflects the assumption that voluntary behavioural change is more likely to occur when interventions modify the structure, accessibility and perceived trade-offs of available options, rather than directly constraining individual choices. By integrating multiple transport services, simplifying access and payment, and offering bundled mobility configurations, MaaS alters how mobility alternatives are accessed, combined and evaluated, thereby influencing behavioural barriers related to complexity, information costs and perceived behavioural control.

Within the logic of Voluntary Travel Behaviour Change (VTBC) programs, MaaS is therefore treated as an enabling context that supports behavioural experimentation and learning processes. Rather than prescribing a specific target behaviour, the MaaS-enabled choice environment allows participants to explore alternative mobility practices under real-world conditions, lowering entry barriers and facilitating gradual adjustments in travel routines.

This conceptualization has important implications for the empirical strategy of the study. First, it justifies the integration of MaaS into both the stated preference and experimental components of the research design, as a means of analysing how changes in the choice context affect behavioural responses. Second, it reinforces the alignment between the analytical steps of the study and the core stages of VTBC programs, namely the identification of the target mobility context, target population,

target behaviour and behavioural barriers, followed by the evaluation of a behaviour-oriented intervention.

By positioning MaaS as a context-enabling component within a broader behavioural governance framework, the research design provides a coherent basis for analysing how MaaS-enabled choice contexts can support voluntary travel behaviour change within complex urban mobility systems.

Quasi-experimental identification strategy and threats to validity

The empirical evaluation of behavioural change processes in real-world mobility contexts poses well-known methodological challenges related to causal attribution. In policy-oriented and behaviour-based research, fully randomized controlled trials are often impractical or ethically undesirable, particularly when interventions rely on voluntary participation and are embedded within existing socio-technical systems. For this reason, the present study adopts a quasi-experimental identification strategy, which represents a widely accepted approach for evaluating behavioural interventions under realistic conditions (Shadish, Cook & Campbell, 2002; Meyer, 1995).

The quasi-experimental logic of the study is based on the comparison of behavioural outcomes across different conditions and over time, combining a treated group, exposed to a MaaS-enabled VTBC intervention, and a control group, not exposed to the intervention but subject to the same broader contextual dynamics. This structure allows the analysis to distinguish behavioural changes plausibly associated with the intervention from changes driven by exogenous factors affecting the mobility system during the observation period.

Consistent with best practices in quasi-experimental design, the methodological strategy explicitly acknowledges and addresses the main threats to internal validity.

First, *self-selection effects* are mitigated through the definition of clear eligibility criteria aligned with the target population and through the random assignment of eligible participants to treatment and control conditions. While voluntary participation cannot be eliminated in VTBC-oriented research, randomization within the eligible sample reduces systematic differences between groups at baseline.

Second, *history effects*, that is, changes in behaviour induced by external events occurring during the study period, are addressed through the inclusion of a control group exposed to the same contextual conditions. Any concurrent changes in transport supply, pricing, or institutional arrangements are therefore expected to affect both groups, allowing their influence to be distinguished from intervention-related effects.

Third, *maturation effects* and short-term behavioural fluctuations are explicitly considered by adopting a panel-based before–after framework. By observing the same individuals over time, the analysis can differentiate transient adaptations from more stable behavioural changes, in line with

the theoretical conceptualization of travel behaviour as a dynamic and process-oriented phenomenon.

Fourth, potential *contamination or spillover effects* between treated and control participants, particularly relevant in shared social environments, are acknowledged as a limitation inherent to real-world behavioural experiments. The study design minimizes such risks by limiting direct interaction between groups within the intervention framework and by interpreting estimated effects as conservative approximations of intervention impacts.

In terms of external validity, the study recognizes that behavioural responses observed within a specific institutional and urban context cannot be mechanically generalized to other populations or settings. Rather than aiming for statistical representativeness, the research adopts an analytical generalization perspective, whereby findings are interpreted in relation to theoretically relevant mechanisms and contextual conditions (Yin, 2014). This approach is consistent with VTBC-oriented research, which prioritizes the identification of conditions under which behavioural change is more or less likely to occur, rather than universal effect sizes.

Overall, the quasi-experimental identification strategy adopted in this study reflects a deliberate trade-off between causal rigor and ecological validity. By explicitly addressing threats to validity and situating the analysis within a transparent methodological framework, the research provides a robust basis for evaluating MaaS-enabled behavioural interventions while remaining faithful to the constraints and objectives of applied mobility policy research.

Ethical considerations and data governance

Given the behavioural and data-intensive nature of the research design, ethical considerations and data governance play a central role in the implementation of the empirical strategy. The study involves the collection of sensitive information related to individual mobility behaviours, attitudes and preferences, including geolocated activity–travel data. As a result, the research design has been developed in accordance with established ethical principles of social and behavioural research and with applicable data protection regulations.

Participation in all phases of the study was strictly voluntary and based on informed consent. Prior to data collection, participants were provided with clear and accessible information regarding the objectives of the research, the types of data collected, the duration of participation, and their right to withdraw from the study at any time without consequences. Consent procedures were designed to be consistent across survey-based and app-based data collection phases, ensuring transparency and continuity throughout the research process.

Particular attention was devoted to the protection of personal and geolocation data, in line with the principles of data minimization, purpose limitation and proportionality established by the General

Data Protection Regulation (GDPR, EU Regulation 2016/679). Personal identifiers were separated from behavioural datasets and replaced with anonymized or pseudonymized codes to prevent the identification of individual participants during analysis. Access to raw data was restricted to the research team and secured through controlled storage and processing environments. Throughout the entire research process, the design and implementation of data collection, storage and processing procedures were developed and continuously reviewed in collaboration with a dedicated team of experts in data protection and information security. This interdisciplinary supervision ensured compliance with applicable data protection standards, supported the adoption of secure-by-design solutions, and contributed to the ongoing assessment of potential risks associated with digital data collection and MaaS-based experimentation.

The use of digital tools for mobility tracking and MaaS interaction raised additional ethical considerations related to surveillance, autonomy and potential behavioural influence. To address these concerns, the study explicitly framed digital data collection as a research instrument rather than a monitoring mechanism, avoiding any form of coercion or automated behavioural enforcement. Participants retained full control over their participation and were informed about the nature and scope of data recorded through the app-based components of the study.

Finally, ethical considerations were integrated into the interpretation and reporting of results. Behavioural changes observed during the study are analysed and discussed at an aggregate level, avoiding stigmatization of specific groups or normative judgments about individual mobility choices. This approach is consistent with the voluntary and non-coercive ethos of VTBC programs and with the broader objective of supporting informed and autonomous behavioural change within sustainable mobility policies.

By embedding ethical reflection and data governance principles into the methodological design, the study ensures that empirical robustness is accompanied by ethical integrity, thereby reinforcing the credibility and policy relevance of its findings.

Overall methodological strategy and phases of the study

This section operationalises the research design into a structured methodological strategy articulated into a sequence of interrelated phases. Rather than presenting a mere chronology of data collection, the phase structure clarifies the analytical purpose of each step and anticipates how each phase contributes to answering the research questions and testing hypotheses.

The overall strategy follows a diagnosis–intervention–evaluation logic, which is consistent with behaviour-oriented and policy-relevant approaches to sustainable mobility. Initial phases are devoted to identifying the target mobility context, the target population, the target mobility behaviour, and the behavioural barriers constraining voluntary change. Subsequent phases focus on

assessing behavioural responses to modifications in the mobility choice environment and evaluating the effectiveness of a MaaS-enabled intervention under real-world conditions.

More specifically, the methodological strategy of the study is organized into five main phases, each addressing a distinct analytical objective while contributing to the coherence of the overall research design.

Phase 1 – Identification of the target mobility context

The first phase is aimed at defining and characterizing the mobility context within which behavioural change is investigated. This phase focuses on the analysis of the urban mobility system of the metropolitan area under study, with particular attention to transport supply, modal availability, pricing structures, and institutional arrangements. The purpose of this phase is not only descriptive, but analytical: by identifying the characteristics of the existing mobility system, the research establishes the contextual conditions that shape individual travel choices and delimit the range of feasible behavioural alternatives.

Phase 2 – Identification of the target population and baseline mobility behaviour

The second phase focuses on the identification of the target population and the analysis of baseline mobility behaviours. Consistent with VTBC principles, the research targets individuals characterized by relatively stable mobility routines and high levels of car use, for whom behavioural change is both more challenging and more policy-relevant. This phase provides a detailed behavioural and socio-psychological profile of the target population, establishing a baseline against which subsequent behavioural changes can be assessed.

Phase 3 – Identification of the target mobility behaviour and behavioural barriers and constraints

The third phase addresses one of the core methodological requirements of VTBC programs: the identification of the target mobility behaviour and barriers and obstacles to voluntary behavioural change. In line with the methodological logic of Voluntary Travel Behaviour Change programs, the target mobility behaviour of the present study is formally defined as the reduction of habitual private car use and the increased adoption of multimodal and sustainable mobility alternatives for both systematic and non-systematic trips. This definition reflects a focus on behavioural routines rather than isolated travel choices and provides the analytical reference against which behavioural barriers and change processes are examined.

Furthermore, building on behavioural theories and the conceptualization of travel behaviour as a context-dependent process, this phase investigates the role of habitual practices, attitudinal dispositions, perceived behavioural control, and structural constraints in shaping mobility decisions. By explicitly focusing on behavioural barriers, this phase informs both the interpretation of behavioural outcomes and the design of the intervention evaluated in the subsequent phases.

Phase 4 – Assessment of behavioural responses to MaaS-enabled choice contexts

The fourth phase examines how modifications in the mobility choice environment influence behavioural preferences and responses. In line with the conceptualization of MaaS as a context-enabling solution, this phase explores how integrated mobility configurations may alter perceived trade-offs between mobility options and affect individuals' willingness to adopt more sustainable travel behaviours. This analytical step bridges the diagnostic phases of the research with the intervention-oriented component, allowing the study to assess the behavioural potential of MaaS-based solutions before their implementation in a real-world setting.

Phase 5 – Evaluation of a MaaS-enabled VTBC intervention and behavioural maintenance

The final phase of the methodological strategy is devoted to evaluating the effectiveness of a MaaS-enabled VTBC intervention in producing observable behavioural change and supporting its short- to medium-term maintenance. This phase adopts a comparative perspective to assess differences in behavioural outcomes under different conditions and over time, consistent with the quasi-experimental logic discussed earlier. Particular attention is given to the relationship between observed behavioural changes and psycho-attitudinal factors, in order to assess whether changes in mobility practices are accompanied by different levels of behavioural dispositions.

Taken together, these five phases constitute a coherent and theory-driven methodological strategy that aligns the empirical investigation with the conceptual foundations of the thesis. By structuring the research process around the key stages of VTBC programs the study ensures that empirical analysis remains closely connected to its theoretical and policy-oriented objectives.

Concluding synthesis: from methodological logic to implementation and analysis

This methodological chapter has established a coherent and theory-driven framework for the empirical research developed in the remainder of the thesis. Building on the behavioural and systems-oriented perspective articulated in the theoretical part, the methodology has been designed to capture travel behaviour as a dynamic, context-dependent process shaped by the interaction between individual dispositions, habitual routines, structural constraints, and modifications in the mobility choice environment.

By explicitly adopting the methodological logic of Voluntary Travel Behaviour Change (VTBC) programs, the research strategy follows a structured diagnosis–intervention–evaluation sequence. This logic ensures that the identification of the target mobility context, target behaviour and target population, as well as the analysis of behavioural barriers and obstacles to change, precedes and informs the assessment of intervention outcomes. In this way, behavioural change is not treated as an isolated outcome, but as the result of a process embedded within a specific socio-technical and policy context.

Methodologically, the chapter has clarified the rationale for adopting a mixed-method, sequential and quasi-experimental research design. The integration of revealed behavioural data, stated behavioural responses and psycho-attitudinal measures reflects the need to combine observational and interpretative perspectives in order to analyse both behavioural outcomes and the mechanisms underlying them. The quasi-experimental logic adopted in the study responds to the constraints of real-world policy experimentation, balancing the need for causal inference with the preservation of ecological validity.

Importantly, methodological design positions Mobility as a Service (MaaS) not merely as a technological artefact, but as a context-enabling component of behavioural governance. By conceptualizing MaaS as a mechanism capable of reshaping the mobility choice environment, the methodology aligns the empirical analysis with theoretical emphasis on choice architecture, behavioural steering and voluntary change. This positioning allows the study to investigate how changes in the structure and accessibility of mobility options may influence both immediate behavioural responses and short- to medium-term maintenance processes.

Overall, the methodological framework developed in this chapter provides a transparent bridge between theory and empirical analysis. It ensures that the research questions, objectives and hypotheses are directly grounded in both the conceptual foundations of the study and the empirical strategy adopted. The following chapter builds upon this framework by detailing how the methodological logic outlined here was implemented in practice within the selected case study, describing the study context, data collection instruments, and operational phases of the research. Subsequent chapters then translate the collected empirical material into analytical results and interpretations, allowing for a systematic evaluation of MaaS-enabled VTBC interventions within metropolitan complex urban mobility systems.

Part 3: Empirical implementation and data collection strategy

Study context and case study selection

This chapter introduces the empirical context of the study and motivates the selection of the case study in relation to the theoretical and methodological framework developed in Parts 1 and 2. Rather than providing a purely descriptive account of the territorial setting, the chapter clarifies the analytical relevance of the Milan metropolitan area and the University of Milan-Bicocca for the study of voluntary travel behaviour change and MaaS-enabled choice contexts.

The empirical investigation developed in this thesis is situated within the Milan metropolitan area, conceptualised as a complex metropolitan urban mobility system characterised by high travel demand, dense and heterogeneous transport supply, and multi-level institutional arrangements. In line with the theoretical framework discussed in Part 1, the study adopts a functional and relational understanding of the metropolitan context, focusing on the mobility system within which daily activity–travel behaviours are embedded and shaped, rather than on strictly administrative boundaries. This perspective is consistent with approaches that conceptualise metropolitan areas as open socio-technical systems, whose structure and functioning emerge from functional interdependencies, commuting patterns, and shared mobility infrastructures rather than from formal jurisdictional limits.

From a systems perspective, the Milan metropolitan area can be interpreted as a complex large-scale integrated open system (CLIOS), in which multiple transport modes, services and governance actors interact across spatial and institutional scales. Rail-based regional and suburban services, metropolitan and local public transport networks, road infrastructures, and an increasingly diversified ecosystem of shared mobility services coexist and overlap, generating a highly articulated and dynamic choice environment. This systemic complexity is further reinforced by strong daily mobility flows connecting the urban core with a wide regional hinterland, resulting in travel patterns that are recurrent, multi-scalar and deeply embedded in everyday routines.

The Milan metropolitan area represents a particularly relevant context for the analysis of Voluntary Travel Behaviour Change (VTBC) programs and MaaS-enabled interventions. On the one hand, the extensive availability of public transport services and alternative mobility options creates favourable structural conditions for reducing car dependence. On the other hand, high levels of car ownership, congestion and time pressure contribute to the persistence of habitual travel behaviours, even in the presence of technically viable alternatives. This coexistence of opportunity and resistance embodies

the core behavioural tension addressed by VTBC approaches, making the metropolitan context analytically meaningful for investigating voluntary change rather than forced modal shifts.

At the same time, the metropolitan mobility system of Milan offers the institutional and infrastructural preconditions necessary for the emergence of MaaS-enabled choice environments. The presence of multiple transport operators, integrated fare systems, digital mobility platforms and a dense supply of shared services support the combinability of modes and services that is central to MaaS concepts. Importantly, such combinability does not automatically translate into behavioural change: rather, it reshapes the structure of the choice environment within which individuals evaluate, compare and experiment with mobility alternatives.

From an analytical perspective, this combination of infrastructural density, modal diversity and behavioural inertia produces a highly articulated choice environment in which observed travel behaviours emerge from the interaction between individual routines, psycho-attitudinal factors and system-level constraints. These characteristics make the Milan metropolitan area particularly suitable for investigating behavioural change processes within complex urban mobility systems, allowing the analysis to focus not only on mobility outcomes, but on the mechanisms through which choice contexts, habits and voluntary interventions interact over time.

University campuses as institutional mobility attractors

Within the Milan metropolitan mobility system, the University of Milano-Bicocca (UniMiB) is selected as the empirical case study. As a large public university embedded in a complex metropolitan context, it constitutes one of major institutional mobility attractor, generating substantial volumes of systematic travel associated with daily home–university commuting, as well as non-systematic trips linked to study-related activities, services and leisure. While academic functions are spatially concentrated within a limited number of campuses, the origins of these daily trips are widely dispersed across the regional scale. This spatial asymmetry reflects a fundamental characteristic of university-related mobility, whereby campuses operate as fixed destinations toward which recurrent and non-recurrent trips converge, rather than as generators of mobility demand.

Beyond their quantitative relevance in terms of trip volumes, higher education institutions are widely recognised as analytically meaningful contexts for the study of travel behaviour and behavioural change. Universities concentrate large and relatively stable populations characterised by recurrent activity patterns, while remaining deeply embedded within complex urban mobility systems. This combination makes them particularly suitable for investigating the interaction between habitual travel routines, structural constraints and policy-oriented interventions aimed at voluntary behavioural change, in line with the theoretical framework adopted in this thesis.

A key element in defining the empirical case study concerns the spatial configuration of university facilities and its implications for delimiting the operational study context. The University of Milano-Bicocca includes a dense cluster of teaching, research and service facilities located in the northern sector of the City of Milan, concentrated in the Bicocca district, alongside additional campuses situated in the Monza urban area and other campuses.

Table 6 provides an overview of the main facilities affiliated with the University of Milano-Bicocca, distinguishing between campuses located in the City of Milan, campuses located in the Monza urban area, and facilities located outside the metropolitan context, including external and international sites. This overview is intended to clarify the institutional and spatial articulation of the university and to make explicit the analytical choices underlying the definition of the empirical study context.

Table 6 University of Milano-Bicocca campuses and teaching facilities

<i>Building</i>	<i>Address</i>	<i>Municipality</i>	<i>Primary use</i>
<i>U1 ATLAS</i>	Piazza della Scienza 1	Milan	Teaching, laboratories, offices
<i>U2 QUANTUM</i>	Piazza della Scienza 3	Milan	Teaching, laboratories, offices
<i>U3 BIOS</i>	Piazza della Scienza 2	Milan	Teaching, laboratories, offices
<i>U4 TELLUM</i>	Piazza della Scienza 4	Milan	Teaching, laboratories, offices
<i>U5 RATIO</i>	Via Cozzi 55	Milan	Teaching, laboratories, offices
<i>U6 AGORÀ</i>	Piazza Ateneo Nuovo 1	Milan	Rectorate, teaching, offices, library
<i>U7 CIVITAS</i>	Via Bicocca degli Arcimboldi 8	Milan	Teaching, laboratories, offices
<i>U9 KOINÈ</i>	Viale dell’Innovazione 10	Milan	Teaching, laboratories, offices
<i>U12 AUDITORIUM</i>	Via Vizzola 5	Milan	Auditorium, offices, sports facilities
<i>U14 ABACUS</i>	Viale Sarca 336	Milan	Teaching, offices
<i>U16 MAIEUTICA</i>	Via Giolli 5	Milan	Teaching, laboratories, offices
<i>U17 IPAZIA</i>	Piazzetta Difesa per le Donne 1	Milan	Student services, medical offices
<i>U21 VIVAIO BICOCCA</i>	Via Cozzi 18	Milan	Teaching, greenhouses
<i>U24A ZEPHYRUM</i>	Viale Sarca 336	Milan / Sesto San Giovanni	Teaching, laboratories, offices
<i>U24B ZEPHYRUM</i>	Viale Sarca 336	Milan / Sesto San Giovanni	Teaching, laboratories
<i>U24C ZEPHYRUM</i>	Viale Sarca 336	Sesto San Giovanni	Teaching
<i>U26 AGON – PalaBicocca</i>	Via Giolli 7	Milan	Sports facilities
<i>U27 BAMBINI BICOCCA</i>	Piazza dei Daini 6	Milan	Teaching, childcare facilities

<i>U36 TORRE DELL'ACQUA</i>	Viale Sarca 232	Milan	Teaching
<i>DB1 Deutsche Bank</i>	Via Martinelli 23	Cinisello Balsamo	Teaching, offices
<i>U8 ASCLEPIO</i>	Via Cadore 48	Monza	Teaching, laboratories, offices, library
<i>U18 YGEIA</i>	Via Raoul Follerau 2	Vedano al Lambro (MB)	Teaching
<i>U28 KYTOS</i>	Via Raoul Follerau 3	Vedano al Lambro (MB)	Teaching, laboratories, offices
<i>U38 VILLA SERENA</i>	Via Pergolesi 33	Monza	Teaching, laboratories, offices
<i>U48 CICLOTRONE</i>	Via Pergolesi 33	Monza	Laboratories, offices
<i>U48 EX INFETTIVI</i>	Via Pergolesi 33	Monza	Laboratories, offices
<i>Ospedale Vecchio San Gerardo – Medicina dello Sport</i>	Via Solferino 16	Monza	Service facilities
<i>ASST A. Manzoni Lecco</i>	Via dell'Eremo 9/11	Lecco	Teaching, laboratories
<i>U88 Polo "Papa Giovanni XXIII"</i>	Via Nini da Fano 11	Bergamo	Teaching, offices
<i>U78 SONDRIO</i>	Via Fumagalli 3	Faedo Valtellino (SO)	Teaching, offices
<i>Istituti Clinici Zucchi</i>	Piazza Madonnina 1	Carate Brianza (MB)	Laboratories
<i>ASST Monza – Desio Hospital</i>	Via G. Mazzini 1	Desio (MB)	Laboratories
<i>ASST Valtellina e Alto Lario – Sondrio Hospital</i>	Via Stelvio 23	Sondrio	Laboratories
<i>University of Pavia</i>	Corso Strada Nuova 65	Pavia	Laboratories
<i>IRCCS Medea Hospital</i>	Via Don Luigi Monza 20		

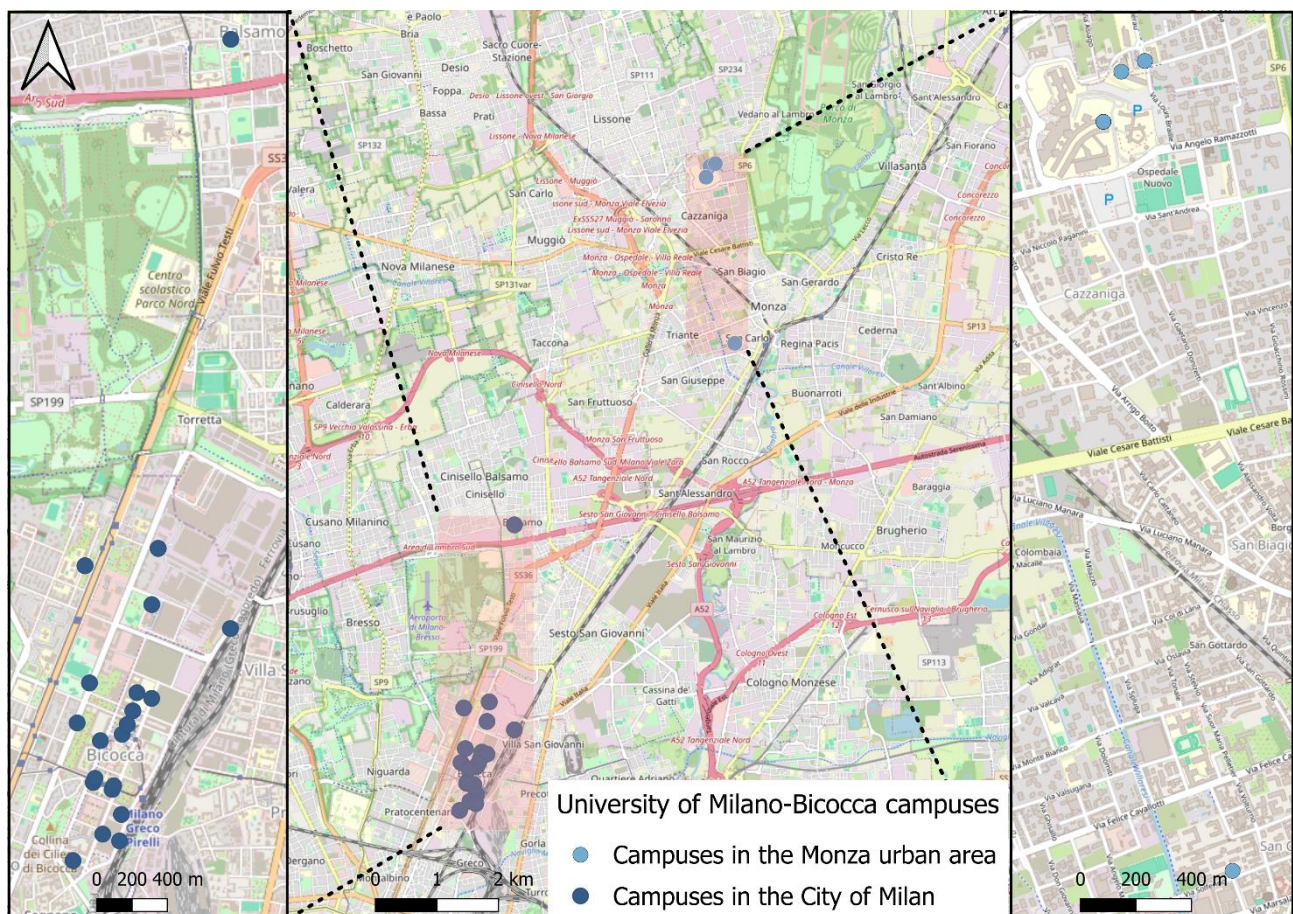
Source 8 Author's elaboration based on University of Milano-Bicocca administrative datasets on campuses and teaching facilities.

Despite the broader institutional geography of the university, the empirical analysis developed in this thesis is deliberately restricted to the campuses located in the City of Milan and in the Monza urban area. Although administratively distinct, Monza is functionally integrated into the Milan metropolitan mobility system, as reflected by strong commuting flows, shared transport infrastructures and overlapping service provision. From a mobility perspective, campuses located in Milan and Monza therefore belong to the same metropolitan system within which daily travel routines are formed, constrained and potentially reshaped. This decision reflects the VTBC methodological requirement that the target mobility context corresponds to the everyday urban mobility system within which

habitual travel routines are formed and within which behavioural constraints and intervention mechanisms can realistically operate. Facilities located outside the metropolitan area, including external clinical sites and international outposts, do not belong to this functional mobility system and are therefore excluded from the operational definition of the study context, as their inclusion would introduce non-comparable conditions and dilute the analytical focus.

Figure 3 illustrates the spatial distribution of the University of Milano-Bicocca campuses within the Milan metropolitan functional area, highlighting their role as spatially concentrated mobility attractors embedded within a wider regional catchment area. The main map situates the campuses within the broader metropolitan context, distinguishing facilities located in the City of Milan from those located in the Monza urban area, while the inset maps provide a more detailed view of the Bicocca campus cluster in Milan and selected campus locations in Monza. This cartographic representation is not intended as a purely descriptive inventory of buildings; rather, it serves an explicit analytical purpose by delineating the spatial perimeter within which the empirical strategy is implemented and by operationalising the concept of *target mobility context* introduced in the methodological framework.

Figure 3 Spatial distribution of the University of Milano-Bicocca campuses within the Milan metropolitan functional area.



Source: 9 Author's elaboration based on University of Milano-Bicocca administrative datasets (campus locations) and open-source basemap data.

The residential locations of students, which constitute the origins of university-related trips, are inherently diffuse and heterogeneous, extending well beyond the immediate urban context and spanning a supra-metropolitan regional scale. As a result, mapping or spatially delimiting mobility generators would not provide a meaningful representation of the target mobility context. Instead, the spatial analysis, at this stage, concentrates on the localisation of campuses as stable destinations within the mobility system, where travel choices converge and where interventions can effectively reshape the choice environment.

This approach is consistent with the VTBC methodological framework and with the conceptualisation of urban mobility systems as open and relational. A more detailed and empirically grounded reconstruction of the actual mobility catchment area, based on observed travel flows derived from the revealed-preference (RP) survey, is therefore intentionally deferred to later stages of the analysis, where individual mobility patterns are used to delineate the functional travel basin of the university.

Overall, the Milan metropolitan area and the University of Milano-Bicocca together provide a theory-consistent and policy-relevant empirical setting. The metropolitan context offers the structural prerequisites for MaaS-enabled choice architectures, while the university represents a concentrated and recurrent mobility attractor that renders behavioural change processes both observable and analytically tractable. By clearly delimiting the empirical context at this stage, the analysis establishes the conditions under which voluntary behavioural change can be meaningfully examined. The specific operationalisation of the target population and the justification for focusing on students, as well as the detailed assessment of transport supply and accessibility conditions, are addressed in the subsequent sections of this part, thereby maintaining a clear separation between contextual definition, behavioural focus and empirical implementation.

Rationale for case study selection within the theoretical framework

The selection of the University of Milan-Bicocca within the Milan metropolitan area is guided by analytical rather than representational criteria. In line with the theoretical framework developed in Part 1, the case study provides a context in which travel behaviour is shaped by strong habitual patterns, high levels of system complexity, and a wide availability of alternative mobility options.

From a Voluntary Travel Behaviour Change (VTBC) perspective, the case is particularly relevant because it combines recurrent travel practices with a non-coercive policy environment, allowing behavioural change processes to be observed without imposing explicit constraints on individual choice. The presence of multiple transport modes and services creates favourable conditions for interventions aimed at modifying the choice context rather than directly targeting behaviour.

Moreover, the metropolitan scale and institutional setting of the case study offer a suitable environment for analysing MaaS-enabled solutions as context-enabling mechanisms. The integration

of heterogeneous services, the reduction of cognitive and organisational costs, and the potential for multimodal experimentation are all features that align with the methodological objectives of the study. For these reasons, the case study supports analytical generalisation by allowing the identification of behavioural mechanisms that may operate in other complex urban mobility systems.

The following sections build on this contextual framing by defining the target population and analytical focus relevant for the empirical investigation.

Target population and analytical focus

Within the methodological logic of Voluntary Travel Behaviour Change (VTBC) programs, the identification of a clearly defined target population represents a core analytical step. Behaviour-oriented interventions are not conceived to address the general population indiscriminately, but rather to focus on specific groups for whom behavioural change is both empirically observable and policy-relevant. In this perspective, the selection of the target population is not a merely descriptive choice, but a theoretically informed decision that directly shapes the interpretation of behavioural mechanisms, barriers and intervention effects.

Consistent with the theoretical framework developed in Part 1, this study adopts a targeted analytical approach centered on a population segment characterised by recurrent mobility routines, high exposure to daily travel decisions, and a heightened potential for behavioural change under appropriate contextual conditions. Such an approach reflects a core assumption of VTBC programs: that voluntary behavioural change is more likely to occur when interventions are aligned with the structural and cognitive conditions experienced by specific population groups, rather than being applied uniformly across heterogeneous contexts.

Conceptual and theoretical rationale for the target population

The analytical focus of the study is placed on university students, conceptualised not merely as a socio-demographic category, but as a population group undergoing a significant life-event transition. Entering higher education is widely recognised in behavioural and mobility research as a phase of increased behavioural plasticity, during which established habits may weaken and individuals become more receptive to new information, incentives and contextual cues. Changes in residential location, daily schedules, social networks and activity patterns often disrupt previously stabilised routines, including travel behaviour.

From a VTBC perspective, such transition phases represent particularly promising windows for voluntary behavioural change. The partial destabilisation of habitual practices creates opportunities for the reconfiguration of mobility choices before new habits become fully consolidated. This makes students an analytically strategic population for investigating how contextual interventions, rather than coercive measures, can influence travel behaviour through changes in the choice environment. In this sense, the focus on students is fully aligned with the voluntary and non-prescriptive ethos of VTBC programs, as well as with theoretical approaches emphasising the role of context and habit disruption in behavioural change processes.

Moreover, universities constitute institutional settings where mobility-related decisions are repeatedly enacted under relatively stable destination conditions, while being embedded within

complex urban transport systems. This combination allows the analysis to capture the interaction between individual routines, perceived constraints and system-level characteristics, which lies at the core of the theoretical framework adopted in this thesis.

Empirical relevance and mobility characteristics of the student population

From an empirical standpoint, the relevance of students as a target population is reinforced by their scale and spatial concentration within the selected case study. In the academic year 2024/2025, the University of Milano-Bicocca counts close to 40,000 enrolled students, including undergraduate and graduate students, PhD candidates and participants in postgraduate programs. Approximately nine out of ten students attend campuses located in the city of Milan, while a smaller share, around one in twelve, is associated with the Monza campus. This spatial configuration confirms the central role of the Milan metropolitan area as the primary locus of daily university-related mobility flows, while also highlighting the relevance of inter-municipal commuting within the broader metropolitan region.

The residential distribution of students further contributes to the analytical relevance of this population. The large majority of students reside within the Lombardy region, while a substantial minority, on the order of one student out of six, lives outside the region or has an international domicile. This implies a wide and heterogeneous mobility basin, extending well beyond the immediate urban core and encompassing both short-distance urban trips and longer-distance regional commuting. As a result, student mobility is shaped by markedly different accessibility conditions, travel distances and transport opportunities, which translate into heterogeneous behavioural constraints and modal choices.

Institutional mobility planning data indicate that student travel behaviour is characterised by a strong reliance on public transport, particularly rail-based modes. More than half of student trips are made by train, reflecting the regional scale of the university's catchment area and the importance of rail accessibility. Local public transport accounts for roughly one quarter of trips, especially for students residing within the metropolitan area. At the same time, private motorised travel remains a significant component of student mobility, accounting for around one sixth of trips, despite the high availability of public transport options. Active modes and mixed mobility practices play a more limited but non-negligible role, particularly for students living closer to university campuses. This coexistence of public-transport-oriented and car-oriented practices within the same population segment provides an analytically rich setting for investigating behavioural barriers and changing processes.

From a methodological perspective, focusing on students enables a coherent alignment between the target population and the target mobility behaviour defined within the VTBC framework. The target behaviour of interest, namely the reduction of habitual private car use and the increased adoption of multimodal and sustainable mobility alternatives for both systematic and non-systematic trips, can

be meaningfully operationalised within this population, where car use is neither dominant nor marginal, but sufficiently prevalent to make behavioural change both challenging and policyrelevant.

Importantly, the selection of students as the target population does not imply behavioural homogeneity or normative assumptions regarding sustainability. Rather, it reflects the theoretical assumption that behavioural change is more likely during periods of routine disruption, and that interventions targeting such phases can provide valuable insights into the mechanisms through which voluntary change may be initiated and stabilised. In this sense, students are treated as an analytically strategic population for studying behavioural change processes, rather than as a privileged or exceptional group.

The specific operationalisation of the target population in empirical terms, including eligibility criteria, recruitment procedures and sample characteristics, is intentionally deferred to the implementation section of this part. This choice preserves the analytical generality of the methodological framework while clarifying that the logic underlying the selection of the target population could, in principle, be applied to other population groups experiencing comparable life-event transitions within metropolitan mobility systems. Precise quantitative evidence on modal shares and behavioural patterns is presented and discussed in the empirical analysis section of the thesis.

Overall, the focus on university students provides a theoretically grounded and empirically substantiated basis for analysing voluntary travel behaviour change within MaaS-enabled choice contexts. By situating the target population at the intersection of life-event transitions, habitual mobility routines and complex urban transport systems, the study is well positioned to examine how behavioural barriers emerge, how they may be reshaped through contextual interventions, and how short-term behavioural changes may evolve toward early forms of maintenance.

Study design implementation and data collection strategy

Overall research workflow

The empirical implementation developed in this thesis is organised around a structured research workflow that operationalises the Voluntary Travel Behaviour Change (VTBC) framework within a real-world metropolitan mobility system. The workflow constitutes the backbone of the empirical strategy and provides the organising logic through which data collection, intervention design and behavioural evaluation are coherently integrated. Rather than treating empirical activities as a sequence of independent tasks, the research design adopts a process-oriented approach, in which each phase fulfils a specific analytical function and produces inputs that are necessary for subsequent stages.

Although the methodological framework presented in Part 2 identifies a set of conceptual phases associated with Voluntary Travel Behaviour Change programs, these phases do not correspond one-to-one to the operational stages through which the empirical study is implemented. The distinction between methodological phases and empirical phases is intentional and reflects the difference between analytical logic and field execution in real-world behavioural research.

In the methodological framework, phases are defined at an abstract level in order to clarify theoretical functions, such as diagnosis, intervention and evaluation, and to position the study within the VTBC literature. In contrast, empirical implementation requires these conceptual stages to be translated into operational phases that reflect data availability, institutional constraints, sequencing of instruments and the need to preserve analytical separation between baseline measurement, intervention exposure and behavioural observation.

For this reason, the methodological phases identified in Part 2 are operationalised in this study through five empirically distinct and partially overlapping phases. These phases do not represent a reformulation of the theoretical framework, but rather its practical articulation in a complex, longitudinal and quasi-experimental research setting. Each operational phase fulfils a specific analytical function while collectively preserving the internal logic of the VTBC approach: from context and baseline diagnosis, through preference elicitation and calibrated intervention exposure, to behavioural response observation and evaluation.

This distinction is particularly important to avoid conflating conceptual stages, such as behavioural preparation or action, with specific empirical instruments or moments of data collection. Behavioural change processes unfold across multiple operational phases, and their observation requires a sequencing of tools and datasets that cannot be reduced to a single methodological step. The workflow presented in this section should therefore be read as an operational translation of the VTBC

framework, designed to ensure analytical coherence while accommodating the constraints and opportunities of real-world implementation.

From an analytical perspective, the phased implementation serves two key purposes. First, it reinforces design coherence by ensuring that intervention exposure is grounded in a prior diagnosis of context, population and behavioural constraints rather than being implemented in an abstract or decontextualised manner. Second, it strengthens causal interpretability by maintaining a clear separation between baseline measurement, intervention exposure and post-intervention observation, consistent with the quasi-experimental logic adopted in this study.

The first phase focuses on contextual and behavioural diagnosis, combining the analysis of the metropolitan transport system with baseline behavioural data in order to characterise existing mobility practices, accessibility conditions and individual predispositions. This phase establishes the empirical reference point against which subsequent behavioural changes are interpreted and allows the identification of both structural and behavioural barriers to voluntary change.

The second phase concerns preference elicitation and intervention calibration. Building on the diagnostic phase, this stage investigates how individuals evaluate alternative mobility configurations and MaaS-enabled service combinations under controlled conditions. The purpose of this phase is not predictive modelling per se, but the calibration of the intervention logic, ensuring that the proposed choice architecture is behaviourally plausible, context-sensitive and aligned with users' constraints and expectations.

The third phase constitutes the intervention exposure stage, in which individuals are confronted with a modified mobility choice environment through a VTBC experiment enabled by a MaaS application. Within this workflow, MaaS is explicitly conceptualised as a context-enabling mechanism rather than as a standalone technological solution. By integrating multiple transport services and facilitating their combinability, the intervention aims to reduce informational, cognitive and organisational frictions that sustain habitual car use, thereby reactivating deliberative choice processes.

The fourth and fifth phases address behavioural response observation and evaluation, adopting a longitudinal perspective. Behavioural outcomes are assessed through before–after comparisons and treatment–control contrasts, allowing changes in mobility behaviour to be interpreted in relation to both individual baseline conditions and external contextual factors. This phase is essential for distinguishing intervention-induced behavioural adaptations from concurrent changes in the mobility system and for identifying early signals of behavioural stabilisation. The potential persistence of these behavioural adjustments is further explored through a follow-up survey, which provides complementary evidence on self-reported post-intervention mobility practices and behavioural orientations beyond the immediate experimental window.

Overall, the research workflow provides a structured yet flexible framework that ensures alignment between theoretical assumptions, methodological choices and empirical implementation. By explicitly articulating the sequence of analytical purposes, expected outcomes and intervention mechanisms, the workflow clarifies how MaaS-enabled VTBC strategies are empirically investigated within a complex metropolitan mobility system. The following subsection details the temporal articulation of this workflow by presenting the timeline of the study and sequencing of data collection and intervention phases.

To support the interpretability of the empirical design, Table 7 provides a synthetic overview of the overall research workflow, linking each phase of the implementation to its analytical purpose, expected outputs and empirical instruments

Table 7 Overall research workflow: phases, analytical purpose, outputs and instruments

<i>Workflow phase</i>	<i>Analytical purpose</i>	<i>Key outputs</i>	<i>Main instruments / data</i>
<i>Context and baseline diagnosis</i>	Characterise the mobility system and baseline behaviours; identify structural and behavioural constraints	Definition of target mobility context; baseline behavioural profiles	Contextual analysis; RP survey
<i>Preference elicitation and calibration</i>	Explore preferences and perceived trade-offs under alternative mobility configurations	Behavioural sensitivities; inputs for intervention design	SP experiments
<i>VTBC intervention exposure</i>	Restructure the choice environment and reduce behavioural barriers through MaaS-enabled integration	Intervention uptake; exposure indicators	MaaS app interaction; PTP logic
<i>Behavioural response observation</i>	Observe short-term behavioural adaptations and early stabilisation mechanisms	Before–after behavioural changes; treatment–control contrasts	App-based tracking
<i>Evaluation and interpretation</i>	Assess effectiveness and interpret behavioural mechanisms	Indicators of behavioural change and barriers	Econometric modelling; follow-up survey

Source 10 Author's elaboration

The following sections build upon this workflow by detailing the temporal sequencing of these phases, the specific data sources employed, and the quasi-experimental logic adopted for behavioural evaluation.

Timeline and phases of data collection

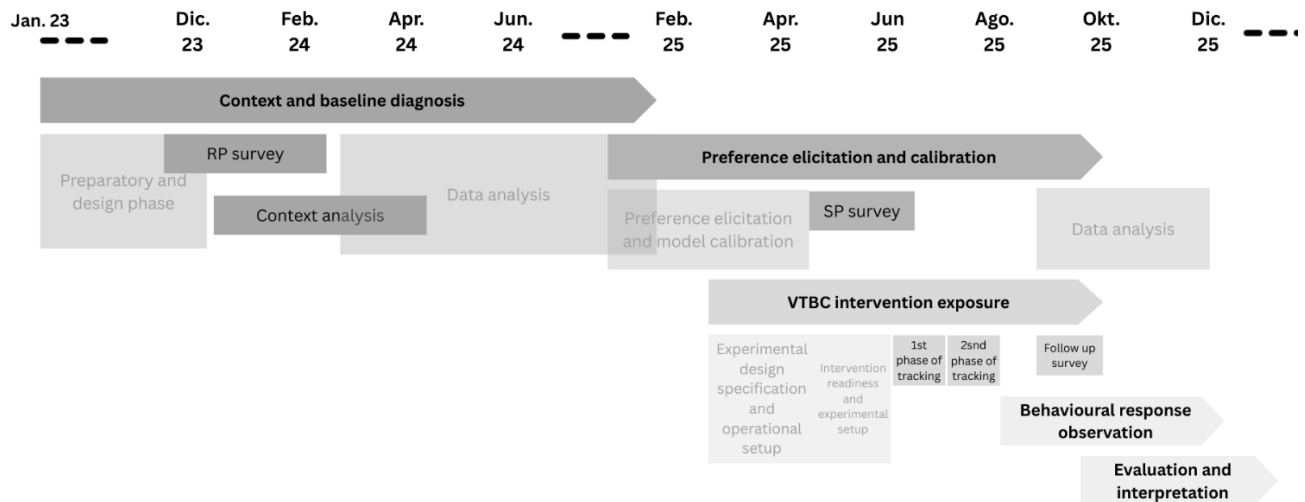
This section translates the analytical workflow introduced in the previous chapter into its empirical temporal implementation, providing both the chronological sequencing of activities and the operational details through which each phase was concretely carried out.

In line with the VTBC framework adopted in Part 2, the empirical process is articulated into five interrelated phases explicated in the previous chapter: Context and baseline diagnosis; Preference elicitation and calibration; VTBC intervention exposure; Behavioural response observation; and Evaluation and interpretation. Each phase fulfils a distinct analytical function while contributing to a coherent identification strategy, in which intervention effects are interpreted against a clearly defined baseline and within a controlled temporal structure.

The overall empirical implementation spans December 2023 to Oktober 2025. This duration reflects both the behavioural nature of the research questions, requiring observation beyond immediate short-term adjustments, and the institutional embedding of the study within the broader research program MOST – Spoke 8 (MaaS & Innovative Services), WP1. Aligning the empirical timeline with the project's governance framework ensured continuity in data collection, stability in intervention exposure, and the possibility of integrating follow-up observations over time within a stable operational setting.

Figure 4 provides a synthetic visual representation of the empirical timeline and the sequencing of the five analytical phases described in this section. The timeline highlights how the methodological framework is operationalised over time through partially overlapping phases, rather than through a strictly linear progression. The figure also explicitly distinguishes preparatory and design activities from the operational phases and from analysis data activities. Overall, the timeline illustrates the cumulative and iterative nature of the empirical strategy, as well as its alignment with the VTBC methodological logic adopted in this study.

Figure 4 Empirical timeline and operationalisation of the research workflow



Source 11 Author's elaboration

Phase 1: Context and baseline diagnosis

The first phase of empirical implementation corresponds to the context and baseline diagnosis, whose primary function is to establish a robust empirical understanding of the mobility system, the target population, and existing behavioural patterns prior to any intervention exposure. In line with the VTBC methodological framework, this phase provides the diagnostic foundation upon which subsequent preference elicitation, intervention design and evaluation stages are constructed.

From an analytical perspective, the baseline diagnosis serves two complementary purposes. First, it allows the identification of structural and contextual constraints shaping everyday mobility choices within the Milan metropolitan system, including transport supply conditions, accessibility patterns and spatial organisation of mobility attractors. Second, it enables the observation and characterisation of pre-intervention travel behaviours, attitudes and perceptions of the target population, thereby establishing a reference point against which behavioural change can later be assessed.

The contextual component of this phase is based on a structured analysis of the metropolitan mobility environment in which university-related travel takes place. This includes the spatial distribution of university campuses, the organisation of public transport networks, and the availability of active and shared mobility options within the relevant catchment areas. This analysis was developed between January and April 2024, in parallel with the early stages of the baseline survey, and focused on the spatial organisation of mobility attractors, transport supply conditions and accessibility patterns within the Milan metropolitan area.

The context analysis served a dual purpose within the implementation strategy. First, it supported the operational delineation of the target mobility system by identifying the functional urban environment within which daily travel routines are formed and constrained. Second, it informed the identification of feasible and realistic mobility alternatives to private car use, thereby grounding subsequent preference elicitation and intervention design in actual system conditions.

Importantly, this diagnostic step ensures that the VTBC intervention is grounded in the actual choice environment experienced by users, rather than being designed in abstraction from existing infrastructural and service conditions. In this sense, context analysis constitutes a prerequisite for interpreting behavioural responses as the outcome of interaction between individual routines and system-level constraints.

The behavioural component of the baseline diagnosis is operationalised through a revealed preference (RP) survey administered between December 2023 and February 2024 aimed at collecting detailed information on current travel behaviours, activity–travel patterns and attitudes toward key dimensions of MaaS services. The survey targeted the university population and was designed to capture both behavioural and attitudinal dimensions relevant for subsequent phases of the research.

To enhance participation and mitigate self-selection biases associated with single-channel recruitment, a multi-channel dissemination strategy was implemented. While direct emailing through institutional mailing lists represented the primary communication channel, additional dissemination tools were employed to increase visibility and repeated exposure of the survey invitation. These included social media posts on institutional accounts, publication on university websites, and the physical distribution of posters and flyers within campus spaces. This multi-channel strategy was adopted to mitigate known limitations of exclusive email-based recruitment, such as uneven engagement with institutional mailboxes among students, and to increase repeated exposure to the initiative across different communication environments. For the first 100 participants, small incentives in the form of goods were also offered to encourage participation.

The dissemination activities were coordinated over several weeks and involved both pre-launch and follow-up actions. Table 8 summarises the main dissemination initiatives implemented during the RP survey phase, highlighting the timing and communication instruments employed.

Table 8 Dissemination strategy and communication channels for the RP survey

<i>Date</i>	<i>Communication instrument</i>	<i>Description</i>
27/11/2023	Posters	Pre-launch poster display across university campuses
27/11/2023	Flyers	Pre-launch flyer distribution in common areas
06/12/2023	Institutional email	First email dissemination via official mailing lists
06/12/2023	Institutional social media	Posts and stories announcing survey launch
06/12/2023	Posters	Launch posters with QR code linking to the survey
06/12/2023	University website	Publication of survey launch notice
13/12/2023	Institutional email	Second email reminder
10/01/2024	Institutional email	Third email reminder
10/01/2024	Institutional social media	Follow-up posts and stories

Source 12 Author's elaboration based on dissemination activities

As a result of this dissemination strategy, the survey collected 3,775 questionnaires, of which 3,564 were retained as valid responses. Among these, 2,756 valid records are attributable to students, who therefore constitute the core empirical reference for the subsequent phases of the study. The identification of valid responses followed a *completion threshold* criterion. Incomplete questionnaires that did not reach the minimum level of task and section completion required for reliable behavioural profiling were excluded from the analytical dataset. This criterion was adopted to ensure consistency in data quality across empirical phases and to minimise noise related to partial or inattentive responses.

The questionnaire covered a broad set of dimensions relevant for baseline diagnosis, including socio-demographic characteristics, travel behaviours and attitudes towards MaaS-related features. A detailed description of the survey instrument, variables and measurement logic is provided in section Revealed Preference (RP) survey: baseline diagnosis and behavioural profiling. Furthermore, a full overview of the questionnaire structure and content is provided in the methodological appendix 1 and summarised in the empirical analysis section

Within the overall research design, the context and baseline diagnosis phase fulfils a strictly preparatory and calibrating function. The RP survey data are not used at this stage to test hypotheses or estimate behavioural effects, but rather to:

- characterise existing mobility practices and heterogeneity within the target population;
- identify behavioural barriers and constraints relevant for intervention design;
- support the construction and calibration of subsequent preference elicitation tasks;
- provide a reference baseline for before–after and intervention–control comparisons.

By clearly separating baseline measurement from intervention exposure, this phase strengthens the internal coherence of the empirical strategy and supports the quasi-experimental logic adopted in the study. The substantive findings emerging from the baseline diagnosis are therefore intentionally discussed later, once the full empirical sequence has been introduced and the analytical focus shifts from implementation to behavioural response and evaluation.

Phase 2: Preference elicitation and calibration

The second implementation phase corresponds to *preference elicitation and calibration* and is operationalised through a Stated Preference (SP) survey. Within the logic of Voluntary Travel Behaviour Change (VTBC) programs, this phase fulfils a specific analytical function: it enables the elicitation of structured evidence on how individuals evaluate and trade off attributes of MaaS-enabled mobility bundles *prior* to intervention exposure, under controlled variation of service configurations. This is particularly relevant in the MaaS domain, where integrated service packages and pricing schemes are not always directly observable in revealed behaviour and where behavioural responses depend on the perceived coherence of bundled alternatives.

In design terms, the SP phase is explicitly grounded in the diagnostic evidence produced during the first phase of the empirical workflow. The construction of MaaS bundles and choice scenarios is informed not only by the RP survey results, but also by the systematic analysis of the transport supply context carried out during the context and baseline diagnosis phase. In particular, the definition of feasible modal combinations, service types and integration levels reflects the actual availability, spatial distribution and operational characteristics of public transport, shared mobility and last-mile options within the Milan metropolitan mobility system. This ensures that the hypothetical scenarios presented to respondents remain anchored to the real choice environment, thereby enhancing behavioural plausibility and interpretability.

At the same time, RP survey evidence was used to calibrate the elicitation process at the individual level. The baseline data supported an initial segmentation of respondents along key behavioural dimensions, such as predominant commuting mode, home–university distance and travel frequency, which informed the assignment of respondents to choice scenarios consistent with their observed mobility profiles. In this sense, the SP survey functions as a *calibrating bridge* between baseline diagnosis and intervention design, rather than as an abstract or standalone preference exercise.

Empirically, the SP survey was implemented as a digital questionnaire administered between 30 April and 30 June 2025. Recruitment followed a two-step strategy designed to balance continuity with baseline measurement and the need to achieve an adequate sample size within the target population. In a first step, individuals who had participated in the RP survey and had provided informed consent to be re-contacted were invited via email to take part in the SP phase. In a second step, the survey was opened to the wider student population of the University of Milano-Bicocca in order to increase the number of observations and strengthen the robustness of subsequent analyses. This sequential recruitment strategy allows the study to combine a panel-like component with a broader cross-sectional inflow, while remaining consistent with the targeted and policy-oriented nature of the research design.

Table 9 summarises the timeline of the SP survey dissemination and fieldwork.

Table 9 Timeline of the SP survey dissemination and fieldwork

Date	Action	Description
30/04/2025	Launch of the SP survey	Email invitation sent to RP respondents who consented to be re-contacted
06/05/2025	First reminder	Email reminder to increase response rate
12/05/2025	Second reminder	Second email reminder
22/05/2025	Extension to full student community	Survey opened to the entire student population
30/06/2025	Fieldwork closure	Survey closed to allow data cleaning and analysis

Source 13 author's elaboration based on SP survey fieldwork records.

Overall, the survey collected 2,476 completed questionnaires. As for the RP survey, valid responses were identified using a *completion threshold* criterion, excluding incomplete questionnaires that did not reach the minimum level of task completion required for reliable preference elicitation. On this basis, 1,426 responses were retained as valid for analysis. Among these, 1,146 valid records are attributable to students, providing a sufficiently large and behaviourally relevant dataset for calibration and interpretation. Table 10 reports the distribution of valid student responses across the two data collection phases of the SP survey.

Table 10 Valid student responses in the SP survey

Dataset	Valid student responses (n)
Re-contacted RP respondents	459
Open call to student population	687
Total	1,146

Source 14 author's elaboration based on SP survey dataset.

Within the overall empirical workflow, the SP phase produces key outputs. It provides preference-based evidence on the relative attractiveness of MaaS bundle configurations under controlled variation of service attributes. These outputs inform both the design of the subsequent *VTBC intervention exposure* phase and the interpretation of behavioural responses observed after exposure.

Detailed information on the SP instrument, including the definition of alternatives and attributes, the experimental design strategy, the blocking procedure, and the administration platform, is provided in section Stated Preference (SP) survey: preference elicitation and intervention calibration, in order to maintain a clear separation between the temporal implementation logic discussed here and the technical specification of empirical instruments.

Phase 3: VTBC intervention exposure

Following the preference elicitation and calibration phase, the empirical strategy enters the VTBC intervention exposure stage, which represents the core experimental component of the study. This phase operationalises the behavioural logic outlined in the theoretical framework by translating

diagnostic knowledge and stated preferences into differentiated exposure conditions designed to activate voluntary travel behaviour change within a MaaS-enabled choice environment.

The intervention exposure phase is not conceived as the simple introduction of a technological tool, but as the deliberate construction of an asymmetric choice context in which information, assistance and decision-support mechanisms are selectively activated. In line with VTBC principles, behavioural change is not imposed through restrictions or pricing measures, but facilitated through personalised feedback, contextual guidance and the reconfiguration of perceived choice sets.

From an operational standpoint, at the end of the SP survey, student respondents were invited to express their willingness to participate in an experimental mobility study promoted by the University of Milano-Bicocca, aimed at exposing participants to a MaaS-enabled mobility choice environment designed to facilitate voluntary shifts towards more sustainable travel practices. Students who declared interest were asked to complete a short supplementary questionnaire collecting additional information required for preliminary profiling and eligibility screening. This step served a dual function: operationally, it supported the selection of participants compatible with the experimental protocol; analytically, it allowed an initial filtering of individuals displaying a minimum level of engagement and readiness to participate in a behaviour-oriented intervention.

Out of 158 students who initially expressed interest, 108 were authorised to participate based on predefined eligibility criteria. Eligibility was assessed with reference to two core dimensions aligned with the VTBC framework: the use of private cars for university-related travel (either for regular commuting or for non-systematic trips), and a sufficiently high frequency of university attendance. These criteria ensured that participants exhibited both a measurable car-use baseline and a recurrent exposure to daily travel decisions, conditions considered necessary for observing meaningful behavioural change within the experimental timeframe.

Following eligibility screening, participants were randomly assigned to either a treatment group or a control group. Within the constraints of a voluntary, real-world VTBC experiment, this random allocation plays a critical methodological role. It ensures initial comparability between groups with respect to both observed and unobserved characteristics, thereby strengthening the internal validity of subsequent treatment–control contrasts. At the same time, randomisation is applied *after* behavioural targeting rather than at the population level, reflecting the VTBC assumption that behavioural change interventions operate on behaviourally relevant and potentially receptive sub-populations rather than on undifferentiated samples.

In this sense, random assignment does not serve to approximate a fully randomised controlled trial, but to support causal interpretability within a quasi-experimental, mechanism-oriented design, where observed behavioural differences can be more plausibly attributed to differentiated intervention exposure rather than to pre-existing individual heterogeneity, while remaining consistent with the voluntary nature of participation inherent in VTBC programs

As part of the intervention implementation and in line with the VTBC emphasis on informed and supported action, all authorised participants were invited to attend a dedicated training meeting. This step was not conceived as a purely operational briefing, but as an integral component of the behavioural change process. Consistent with the Trans-theoretical Model of behaviour change, the training phase was designed to support the transition from earlier stages of contemplation and preparation towards action, by providing structured information, clarifying expectations, and increasing participants' perceived behavioural control.

Five training sessions were organised in June 2025, specifically on 13, 16, 18, 19 and 23 June, in order to maximise participation flexibility. For all participants, the meetings introduced the objectives of the research, the experimental protocol and the data collection procedures. For participants assigned to the treatment group, the training also included a structured explanation of the VTBC logic, the role of Personalised Travel Plans (PTPs), and the functionalities of the MaaS-enabled choice context beyond simple tracking.

The training thus constituted the first moment of differentiated exposure within the experimental design. In theoretical terms, it operationalised the shift towards the action stage by framing treatment participants as active agents in a voluntary behavioural change process, supported by personalised feedback and contextual facilitation. By contrast, control participants were instructed exclusively on tracking and compliance requirements, without exposure to behavioural framing or decision-support elements.

To ensure uniform access to information and procedural consistency, a recorded version of the training was made available to participants unable to attend in person.

The empirical observation of behavioural change is structured around two distinct tracking phases, which operationalise the transition from baseline measurement to action-oriented exposure within the VTBC framework. Consistent with the Trans-theoretical Model of behaviour change, this structure allows the empirical design to distinguish between stable pre-intervention routines and behavioural responses emerging once individuals move from preparation to action under differentiated exposure conditions.

At the same time, this phased structure reflects the multi-systemic nature of travel behaviour change as conceptualised in Haustein's framework. In particular, it allows the analytical separation between behavioural routines shaped by habitual and contextual systems, and behavioural responses emerging when cognitive, motivational and control-related systems are selectively activated through intervention exposure.

The *first tracking phase*, conducted between 23 June and 2 July 2025, establishes a behavioural baseline within the experimental sample. Within the overall empirical design, it is important to distinguish between two analytically distinct baseline conditions. The first baseline is represented by the context and revealed-preference diagnosis, which characterises the broader mobility system and pre-existing behavioural patterns of the target population at an aggregate level. The second is an

experimental baseline, constructed through high-frequency tracking within the intervention sample, and serves as the reference condition for subsequent within-subject and treatment–control comparisons.

During this first tracking phase, both treatment and control participants used the MaaS-enabled tracking system exclusively as a passive observation tool. No personalised feedback, behavioural recommendations, incentives or service-purchasing functionalities were activated for either group. This design choice ensures that observed mobility patterns can be interpreted as habitual routines, primarily governed by the habit and contextual constraint systems described by Haustein, and only marginally influenced by deliberative or motivational processes. In behavioural terms, this phase corresponds to the observation of routine mobility practices prior to the activation of change mechanisms, consistent with pre-action stages in the Trans-theoretical Model.

The *second tracking phase*, conducted between 23 July and 1 August 2025, corresponds to the effective VTBC intervention exposure and to the empirical observation of behavioural response under action-oriented conditions. Prior to its start, participants assigned to the treatment group received a personalised travel plan derived from their individual mobility profiles reconstructed during the first tracking phase. PTP provided structured feedback on observed behaviour and proposed tailored suggestions aimed at reducing car dependence and increasing the uptake of sustainable alternatives.

During this phase, treatment participants were encouraged to engage with a MaaS-enabled choice context not only for passive tracking, but also as an active decision-support environment for accessing and purchasing mobility services. From a behavioural perspective, this configuration is designed to selectively activate cognitive, motivational and perceived control systems, again in line with Haustein’s model, thereby facilitating the transition from preparation to action by lowering cognitive and organisational barriers, supporting experimentation, and enabling the operationalisation of alternative mobility choices within everyday travel routines.

In contrast, participants assigned to the control group were exposed exclusively to the tracking component of the MaaS-enabled system and continued to record their trips without receiving any personalised feedback, behavioural recommendations or decision-support inputs. No prompts related to mobility services or alternative choice options were activated for this group, thereby preserving a clear separation between intervention and non-intervention conditions.

This *asymmetric exposure structure* is a deliberate design choice within the VTBC framework. It allows behavioural differences observed during the second phase to be interpreted as the effect of intervention-induced activation of cognitive, motivational and control-related mechanisms, rather than as a by-product of self-monitoring or data collection alone. By explicitly separating passive observation from active behavioural support, the design allows observed changes to be interpreted as the result of deliberate modifications to the choice environment rather than as artefacts of tracking or increased attention to one’s behaviour.

From a VTBC perspective, this phase operationalises the critical transition from contemplation and preparation to action, as conceptualised in behavioural change theories. Personalised feedback, contextual facilitation and decision-support mechanisms embedded within the MaaS-enabled choice environment act as enabling conditions that lower cognitive and practical barriers to change, thereby supporting the translation of intentions and preferences into observable mobility behaviour.

Table 11 summarises the differentiated exposure conditions implemented for the treatment and control groups, clarifying which components are shared across groups and which are specific to the VTBC intervention.

Table 11 Differentiated exposure conditions for treatment and control groups

<i>Experimental component</i>	<i>Treatment group</i>	<i>Control group</i>	<i>Analytical role</i>
<i>Training meeting on project objectives and protocol</i>	✓	✓	Common procedural alignment
<i>Training on VTBC logic and behavioural objectives</i>	✓	✗	Activation of behavioural awareness and intention
<i>Training on MaaS app beyond tracking</i>	✓	✗	Differentiated cognitive and informational exposure
<i>Access to MaaS app for passive tracking (Phase 1)</i>	✓	✓	Experimental baseline (self-monitoring only)
<i>Behavioural tracking – Phase 1 (baseline)</i>	✓	✓	Within-sample experimental baseline
<i>Receipt of Personalised Travel Plan (PTP) with behavioural recommendations and personalised feedback</i>	✓	✗	Individualised behavioural guidance
<i>Use of MaaS app for service purchase (Phase 2)</i>	✓	✗	Operationalisation of MaaS-enabled choices
<i>Push notifications for tracking compliance (Phase 2)</i>	✓	✓	Attrition mitigation and data completeness
<i>Push notifications activating behavioural change (Phase 2)</i>	✓	✗	Reinforcement of VTBC mechanisms
<i>Behavioural tracking – Phase 2 (intervention)</i>	✓	✓	Treatment–control comparison
<i>Follow-up survey</i>	✓	✓	Post-intervention behavioural and cognitive assessment

Source 15 author's elaboration based on experimental design and implementation.

To ensure transparency regarding sample dynamics and data coverage, participation levels across the different stages of the experimental process are summarised in Table 12. As in most longitudinal VTBC experiments relying on app-based tracking and sustained participant engagement, a progressive reduction in active participation is observed across phases.

While attrition inevitably reduces statistical power, it does not compromise the internal validity of within-subject and treatment–control comparisons, which remain the primary analytical focus of the study. The empirical strategy therefore prioritises behavioural realism over statistical representativeness, leveraging high-frequency, individual-level observations to detect early adaptation signals and changes in behavioural structure rather than average population effects.

Table 12 Participation levels across experimental phases

Experimental stage	Total participants	Treatment group	Control group
<i>Students expressing initial interest</i>	158	–	–
<i>Authorised participants</i>	108	57	51
<i>Registered to experimentation</i>	37	–	–
<i>Participants – 1st tracking phase</i>	30	17	13
<i>Participants – 2nd tracking phase</i>	19	11	8
<i>Follow-up survey respondents</i>	27	–	–
<i>Participants completing all activities</i>	18	11	7

Source 16 author’s elaboration.

To support sustained engagement and mitigate attrition during the intervention phase, a structured communication strategy combining emails and push notifications was implemented as an integral component of the VTBC intervention logic, rather than as a purely operational support tool.

From a behavioural perspective, these communications were explicitly designed to intervene on the stability of existing travel routines, in line with the conceptualisation of behavioural change proposed by Haustein. In particular, the messaging strategy aimed at *disrupting habitual travel patterns*, *defreezing automatic behaviour* and creating moments of deliberate reconsideration of everyday mobility choices.

Within the Trans-Theoretical Model, this function corresponds to supporting the transition from preparation to action, by maintaining behavioural salience and preventing relapse into routine-driven behaviour during the early stages of change. Repeated and context-sensitive prompts were used to destabilise routine execution and to encourage active engagement with alternative mobility options.

Messages addressed to both groups primarily reinforced self-monitoring and behavioural awareness, contributing to the weakening of automatic routines by making everyday mobility choices more visible and cognitively salient. Messages sent exclusively to the treatment group went a step further, actively supporting the *defreezing* of behaviour through personalised prompts encouraging the consultation and application of the personalised travel plan and the use of MaaS-enabled mobility services.

In this sense, the communication strategy operated as a behavioural disruption mechanism embedded within the MaaS-enabled choice environment, designed to temporarily loosen habitual constraints and to create the conditions under which voluntary behavioural change could emerge, rather than as a prescriptive or coercive intervention.

The timing and content of push notifications are summarised in Table 13. Notifications were scheduled to accompany participants throughout the second tracking phase, ensuring continuity of exposure and reinforcing the differentiated treatment conditions.

Table 13 Push notification plan during intervention phase

<i>Date and time</i>	<i>Recipient</i>	<i>Notification title</i>	<i>Message</i>
22 July, 09:00	Treatment & Control	The second phase is about to start!	Tomorrow phase 2 of Track2Change begins. Check your email and stay updated.
22 July, 09:00	Treatment	Check your Mobility Plan!	Open the email and discover your personalised plan. Try applying it to your trips!
23 July, 09:00	Treatment & Control	Track2Change – Phase 2 starts	From today remember to record your trips daily in the Mobility Company app.
25 July, 09:00	Treatment & Control	Every day counts	Remember to use the app every day to record your trips. Your contribution matters.
26 July, 09:00	Treatment	Discover services in the app	Use the app to purchase available mobility services. Try them now!
27 July, 09:00	Treatment & Control	Record every trip	Remember to record every trip in the Mobility Company app. Every data point counts.
28 July, 09:00	Treatment	Apply your Mobility Plan	Have you checked your personalised plan? Try applying it to your daily trips.
29 July, 09:00	Treatment & Control	Keep participating	Don't forget to use the app daily to track your trips. Help improve mobility.
30 July, 09:00	Treatment	Use the app for mobility services	Remember to purchase mobility services directly through the app.
31 July, 09:00	Treatment & Control	Every trip matters	Keep recording your trips. Even the shortest trip is useful.
1 August, 09:00	Treatment	Follow your personalised plan	Remember to follow your personalised mobility plan. Every step counts.
2 August, 09:00	Treatment & Control	Track your trips today	Use the app today to record your trips. Your contribution is essential.
3 August, 09:00	Treatment & Control	Last day to contribute	Today is the last day. Remember to record all your trips!

Source 17 author's elaboration.

A follow-up survey was administered on 24 September 2025, with the closing date extended to 15 October 2025 in order to maximise response rates and ensure adequate post-intervention coverage. Within the VTBC framework, the follow-up survey serves to complement observed behavioural data by capturing self-reported mobility practices, perceptions and cognitive responses after the experimental exposure phase.

From a behavioural change perspective, the follow-up survey is explicitly designed to assess whether the behavioural adaptations observed during the intervention phase are accompanied by changes in

attitudes, intentions and perceived behavioural control, consistent with the post-action and early maintenance stages of the Trans-Theoretical Model.

In addition, the follow-up instrument allows the observation of potential changes in habit strength, routine salience and self-identity related to mobility, in line with Haustein's behavioural framework. In this sense, the survey provides evidence on whether the disruption of routines induced during the intervention phase translates into more durable cognitive and motivational adjustments, or whether behavioural responses remain situational and context-dependent.

Participants who completed all experimental activities were awarded incentives in recognition of their sustained commitment. While incentives support retention in longitudinal designs, they are not conceived as behavioural drivers within the intervention logic and are therefore analytically separated from the mechanisms of voluntary behavioural change examined in this study.

Within the overall research design, this phase completes the transition from diagnostic and hypothetical analysis to real-world behavioural observation, establishing the empirical basis for evaluating how MaaS-enabled choice environments and personalised behavioural support interact with habitual mobility routines under controlled exposure conditions.

Phase 4: Behavioural response observation

Following the VTBC intervention exposure phase, the empirical strategy moves to the observation of behavioural responses, which constitutes a distinct and analytically autonomous stage within the research design. This phase focuses on observed mobility behaviour rather than on stated intentions or expressed preferences, in line with the VTBC framework that conceptualises behavioural change as an empirical outcome emerging from the interaction between individuals and their choice environment. Behavioural response is therefore treated as conceptually separate from both preference elicitation and intervention exposure and is analysed through direct observation of travel practices under differentiated exposure conditions. The analysis of behavioural response data was conducted between August and November 2025. This phase corresponds to the post-collection analytical processing of tracking and MaaS interaction data generated during the experimental phases and is analytically distinct from both the intervention exposure period and the subsequent follow-up survey.

Behavioural response is observed through high-frequency, app-based tracking data collected at the individual trip level. Each recorded activity corresponds to a single observed movement (trip-level observation), identified through a unique *activityID*, while each participant is identified through a unique *userId*, enabling longitudinal tracking across experimental phases. This structure allows the reconstruction of daily mobility portfolios and activity–travel sequences, rather than isolated trips, which is essential for analysing behavioural adaptation processes within VTBC frameworks. The

tracking data are passive and non-declarative, thereby reducing recall bias and social desirability effects that typically affect self-reported mobility behaviour.

Table 14 summarises the main characteristics of the behavioural tracking dataset and clarifies its analytical relevance within the empirical design.

Table 14 Characteristics of the behavioural tracking dataset

<i>Dimension</i>	<i>Description</i>
<i>Data source</i>	MaaS app-based passive tracking
<i>Observation unit</i>	Individual trip (<i>activityID</i>)
<i>Individual identifier</i>	<i>userId</i> (longitudinal tracking)
<i>Temporal resolution</i>	Timestamped trip-level records
<i>Observation periods</i>	Phase 1 (baseline tracking); Phase 2 (intervention exposure)
<i>Data type</i>	Revealed behaviour (non-declarative)
<i>Behavioural scope</i>	Daily mobility portfolios and trip sequences
<i>Bias mitigation</i>	Reduced recall and social desirability bias
<i>Analytical structure</i>	Within-subject longitudinal comparison

Source 18 author's elaboration.

In addition to trip-level tracking, the behavioural observation phase also incorporates information on the actual purchase of mobility services accessed through the MaaS-enabled choice context, capturing instances in which behavioural adaptation translated into active engagement with integrated mobility services. For participants in the treatment group, transactional data were collected at the individual level, recording the user identifier, date of purchase and type of mobility service accessed through the integrated mobility environment.

This information provides a complementary behavioural layer that goes beyond observed movement patterns by capturing concrete engagement with MaaS-enabled services. While not all behavioural change necessarily translates into service purchases within the short observation window, the presence of transactional data allows the analysis to distinguish between behavioural adaptation expressed through modal reconfiguration and behavioural commitment expressed through active use of integrated mobility services. This distinction allows behavioural response to be analysed not only in terms of mobility outcomes, but also in terms of the degree to which MaaS functions as an effective choice-enabling infrastructure. From a VTBC perspective, service purchase represents a higher-intensity behavioural signal, indicating not only experimentation but also willingness to operationalise alternative mobility choices within the MaaS-enabled environment.

Furthermore, behavioural response observation is not limited to passively observed mobility behaviour. To capture post-intervention behavioural self-assessment, attitudinal shifts and latent mechanisms associated with voluntary change, a follow-up survey was administered after the conclusion of the tracking phases. The follow-up survey complements app-based tracking by capturing declared mobility behaviour, MaaS engagement and psychological constructs in line with the Haustein behavioural model.

Within this empirical framework, behavioural response is operationalised through a set of interrelated behavioural dimensions that capture both *observed mobility practices* and *post-intervention cognitive and attitudinal responses*. Rather than treating behavioural change as a single outcome, the analysis adopts a multidimensional perspective consistent with VTBC theory, according to which voluntary change emerges through the interaction between habitual behaviour, situational constraints and cognitive–motivational processes.

Behavioural response is first observed through changes in *revealed mobility behaviour*, derived from high-frequency app-based tracking data. These dimensions include variations in car-use frequency and share, changes in modal composition and multimodality, uptake of public transport and active modes, restructuring of daily trip chains, and increased behavioural variability as a signal of routine disruption. Together, these indicators describe how individuals reorganise their daily mobility portfolios when exposed to personalised feedback and MaaS-enabled choice environments.

In addition to observed behaviour, behavioural response is also captured through *post-intervention declared behaviour and latent constructs*, collected via the follow-up survey. These dimensions provide complementary evidence on self-reported mobility adjustments, perceived engagement with MaaS services and underlying psychological mechanisms, such as attitudes, social norms, perceived and actual behavioural control, environmental norms and self-identity, intentions and habit strength. While declared behaviour and latent constructs do not substitute observed mobility data, they allow behavioural adaptation to be interpreted in relation to cognitive and motivational processes activated by the intervention.

Table 15 provides a synthetic overview of the observed behavioural dimensions, the corresponding empirical indicators and their interpretation within the VTBC framework.

Table 15 Observed behavioural dimensions and VTBC mechanisms

<i>Behavioural dimension</i>	<i>Empirical indicator</i>	<i>VTBC mechanism</i>
<i>Car-use frequency / share</i>	% of trips by car; share of car-use days	Reduction of habitual car dependence
<i>Modal composition</i>	Distribution of modes across trips	Reconfiguration of mobility portfolio
<i>Multimodality</i>	Number of modes per user/day	Increased flexibility and choice awareness
<i>Public transport usage</i>	PT trips and modal share	Uptake of sustainable alternatives
<i>Active mobility</i>	Walking and cycling	Last-mile integration and experimentation
<i>Trip chaining</i>	N. and sequence of trips per day	Restructuring of daily activity patterns
<i>Behavioural variability</i>	Trip-to-trip modal variation	Routine disruption and habit weakening
<i>MaaS service purchase behaviour</i>	Observed purchases of mobility services through the MaaS app (user, date, service type)	Behavioural commitment; operationalisation of MaaS-enabled choices
<i>Declared post-intervention mobility</i>	Main mode, multimodality, frequency	Self-reported behavioural adjustment
<i>Latent behavioural constructs</i>	Attitude, social norms, environmental norms & self-identity, perceived behavioral control, actual behavioral control, intention, habits (Haustein scales)	Cognitive and motivational response

Source 19 author's elaboration.

Taken together, these dimensions allow behavioural response to be interpreted not merely as a modal shift, but as a broader process affecting the structure, diversity and flexibility of daily travel practices. From a VTBC perspective, reductions in car use are therefore analysed in conjunction with changes in multimodality, trip sequencing, behavioural variability and cognitive readiness for change, enabling a nuanced interpretation of early-stage behavioural adaptation within MaaS-enabled choice contexts.

The comparative logic adopted in this phase is explicitly aligned with the quasi-experimental structure of the study and is designed to maximise causal interpretability under real-world conditions. Behavioural responses are analysed through a combination of within-subject comparisons between tracking phase 1 and tracking phase 2 and between-group contrasts comparing treatment and control participants over identical observation windows.

This dual comparison strategy allows behavioural changes to be interpreted simultaneously relative to individual baseline routines and to a contemporaneous counterfactual represented by the control group, which is exposed to the same external contextual conditions but not to the VTBC-oriented

intervention components. By jointly leveraging temporal variation at the individual level and cross-sectional variation between exposure conditions, the design reduces the risk of confounding due to exogenous system-level changes and supports a mechanism-oriented interpretation of observed behavioural adaptations rather than simple descriptive before–after differences.

Table 16 summarises participation levels and behavioural data coverage across experimental phases, highlighting the progressive reduction in sample size that characterises longitudinal app-based experiments while preserving analytical transparency.

Table 16 Summary of behavioural tracking data

<i>Experimental phase</i>	<i>Group</i>	<i>Users (n)</i>	<i>Observation window</i>	<i>Trips</i>	<i>GPS records</i>
<i>Phase 1</i>	Treatment	17	23 Jun – 2 Jul 2025	176	23,194
<i>Phase 1</i>	Control	13	23 Jun – 2 Jul 2025	91	17,775
<i>Phase 2</i>	Treatment	11	23 Jul – 1 Aug 2025	175	25,046
<i>Phase 2</i>	Control	8	23 Jul – 1 Aug 2025	69	9,704

Source 20 author’s elaboration.

Importantly, the richness and granularity of the behavioural data partially compensate for the limited sample size by enabling detailed analysis of behavioural mechanisms at the individual level.

Within the overall research design, this phase completes the transition from hypothetical and diagnostic analysis to real-world behavioural observation. Behavioural response is interpreted as an emergent process shaped by personalised feedback, contextual facilitation and MaaS-enabled integration, rather than as an immediate or fully stabilised outcome. The evidence produced in this phase provides the empirical foundation for the subsequent evaluation and interpretation stage, where behavioural changes are formally assessed and linked to explanatory mechanisms through econometric modelling and follow-up analysis.

Phase 5: Evaluation and interpretation

The final phase of empirical implementation concerns the evaluation and interpretation of the VTBC experiment. This phase completes the methodological sequence by integrating the different streams of empirical evidence generated during the intervention and observation stages, with the explicit aim of assessing whether, how and through which mechanisms voluntary travel behaviour change emerges within a MaaS-enabled choice environment.

Within the VTBC framework adopted in this thesis, evaluation is not conceived as a generic assessment of mobility outcomes, nor as a simple measurement of modal shifts. Rather, it is framed as a theory-informed interpretative process that links observed behavioural responses to the underlying mechanisms activated by the intervention, taking into account both individual baseline conditions and contextual constraints. Accordingly, this phase focuses exclusively on the

experimental setting and on the population exposed to the VTBC intervention, and does not aim to provide a comprehensive evaluation of urban mobility patterns beyond the scope of the experiment.

From a methodological perspective, evaluation relies on the integration of multiple empirical sources collected throughout the experimental process. High-frequency app-based tracking data provide objective evidence of observed behavioural adaptations, while MaaS interaction and service purchase data capture levels of engagement with the integrated mobility environment. These revealed behavioural signals are complemented by post-intervention self-reported information collected through the follow-up survey, which captures declared mobility behaviour, perceived changes, and a set of latent behavioural constructs grounded in the behavioural theories discussed in Part 1.

The analytical role of this phase is therefore twofold. First, it assesses the effectiveness of the VTBC intervention by examining whether behavioural responses differ across time and exposure conditions, through before–after comparisons and treatment–control contrasts. Second, it supports the interpretation of behavioural change by relating observed outcomes to cognitive, motivational and contextual dimensions, thereby enabling a mechanism-oriented reading of the results. In this sense, evaluation does not treat behavioural change as a binary outcome, but as a process that may manifest through partial adaptations, increased behavioural flexibility, experimentation with alternative modes, or early signals of habit disruption.

The quasi-experimental logic adopted throughout the study is central to this evaluation phase. Behavioural changes are interpreted relative to individual baseline routines and contemporaneous external conditions, rather than in absolute terms. The presence of a control group, the longitudinal structure of the data, and the consistency of measurement instruments across phases collectively strengthen causal interpretability, while acknowledging the inherent constraints of real-world VTBC experiments, such as voluntary participation and attrition.

Importantly, the evaluation phase is explicitly designed to precede and inform formal modelling efforts. Rather than directly estimating causal effects, it structures the empirical evidence in a way that supports subsequent econometric analysis and hypothesis testing. The indicators and constructs examined in this phase define the dependent variables, mediating mechanisms and explanatory dimensions that are formally analysed in the next part of the thesis.

In this sense, evaluation and interpretation represent the analytical bridge between empirical implementation and results. By systematically integrating observed behaviour, MaaS usage and self-reported behavioural constructs, this phase provides the conceptual and empirical foundation for assessing the effectiveness of MaaS-enabled VTBC strategies and for interpreting behavioural change as an emergent, context-dependent process rather than as an immediate or fully stabilised outcome.

Identification limitations and scope conditions

The empirical design adopted in this thesis is subject to a number of structural and methodological limitations that should be explicitly acknowledged when interpreting the results. These limitations do not undermine the internal coherence of the analytical framework, but rather define the scope conditions under which the empirical findings should be read and evaluated.

First, participation in the VTBC experiment is voluntary and therefore subject to self-selection. Individuals who agreed to participate exhibit a minimum level of engagement, behavioural relevance, such as car use for university-related travel and relatively high attendance frequency, and openness to experimentation. While this limits population-level generalisability, it is consistent with the behavioural logic of VTBC programs, which are explicitly designed to target individuals who are both constrained by habitual practices and potentially receptive to change. Accordingly, the analysis does not aim to estimate average treatment effects for the entire student population, but to investigate behavioural responses within a behaviourally relevant and policy-relevant sub-sample.

Second, the empirical implementation relies on a quasi-experimental rather than a fully randomised controlled design. Although participants were randomly assigned to treatment and control groups following eligibility screening, full experimental control over participation, exposure intensity and contextual influences is not achievable in open, real-world mobility systems. As a result, causal interpretation is necessarily framed in comparative and mechanism-oriented terms, rather than as strict causal attribution. The identification strategy therefore focuses on within-subject comparisons and treatment–control contrasts under shared contextual conditions, supporting inference on behavioural mechanisms rather than on universal causal effects.

Third, attrition across experimental phases represents an inherent challenge of longitudinal, app-based behavioural studies. Progressive reductions in active participation are observed between recruitment, tracking phases and follow-up surveys. While attrition reduces statistical power and constrains the size of the final analytical sample, it does not compromise the internal validity of within-subject and treatment–control comparisons, which remain the primary analytical focus of the study. Nevertheless, the limited sample size restricts the possibility of fine-grained subgroup analysis and calls for caution when interpreting the magnitude and heterogeneity of estimated effects.

Fourth, the temporal scope of behavioural observation is limited to short-term responses and early-stage adaptation signals. The design does not capture long-term behavioural maintenance or habit stabilisation, which would require extended observation periods beyond the institutional, operational and ethical constraints of the research program. The empirical evidence should therefore be interpreted as indicative of behavioural adjustment, exploration and routine disruption, rather than as proof of sustained behavioural change.

Finally, behavioural observation is concentrated on mobility practices and MaaS-related interactions within the experimental window. While the integration of app-based tracking, service purchase data and follow-up surveys enables a rich and multi-layered behavioural assessment, the analysis does not explicitly account for broader life-course dynamics, exogenous shocks or contextual changes outside the scope of the intervention that may influence mobility behaviour over longer horizons.

Taken together, these limitations delineate the analytical boundaries of the study. The empirical results presented in the subsequent evaluation phase should be interpreted as context-specific, mechanism-oriented evidence on how MaaS-enabled choice environments and personalised behavioural support interact with existing mobility routines. They are not intended as generalisable impact estimates, but as empirically grounded insights into the conditions under which voluntary travel behaviour change may emerge in real-world metropolitan settings.

Empirical data sources and behavioural measurement framework

This chapter documents the measurement architecture of the study by specifying the empirical instruments, the constructs they operationalise, and the way their outputs jointly support the identification strategy. The focus is not on the chronology of fieldwork, which is addressed in the implementation section, but on instrument-level design choices: observation units, measurement logic, construct operationalisation, and the alignment between data sources and the behavioural mechanisms posited in the theoretical framework developed in Part 2.

Methodologically, the study adopts a multi-source design to address a central challenge of behavioural evaluation in mobility: behavioural change cannot be inferred reliably from a single empirical layer, because intentions, stated preferences and observed practices may diverge, and because short-term adaptations may coexist with persistent habits and contextual constraints. The empirical strategy therefore combines complementary data types (self-reported revealed behaviour, controlled hypothetical choices, passive behavioural traces and post-intervention psychometric measures) so that behavioural outcomes can be interpreted through converging evidence rather than through isolated indicators. In validity terms, this configuration strengthens interpretability through triangulation: it reduces reliance on a single measurement mode, mitigates mode-specific biases (e.g., recall and social desirability in surveys), and enables a distinction between behavioural outcomes and the cognitive–motivational mechanisms that may generate or inhibit them.

The chapter is organised around five instruments, each corresponding to a specific function within the VTBC logic and the broader behavioural framework adopted (including stage-based change dynamics and dual-process mechanisms). The RP survey provides the diagnostic baseline, capturing mobility practices, constraints, mobility capital, and MaaS predispositions before exposure. The SP experiment elicits structured trade-offs and adoption intentions for MaaS bundles under controlled attribute variation, and functions as a calibration device for the intervention logic rather than as a stand-alone demand exercise. The MaaS-enabled platform constitutes the operational measurement and delivery layer: it enables high-frequency, trip-level behavioural observation and (for the treatment group) captures engagement with integrated mobility services through transactional traces. Personalised Travel Plans translate observed routines into individualised, non-coercive behavioural support consistent with VTBC principles, operationalising reflective feedback and contextual facilitation within a real-world choice environment. Finally, the follow-up survey measures declared post-intervention behaviour and latent constructs, providing mechanism-oriented evidence to interpret behavioural adaptation and to assess early indications of behavioural maintenance beyond the active exposure window.

Overall, the chapter clarifies how each instrument maps onto the theoretical mechanisms discussed in Part 2 and how the combined measurement strategy enables the empirical analysis to move beyond simple modal shifts, towards a process-oriented interpretation of behavioural change grounded in both observed routines and their cognitive–contextual determinants.

Revealed Preference (RP) survey: baseline diagnosis and behavioural profiling

The Revealed Preference (RP) survey constitutes the primary diagnostic instrument within the empirical workflow of the study. Its function is not to evaluate behavioural change, but to establish a robust empirical baseline describing existing mobility practices, constraints and predispositions of the target population prior to any intervention exposure. Within the VTBC framework adopted in this thesis, the RP survey serves as a foundational input for population targeting, preference elicitation calibration and intervention design.

The survey was administered using a CAWI (Computer Assisted Web Interviewing) approach. An online questionnaire was developed and implemented in a Qualtrics environment, and participation was solicited through the dissemination of a web link across multiple institutional and non-institutional communication channels. Given the exploratory and diagnostic nature of this phase, the survey adopted a non-probabilistic sampling strategy based on broad outreach rather than predefined quotas. This choice reflects both practical constraints inherent to large-scale university surveys and the analytical objective of maximising heterogeneity in observed mobility behaviours and attitudes, rather than producing population-level estimates.

Despite its non-probabilistic nature, the achieved sample exhibits a satisfactory degree of alignment with the underlying university population along a set of key structural characteristics, including gender distribution, type of degree program, year of study and campus location. This empirical alignment supports the use of RP data as a meaningful behavioural and attitudinal baseline for subsequent analytical phases, while maintaining transparency regarding the limits of statistical representativeness. In line with the VTBC logic, the RP survey is therefore treated as a diagnostic and calibrating instrument rather than as a basis for population-wide inference.

From a substantive perspective, the RP questionnaire was designed to collect a comprehensive set of information relevant to the study objectives. The survey captures: (i) socio-demographic and academic characteristics; (ii) spatial attributes of residence and campus attendance; (iii) revealed mobility behaviours for both systematic (e.g. home–university) and non-systematic trips; (iv) perceived barriers and constraints affecting modal choice; and (v) attitudes towards integrated and digital mobility services. This combination allows behavioural observations to be interpreted in relation to both structural conditions and individual predispositions.

In addition to standard modal and frequency indicators, the RP survey was explicitly designed to support the reconstruction of individual travel chains and daily activity–travel patterns. Respondents were asked to report detailed information on trip sequences, including origins, destinations, purposes and modes used for systematic and non-systematic trips. This structure allows mobility behaviour to be analysed not only at the level of isolated trips, but also in terms of chained movements and daily mobility portfolios, which is particularly relevant for interpreting multimodal practices and the constraints shaping travel routines. The possibility to reconstruct trip chains constitutes an important analytical asset, as it enables subsequent phases of the research to link behavioural responses to changes in the structure and organisation of daily mobility rather than to modal shifts alone.

Furthermore, the RP survey includes a dedicated set of questions aimed at capturing elements of individual mobility capital. In line with the literature on mobility resources and behavioural capability, the questionnaire collects information on access to transport modes (e.g. car availability, public transport subscriptions, access to bicycles or shared mobility services), digital resources (e.g. smartphone ownership and familiarity with mobility-related applications), and experiential factors related to prior exposure to alternative mobility options. These variables provide an empirical basis for distinguishing between structural constraints and behavioural predispositions, and for interpreting heterogeneity in both stated preferences and observed behavioural responses in later phases of the study. In doing so, the RP survey enables a clearer distinction between behavioural resistance driven by structural constraints and resistance driven by attitudinal or capability-related factors.

By integrating trip-chain reconstruction and mobility capital indicators, the RP survey strengthens its role as a diagnostic instrument within the VTBC framework. It allows baseline mobility behaviour to be interpreted as the outcome of both structural opportunity sets and individual capability endowments, thereby supporting a more nuanced calibration of the preference elicitation phase and a more informed interpretation of behavioural adaptation during the intervention exposure.

A specific component of the RP survey is devoted to the operationalisation of user predisposition towards Mobility as a Service (MaaS). The operationalisation of MaaS-related attitudinal dimensions is grounded in the consolidated literature on MaaS adoption and acceptance, drawing in particular on Alonso-González et al. (2020), Fioreze et al. (2019), Kamargianni et al. (2018) and Schikofsky et al. (2020), which collectively identify key cognitive, behavioural and motivational drivers and barriers shaping individuals' predisposition towards MaaS-enabled mobility solutions. This analytical framework identifies six latent dimensions relevant for characterising attitudes and readiness towards MaaS-enabled mobility solutions: Multimodality, Attitude Towards Use, Technophilia, Intention to Use, Perceived Ease of Use, and Perceived Usefulness. These dimensions reflect both behavioural orientations (e.g. openness to multimodal travel) and cognitive–motivational factors

(e.g. perceived usefulness and ease of use), which are considered central in shaping responses to MaaS-based interventions.

Each dimension was operationalised through the aggregation of multiple survey items, for a total of 19 statements measured on five-point Likert-type scales ranging from 1 (“Strongly disagree”) to 5 (“Strongly agree”). The items were selected based on their conceptual alignment with the underlying constructs and with established models of technology acceptance and mobility behaviour. Prior to index construction, the internal consistency of each MaaS-related attitudinal dimension was assessed through Cronbach’s alpha. Reliability tests were conducted separately for each latent construct, based on the set of items assigned to it. Given the exploratory nature of the study and the behavioural focus of several constructs, particularly those related to multimodality and everyday mobility practices, Cronbach’s alpha values were interpreted with caution, taking into account both the number of items per scale and the conceptual breadth of the underlying dimensions.

Overall, the reliability analysis indicates satisfactory internal consistency for most MaaS-related dimensions, with particularly strong values for perceived usefulness, perceived ease of use, intention to use and technophilia. Lower alpha values were observed for the multimodality and attitude towards use dimensions, which likely reflect the heterogeneous and context-dependent nature of these constructs rather than measurement error per se. In these cases, the indices are retained as composite indicators capturing broad behavioural orientations, rather than narrowly defined psychometric scales.

Table 17 reports Cronbach’s alpha coefficients and the number of items for each MaaS-related dimension.

Table 17 Cronbach’s alpha coefficients for MaaS-related dimension.

<i>MaaS-related dimension</i>	<i>Cronbach’s alpha</i>	<i>Number of items</i>	<i>Interpretation</i>
<i>Multimodality</i>	0.400	3	Low internal consistency; reflects heterogeneity of multimodal practices and context-dependent travel behaviour
<i>Attitude towards use</i>	0.523	3	Moderate consistency; acceptable for exploratory behavioural constructs
<i>Technophilia</i>	0.730	4	Good internal consistency
<i>Intention to use</i>	0.752	3	Good internal consistency
<i>Perceived ease of use</i>	0.788	3	Good to very good internal consistency
<i>Perceived usefulness</i>	0.893	3	Excellent internal consistency

Source 21 *author’s elaboration*

Table 18 summarises the mapping between individual items and the corresponding MaaS-related dimensions.

Table 18 MaaS-related items and latent dimensions operationalised in the RP survey

<i>Item n.</i>	<i>Survey item</i>	<i>Latent dimension</i>
1	I choose to travel by public transport or to share rides (e.g. carpooling) to reduce travel costs	Multimodality
2	I don't care which means of transport to use, as long as it suits my travel needs	
3	I'm willing to try new ways of travelling	
4	Innovative mobility services (e.g. Uber, BlaBlaCar, bike-sharing) excite me	Attitude towards use
5	From time to time I look for alternatives to owning a car	
6	If I had an app with updated information on public transport and shared mobility, I would use a private car less	
7	I prefer to pay for rides via a smartphone application rather than using a paper ticket	Technophilia
8	I am available to try new smartphone applications	
9	I would use a smartphone application if it gave me easy access (payment, information, routes, times, etc.) to all transport modes	
10	I often use smartphone applications to get information on transport services and plan my trips	
11	I would be willing to sign up for a single subscription plan (weekly or monthly) including multiple transport services	Intention to use MaaS
12	I would be willing to try transport modes I had not previously used if they were included in an integrated mobility subscription	
13	I would use sustainable transport modes more if a single application allowed easy access to them	
14	It is easy for me to find the access point to a transport service if it is displayed on a map in a smartphone application	Perceived ease of use
15	I think it would be easy for me to become proficient in using an application offering integrated mobility services	
16	I think learning to use innovative and integrated mobility services would be easy for me	
17	A subscription plan for integrated mobility services would be useful for my daily mobility	Perceived usefulness
18	A subscription plan for integrated mobility services would allow me to complete my daily journeys more quickly	
19	Using a subscription plan for integrated mobility services would increase the effectiveness of my daily mobility	

Source: 22 author's elaboration based on Alonso-González et al. (2020); Fioreze et al. (2019); Kamargianni et al. (2018); Schikofsky et al. (2020)

Within the overall empirical strategy, the RP survey fulfils four interrelated analytical functions. First, it provides a behavioural baseline against which subsequent changes observed during the VTBC

experiment can be interpreted. Second, it supports the identification of behavioural barriers and constraints relevant for intervention design. Third, it informs the calibration and personalisation of the stated preference experiment by enabling respondent segmentation based on observed mobility profiles. Fourth, it allows the construction of MaaS-related attitudinal indicators that are later used to interpret both hypothetical preferences and observed behavioural responses.

Importantly, the RP data are not used in this thesis to test causal hypotheses or to estimate behavioural effects. Their role is explicitly preparatory and diagnostic, ensuring that subsequent preference elicitation and intervention exposure phases are grounded in empirically observed mobility practices and user predispositions, rather than in abstract or decontextualised assumptions.

Stated Preference (SP) survey: preference elicitation and intervention calibration

The Stated Preference (SP) survey constitutes a central analytical component of the empirical strategy and performs a function that goes beyond conventional preference elicitation. Within the Voluntary Travel Behaviour Change (VTBC) framework adopted in this thesis, the SP experiment operates as a calibration device that bridges baseline behavioural diagnosis and intervention design. By eliciting hypothetical choices under controlled and systematically varied conditions, the SP method allows the identification of latent preferences, behavioural sensitivities and trade-offs that cannot be directly inferred from revealed behaviour alone, particularly in contexts characterised by innovation and limited market maturity such as Mobility as a Service.

The use of SP methods is especially appropriate in the MaaS domain, where integrated mobility bundles, subscription models and pricing schemes are not yet fully observable in real-world settings. In this context, hypothetical choice experiments provide a structured environment in which individuals are required to confront realistic yet novel mobility configurations, thereby revealing how cost, service integration, information framing and ancillary features jointly shape stated adoption intentions. Importantly, the objective of the SP phase in this study is not to predict market shares or to estimate stand-alone demand functions, but to inform the design and interpretation of behavioural intervention by identifying which configurations are perceived as credible, attractive and behaviourally acceptable by different user profiles.

The SP experiment focuses on students' stated intention to adopt MaaS bundles within a university mobility context (Appendix 2). Its design is explicitly grounded in the diagnostic evidence produced during the context analysis and revealed preference phase, ensuring consistency between observed travel behaviour, hypothetical scenarios and the actual transport supply environment. This alignment is crucial within a VTBC perspective, as it prevents the intervention from being calibrated on abstract or decontextualised assumptions and anchors preference elicitation to the structural and behavioural constraints experienced by users in their daily mobility.

The alternatives presented in the SP experiment consist of MaaS bundles combining multiple mobility services into integrated monthly packages. The construction of the alternatives and the selection of attributes were informed by the transport supply analysis conducted during the baseline diagnostic phase, ensuring that all proposed services correspond to options that are realistically available within the Milan metropolitan mobility system. Each MaaS bundle is characterised by a set of attributes designed to jointly capture economic, functional and communicative dimensions of MaaS adoption:

- Monthly cost of the bundle, defined at tariff levels consistent with existing pricing and discount policies. For the purposes of the empirical analysis presented in this thesis, only student tariffs are considered, ensuring coherence with the target population of the intervention.
- Modal composition of the bundle, expressed as quantities of service measured in minutes per month. Bundles include different combinations of urban public transport, suburban or regional public transport, integrated shared mobility services (bike sharing, scooter sharing), car sharing or taxi services, where car sharing availability or licence possession is limited, park & ride options. The degree of modal integration increases across bundles, reflecting different levels of service richness, flexibility and substitute potential.
- Package naming, with two levels:
 - neutral naming (e.g. “Option A”, “Option B”, “Option C”),
 - descriptive naming (e.g. “Eco-Base”, “Eco-Standard”, “Eco-Premium”), explicitly introduced to test the role of framing and symbolic communication in shaping stated choices.
- Discount visibility, treated as a dummy attribute indicating whether information on the discount embedded in the bundle price, relative to the sum of individual services, is explicitly displayed to the user, thereby testing transparency and salience effects.
- 24-hour assistance, treated as a dummy attribute capturing the availability of continuous customer support, reflecting perceived reliability and service reassurance.
- Personalised shopping voucher, treated as a dummy attribute and derived from a preliminary choice among four options (supermarket, restaurant, cinema, gym), used both as an incentive and as a behavioural marketing lever.

The discount associated with each bundle is fixed but varies across bundles and increases with the degree of modal integration, consistently with the MaaS principle “*the more you buy/use, the more you save*”. This structure allows the SP experiment to test whether users internalise the logic of bundled mobility and respond positively to increasing levels of integration.

Each stated choice task presents respondents with three MaaS bundles characterised by different attribute combinations, plus a no-purchase (opt-out) option. The inclusion of the opt-out alternative is methodologically essential to preserve behavioural realism and to avoid upward bias in adoption

propensity by allowing respondents to explicitly express non-adoption preferences. Respondents are asked to select the option they would most likely choose under the presented conditions, assuming that the bundles are available within their actual mobility context.

Before exposure to the choice tasks, participants undergo a structured preparatory phase aimed at aligning cognitive frames, enhancing realism and reducing hypothetical bias. First, respondents watch a short introductory video explaining the concept of Mobility as a Service, its rationale and its potential implications for daily mobility choices. This step ensures a shared baseline understanding of MaaS across participants and limits heterogeneity in the interpretation of the proposed alternatives. Second, a socio-demographic and behavioural profiling questionnaire is administered, serving a dual purpose:

- assigning respondents to choice scenarios consistent with their observed mobility profile (e.g. predominant mode, commuting distance, travel frequency), thereby increasing the plausibility of the hypothetical tasks;
- generating a personalised summary of the respondent's mobility profile.

For respondents reporting predominant use of private cars, personalised feedback on monthly car travel costs is provided prior to the SP tasks. This feedback includes estimates of both fuel-only costs and total costs (including depreciation, maintenance and tyres), computed using reference values from official cost tables and based on the following formulation:

$$\text{Monthly cost} = \text{Unit cost per kilometer} \times \text{Average distance} \times \text{Average monthly frequency} \times 2$$

This information acts as a contextual anchor, increasing awareness of the economic implications of current mobility behaviour and reinforcing the salience of MaaS bundles as potential substitutes.

The SP survey was implemented using the SurveyEngine platform, which allows advanced customisation of choice experiments, dynamic routing based on individual profiles and integration of multimedia content. Digital administration ensured consistency in task presentation, randomisation procedures and data quality control across respondents.

The experimental design follows a fractional factorial orthogonal design, selected to minimise correlations among attribute levels across choice tasks while preserving control over dominant and dominated alternatives. This choice is particularly appropriate given the high degree of customisation required by respondent segmentation and the number of attributes involved. Based on evidence from the RP survey, respondents were segmented according to four key dimensions of systematic home-to-university mobility: institutional role, predominant mode of transport, commuting distance and travel frequency. This segmentation enabled the development of multiple experimental designs calibrated to different user profiles while maintaining internal consistency and perceived plausibility of the alternatives.

For each design, the full set of hypothetical choice situations was divided into experimental blocks of six choice tasks, and each participant was randomly assigned to a single block. This blocking strategy was adopted to limit cognitive burden and respondent fatigue, preserve the statistical properties of the experimental design, and ensure that each choice situation is evaluated by a sufficient number of respondents.

Within the overall empirical strategy, the SP survey fulfils a clearly defined calibrating and anticipatory role. It identifies behavioural sensitivities, trade-offs and framing effects that inform the construction of the VTBC intervention and provide an interpretative lens for analysing observed behavioural responses in subsequent phases. Rather than constituting an isolated modelling exercise, the SP phase is integrated with revealed preference evidence, app-based behavioural observation and post-intervention evaluation, thereby strengthening the internal coherence, explanatory depth and policy relevance of the research design.

MaaS-enabled choice context: behavioural exposure and tracking

The MaaS platform employed in the experiment constitutes the core operational layer through which the empirical design is translated into an observable behavioural setting. Within the logic of this study, the platform is not conceptualised as a technological artefact per se, but as a deliberately configured MaaS-enabled choice context, designed to activate, mediate and differentiate Voluntary Travel Behaviour Change (VTBC) mechanisms in a real-world mobility system. Its analytical relevance therefore lies in its capacity to restructure the decision environment in which mobility choices are made, rather than in the provision of digital services alone.

From a behavioural perspective, the platform operationalises key assumptions of the Trans-Theoretical Model of behaviour change, particularly the progression from contemplation and preparation towards action. By combining self-monitoring tools, personalised feedback and facilitated access to alternative mobility options, the platform supports the transition from intention to behaviour, while avoiding coercive or restrictive measures. In this sense, it functions as an enabling infrastructure that lowers the cognitive, informational and organisational barriers that typically prevent the translation of pro-sustainability intentions into concrete mobility choices.

From a methodological standpoint, the platform represents the instrument through which diagnostic knowledge, stated preferences and behavioural interventions converge. It allows the experimental manipulation of information availability, decision-support mechanisms and service accessibility while preserving ecological validity. In doing so, it aligns with VTBC principles by targeting behavioural routines through contextual facilitation and feedback rather than through external enforcement. The platform thus operates as an intermediate behavioural infrastructure, supporting both reflective decision-making and the gradual weakening of habitual, car-oriented routines.

Operationally, the platform is a pre-existing MaaS solution provided to the University of Milano-Bicocca by a third-party operator within an institutional research program. For the purposes of the VTBC experiment, the platform was specifically adapted to meet the requirements of the quasi-experimental design. Two closed and fully segregated digital environments were created, one for the treatment group and one for the control group, in order to prevent contamination effects and to enable differentiated exposure conditions. This separation is methodologically essential, as it ensures that observed behavioural differences can be attributed to variation in intervention exposure rather than to uncontrolled information spillovers.

Access to the platform environments was restricted through institutional email authentication and a project-specific access code, ensuring that only authorised participants could interact with the experimental setting. Participation required explicit informed consent, including authorisation for personal data processing and mobility tracking. A dedicated experimental regulation and a detailed privacy notice were made continuously accessible within the user account, specifying the duration of the experiment, the nature of the data collected, the scientific objectives and the conditions of participation. This governance framework strengthens both the ethical robustness and the internal validity of the empirical implementation.

Within the MaaS-enabled choice context, the platform integrates multiple functional modules that collectively define the effective opportunity set available to participants.

The RIDE&GO module (Figure 5) enables real-time access to a range of mobility services available in the metropolitan area, including public transport tickets, rail services, taxis, parking payments and shared mobility, through a unified interface. By integrating information, payment and service activation, this module reduces informational and transactional frictions that often reinforce habitual car use.

The ACTIVITIES (Figure 6) module allows participants to record their trips through voluntary activation of tracking, generating high-frequency, trip-level behavioural data. Beyond its measurement function, this module activates self-monitoring processes that are central both to VTBC programs and to the Trans-Theoretical Model, particularly in the transition from contemplation to action. The platform also provides participants with synthetic feedback reports summarising their mobility behaviour over time, including information on modes used, travel

Figure 5 RIDE&GO module



Source 23 Screenshot of MaaS platform

Figure 6 ACTIVITIES module



Source 24 Screenshot of MaaS platform

duration, distance covered and estimated CO₂ savings. These reports serve as reflective feedback mechanisms, reinforcing awareness of behavioural patterns and supporting the cognitive processes associated with self-evaluation and behavioural reappraisal.

The CARPOOLING module (Figure 7) introduces a social and cooperative dimension into the mobility choice context, enabling shared home–university trips and facilitating cost and resource sharing.

The BENEFITS module (Figure 8) complements this structure by offering discounted mobility-related vouchers, functioning as a soft incentive mechanism that lowers the perceived cost and risk of experimenting with alternative mobility options.

Table 19 provides a synthetic overview of the functional modules implemented within the platform, their core functionalities, the types of data generated and their analytical and behavioural role within the experimental design.

Figure 7 CARPOOLING module



Source 26 Screenshot of MaaS platform

Figure 8 BENEFITS module



Source 25 Screenshot of MaaS platform

Table 19 Functional modules of the MaaS-enabled choice context and their behavioural role

<i>Platform module</i>	<i>Core functionality</i>	<i>Type of data generated</i>	<i>Behavioural role</i>
<i>Ride&go</i>	Real-time access to integrated mobility services (public transport tickets, rail services, taxis, parking payments, shared mobility) through a unified interface combining information, payment and service activation	Service access and purchase logs	Reduces informational and transactional frictions; expands the feasible choice set; facilitates the translation of intentions into action by lowering cognitive and organisational barriers
<i>Activities</i>	Voluntary activation of trip tracking and recording of daily movements; provision of synthetic mobility feedback reports (modes used, travel duration, distance, estimated CO ₂ savings)	High-frequency, trip-level behavioural data; behavioural feedback indicators	Activates self-monitoring and self-reflection processes; supports awareness raising and self-evaluation; enables observation of behavioural routines and early adaptation signals
<i>Carpooling</i>	Matching and coordination of shared home–university trips among participants	Shared trip records and participation logs	Introduces a social and cooperative dimension; supports experimentation with alternative mobility practices; weakens individual car-use routines through collective arrangements
<i>Benefits</i>	Access to discounted mobility-related vouchers (fuel, electric charging, sharing services, high-speed rail)	Voucher acquisition and redemption data	Acts as a soft incentive mechanism; reduces perceived cost and risk of behavioural experimentation; supports reinforcement and commitment processes

Source 27 author's elaboration based on platform functionalities and experimental configuration.

Taken together, these modules do not merely expand the set of available services but actively reconfigure the behavioural context in which mobility decisions are made. By combining facilitated access, self-monitoring, feedback and incentives, the platform supports both exploratory behaviour and higher-intensity forms of behavioural commitment. Within the Trans-Theoretical Model, this corresponds to the activation of multiple change processes—such as consciousness raising, self-reevaluation and reinforcement, while remaining consistent with the voluntary and non-coercive logic of VTBC interventions.

Within the overall research design, the MaaS-enabled choice context constitutes the operational backbone of the VTBC intervention, enabling the delivery of personalised travel plans, the provision of behavioural feedback, the collection of high-resolution behavioural and transactional data, and the observation of differentiated behavioural responses under controlled exposure conditions. Its role is therefore central to the identification strategy of the study, as it allows behavioural change to

be analysed as a context-dependent and process-oriented phenomenon rather than as a purely declarative or technology-driven outcome.

Personalised Travel Plans as individual-level behavioural support

Within the VTBC intervention framework, Personalised Travel Plans (PTPs) constitute the core individual-level behavioural support instrument through which diagnostic information is translated into tailored, actionable guidance. In line with established VTBC methodologies, the PTPs are conceived not as prescriptive or coercive tools, but as reflective and facilitative instruments aimed at supporting voluntary behavioural adjustment by increasing awareness, lowering perceived barriers and highlighting feasible alternatives within the individual's actual mobility context.

In the present study, PTPs were developed exclusively for participants assigned to the treatment group and were delivered prior to the start of the second experimental phase. Each PTP was constructed using behavioural data passively observed during the first tracking phase, thereby ensuring full consistency between recommendations and participants' revealed mobility practices. This temporal sequencing is central to the internal logic of the intervention, as it anchors personalised feedback to empirically observed routines rather than to self-reported or hypothetical behaviour.

The content of each PTP was personalised along multiple behavioural and spatial dimensions. Specifically, plans were based on: (i) modes of transport actually used; (ii) structure and complexity of trip chains; (iii) frequency of use of each mode; (iv) distinction between systematic and non-systematic trips; (v) spatial scale of mobility (intra-municipal, inter-municipal, metropolitan, regional or extra-regional); and (vi) differentiation between weekday and weekend mobility. This multidimensional profiling allowed the PTPs to address mobility behaviour as an organised system of practices rather than as a collection of isolated trips.

Based on this profiling, each PTP provided a concise synthesis of the participant's observed mobility behaviour, followed by a set of context-specific suggestions aimed at improving efficiency and sustainability. Suggested actions typically included opportunities for enhanced intermodality, optimisation of access to public transport nodes, increased use of active or shared modes for specific trip segments, and strategic integration of private car use with park-and-ride or interchange facilities where relevant. Importantly, recommendations were formulated to be compatible with the participant's existing constraints and resources, thereby reinforcing behavioural plausibility and avoiding unrealistic prescriptions.

In addition to behavioural feedback and mobility improvement suggestions, the PTPs explicitly encouraged participants to operationalise proposed changes through the use of the MaaS-enabled platform made available within the experiment. Where relevant, recommendations highlighted how specific mobility needs identified in the observed behaviour could be addressed through integrated

services accessible via the platform, including public transport tickets, shared mobility options and complementary services.

This component of the PTP serves a dual behavioural function. First, it reduces the intention–action gap by linking abstract recommendations to concrete, immediately actionable tools embedded in the choice environment. Second, it reinforces the role of MaaS as a contextual enabler rather than as a standalone technological artefact, positioning the platform as an instrument through which behavioural intentions can be translated into practice with reduced cognitive and transactional effort.

From a VTBC and Trans-Theoretical Model perspective, this integration supports the transition from preparation to action by coupling personalised guidance with an accessible implementation channel. In terms of Haustein’s dual-process framework, the encouragement to use the MaaS-enabled platform interacts with both (i) reflective mechanisms by making alternative choices salient and feasible and (ii) automatic mechanisms by lowering friction and facilitating repetition, which may contribute to the gradual restructuring of habitual mobility routines. Importantly, the use of the platform for service purchase remained entirely voluntary and was not framed as a performance requirement, preserving the non-coercive nature of the intervention while enabling observation of higher-intensity behavioural engagement in the subsequent analysis phase.

Table 20 summarises the main design features of the Personalised Travel Plans, highlighting their individual-level customisation, non-coercive nature and role as a behavioural facilitation tool within the VTBC intervention framework.

Table 20 Key characteristics of the Personalised Travel Plans (PTPs)

<i>Dimension</i>	<i>Description</i>
<i>Target group</i>	Treatment group only
<i>Timing of delivery</i>	Delivered once, prior to the start of the second tracking phase
<i>Basis for personalisation</i>	Observed mobility behaviour collected during the first tracking phase (app-based data)
<i>Level of personalisation</i>	Individual-level (one PTP per participant)
<i>Mobility dimensions considered</i>	Modal split; trip chaining; frequency of use by mode; systematic vs non-systematic travel; intra- and inter-municipal trips; spatial scale of mobility; weekday vs weekend mobility
<i>Type of recommendations</i>	Qualitative and contextualised suggestions aimed at improving sustainability, efficiency and modal balance of daily mobility
<i>Link to MaaS-enabled services</i>	Explicit encouragement to use the MaaS-enabled platform to access and purchase suitable mobility services
<i>Role in experimental design</i>	Behavioural facilitation tool supporting the transition from preparation to action within the VTBC framework
<i>Coerciveness</i>	Non-coercive; informational and supportive only

Source 28 Author’s elaboration based on the VTBC experimental protocol and PTP design.

The PTPs were delivered in PDF format (Appendix 3) via email and could be consulted at any time during the intervention phase. No mandatory compliance, quantitative targets or penalties were imposed, fully respecting the voluntary nature of the VTBC approach. Participants were not required to follow the recommendations, and no explicit performance benchmarks were defined. This design choice is consistent with the underlying behavioural philosophy of VTBC programs, which seek to enable and support change rather than enforce it.

Operationally, the PTPs function as a bridging mechanism between behavioural diagnosis and intervention exposure. They translate high-frequency tracking data into cognitively accessible information and actionable guidance, thereby strengthening the interpretability of subsequent behavioural responses observed during the second tracking phase. In the empirical analysis, the PTPs are not treated as deterministic drivers of change, but as contextual facilitators whose role is evaluated through observed behavioural adaptations, engagement with MaaS-enabled services and self-reported responses captured in the follow-up survey.

Follow-up survey: post-intervention behavioural and psychological assessment

The follow-up survey constitutes a critical evaluative instrument within empirical design, addressing dimensions of behavioural change that cannot be directly inferred from observed mobility behaviour alone (Appendix 4). While the VTBC intervention exposure and the app-based tracking phases capture short-term behavioural responses under controlled conditions, the follow-up survey is explicitly designed to assess the *cognitive, motivational and normative correlates* of behavioural adaptation once the experimental stimulus is no longer active. Within the VTBC framework, this instrument therefore supports the interpretation of behavioural outcomes by identifying whether intervention exposure is associated with changes in the underlying determinants of mobility behaviour.

In addition to latent psychological and normative constructs, the follow-up survey also collects self-reported mobility behaviour after the conclusion of the experimental phases. This includes information on main transport modes, frequency of use, and self-declared multimodality.

The inclusion of declared behavioural indicators serves a complementary analytical purpose. While app-based tracking provides high-frequency revealed behaviour during the intervention window, the follow-up survey captures *post-intervention behavioural self-assessment*, allowing the analysis to explore perceived behavioural adjustment and early signals of behavioural maintenance once active intervention exposure has ceased.

From a methodological perspective, these self-reported indicators are not treated as substitutes for observed behaviour, but as interpretative complements. Their role is to contextualise observed behavioural responses and to assess whether changes detected during the experimental phases are

reflected in participants' own perception of their mobility practices, thereby strengthening the interpretation of behavioural dynamics within the VTBC framework.

The survey was administered exclusively to individuals who had taken part in the VTBC experimentation, including both treatment and control groups, regardless of whether they completed all experimental phases or discontinued participation at an earlier stage. The same questionnaire was administered to all respondents, ensuring full comparability across experimental conditions and preserving the internal coherence of the quasi-experimental design. This inclusive strategy reflects the logic of VTBC programs, which conceptualise behavioural change as a gradual and potentially non-linear process, in which cognitive and motivational effects may persist even when observable behavioural engagement weakens or ceases.

From an identification perspective, the follow-up survey does not aim to establish causal effects in isolation, but to complement behavioural tracking data by providing mechanism-oriented evidence. Its analytical contribution lies in strengthening *internal validity* through triangulation: observed behavioural responses are interpreted jointly with post-intervention attitudes, intentions, perceived constraints and habit-related constructs. At the same time, the survey enhances *interpretive validity* by allowing the analyst to distinguish between behavioural change driven by temporary compliance or situational factors and change associated with deeper shifts in behavioural predispositions.

The conceptual structure of the follow-up survey is explicitly grounded in two complementary theoretical frameworks: the Voluntary Travel Behaviour Change (VTBC) approach and the Trans-Theoretical Model of behaviour change. Within this perspective, behavioural adaptation is understood as the outcome of interactions between reflective processes and automatic processes. The survey therefore focuses on constructs that are theoretically linked to transitions between stages of change, particularly the movement from action towards potential maintenance, as well as the destabilisation of habitual car use.

To ensure transparency and conceptual coherence, Table 21 summarises the latent constructs and declared behavioural dimensions measured in the follow-up survey, together with their conceptual meaning and illustrative survey items.

Table 21 Latent constructs and declared mobility behaviour measured in the follow-up survey

Latent construct	Conceptual meaning	Survey items (examples)	Analytical role
<i>Declared mobility behaviour</i>	Self-reported post-intervention mobility practices		Post-intervention self-assessment
<i>Subjective car dependence</i>	Degree to which car use is embedded in lifestyle and enacted automatically	<i>My lifestyle depends on owning a car</i> <i>I do not really think about how to travel: I just take the car</i> <i>I would like to use the car less, but there are no really practical alternatives</i>	Habit strength; behavioural inertia
<i>Intention to reduce car use</i>	Reflective motivation to decrease car use	<i>I actively try to reduce my car use</i> <i>I have no interest in reducing my car use</i> (reverse coded)	Readiness for change
<i>Attitude toward behaviour</i>	Cognitive and affective evaluation of sustainable mobility choices	<i>I would feel uncomfortable using the car when others choose sustainable modes</i> <i>Using sustainable transport is my moral responsibility</i> <i>Reducing my car use can make a difference</i> <i>My behaviour does not affect congestion or environmental problems</i> (reverse coded)	Norm activation and self-efficacy
<i>Perceived behavioural control</i>	Subjective perception of barriers and difficulties	<i>Public transport is unreliable or unavailable</i> <i>Difficulties with public transport make car use my preferred option.</i> <i>Lack of infrastructure makes alternatives difficult</i>	Perceived constraints
<i>Actual behavioural control</i>	Objective and perceived access to resources and capabilities	<i>I have easy access to public transport</i> <i>I have the skills to use transport services autonomously</i> <i>The infrastructure for active mobility (e.g. cycle paths and sidewalks) along my daily routes is safe and well maintained.</i> <i>My physical condition allows me to walk or cycle for my daily trips.</i> <i>I can flexibly organise my daily activities</i>	Structural feasibility
<i>Social norms</i>	Influence of reference groups on behaviour	<i>Seeing others use sustainable transport motivates me</i> <i>My social environment influences my travel choices</i> <i>If more people in my group of friends used public transport and shared mobility services, I would be more inclined to do the same.</i>	Social diffusion
<i>Environmental self-identity</i>	Integration of sustainability into self-concept	<i>I feel proud when I make environmentally friendly travel choices</i> <i>Sustainable behaviour is part of who I am</i> <i>I believe I have a good understanding of the different environmental impacts associated with various modes of transport.</i>	Identity alignment

Source 29 Author's elaboration based on Haustein and Hunecke (2007), Haustein (2012), Ajzen (1991), Bamberg et al. (2003), Verplanken et al. (1997)

Together, these constructs capture both cognitive–motivational responses and self-declared behavioural adjustments following the experimental exposure, providing an essential interpretative layer for the evaluation of VTBC mechanisms beyond observed short-term behavioural changes.

A central construct addressed in the follow-up survey is subjective dependence on private car use. This dimension is operationalised through three indicators capturing (Zhao, 2011): (i) perceived reliance of one's lifestyle on car ownership; (ii) the extent to which car use is enacted automatically, without reflective evaluation of alternatives; and (iii) perceived absence of viable non-car options. Together, these items provide a direct measure of habitual car dependence and behavioural inertia, closely aligned with the automatic behavioural system described in dual-process and habit-based models of travel behaviour (Verplanken et al., 1997; Bamberg et al., 2003), and with the distinction between automatic and reflective systems underlying VTBC interventions. Complementarily, intention to reduce car use is measured through two items capturing both proactive commitment to reduction and lack of interest in decreasing car use. These indicators allow the identification of shifts in reflective intention that may precede, accompany or fail to translate into observable behavioural change.

Beyond car dependence and intention, the follow-up survey systematically operationalises the set of latent behavioural dimensions proposed by Haustein (2012; Haustein & Hunecke, 2007) to explain voluntary mobility behaviour change. These dimensions capture the multi-layered cognitive and contextual mechanisms through which behavioural adaptation may be initiated, sustained or constrained. Attitude towards the behaviour is measured in both its cognitive and affective components, reflecting beliefs about the instrumental value of sustainable mobility choices as well as emotional responses associated with them. These two dimensions were operationalised through two additional constructs: moral norms and perceived self-efficacy. Social norms capture perceived expectations and behaviours within relevant reference groups, while environmental norms and self-identity assess the extent to which sustainable mobility choices are integrated into moral responsibility and self-concept.

Perceived behavioural control is operationalised through items capturing subjective barriers related to public transport availability, reliability and infrastructural adequacy, while actual behavioural control is measured through indicators reflecting concrete access to transport services, infrastructure quality, Physical and cognitive ability, and time flexibility. This distinction allows the analysis to disentangle motivational willingness from structural feasibility, a separation that is central to both VTBC theory and behavioural models of transport choice (Ajzen, 1991; Haustein, 2012). Intention and habit-related constructs, *ricinducibili* a subjective dependence on private car use and intention to reduce car use, complete the framework, enabling the assessment of whether intervention exposure is associated with a weakening of automatic routines and a reactivation of reflective decision-making processes.

All survey items were adapted from established and widely used measurement scales in transport behaviour and environmental psychology literature. Items measuring subjective car dependence and

intention to reduce car use are based on habit- and car-dependence scales commonly employed in travel behaviour studies (Verplanken et al., 1997; Bamberg et al., 2003; Haustein, 2012).

Attitudinal, normative and identity-related constructs follow the operationalisation proposed by Haustein and Hunecke (2007) and Haustein (2012), which integrates elements from the Theory of Planned Behaviour (Ajzen, 1991) with moral norm activation and habit theory.

Perceived behavioural control and actual behavioural control items are adapted from the Theory of Planned Behaviour and its extensions in the mobility domain (Ajzen, 1991; Bamberg & Schmidt, 2003), distinguishing between subjective constraints and objective access to resources and infrastructure.

Social norms and environmental self-identity items are adapted from norm-based models of pro-environmental behaviour and transport choice (Schwartz, 1977; Whitmarsh & O'Neill, 2010; Haustein, 2012).

All items were translated and contextually adapted to the university mobility setting and measured on five-point Likert-type scales ranging from 1 ("Strongly disagree") to 5 ("Strongly agree"), ensuring consistency across dimensions and facilitating the construction of internally coherent latent indicators. The adaptation process prioritised conceptual equivalence over literal translation.

Importantly, the follow-up survey is not used to replicate behavioural measurement, but to contextualise and interpret observed behavioural responses, supporting a mechanism-oriented evaluation rather than a purely outcome-driven assessment.

Within the overall empirical strategy, the follow-up survey thus performs a complementary and interpretative function. While behavioural tracking provides high-frequency, low-bias evidence on what participants did under intervention exposure, the follow-up survey provides insight into *why* behavioural changes may have occurred, *whether* they are cognitively and normatively supported, and *under which conditions* they might persist. This interpretative role is consistent with evaluation approaches in VTBC programs, where post-intervention attitudinal and normative measures are used to assess whether observed behavioural changes are supported by deeper cognitive and motivational shifts, which are necessary conditions for behavioural maintenance (Bamberg, 2013; Richter et al., 2011).

Concluding remarks on empirical implementation and data collection strategy

This part has articulated the empirical implementation and data collection strategy through which the theoretical and methodological framework developed in the previous parts of the thesis is rendered analytically operational. The empirical design is not conceived as a neutral or technical layer appended to the conceptual framework, but as an integral component of the analytical logic of the study. Each implementation choice is explicitly grounded in the behavioural–contextual understanding of mobility developed in Part 1 and in the theory-driven methodological positioning articulated in Part 2.

A central strength of the empirical strategy lies in its explicit alignment with a process-oriented conception of travel behaviour. Consistent with the theoretical rejection of static and purely outcome-based representations of mobility, the empirical implementation is structured to observe behavioural change as a trajectory unfolding over time. The longitudinal articulation of baseline diagnostics, intervention exposure, and follow-up observation directly reflects the VTBC logic of diagnosis–intervention–evaluation and allows for the analytical distinction between short-term behavioural responses, experimentation effects, and early indications of behavioural stabilisation. This temporal design constitutes a key methodological asset for interpreting behavioural outcomes within complex urban mobility systems.

A second major strength concerns the theory-informed integration of multiple data sources. The empirical strategy combines revealed preference data, stated preference experiments, behavioural tracking, and psycho-attitudinal measures not as parallel or redundant streams of information, but as analytically complementary lenses through which behavioural mechanisms can be examined. This integration operationalises the conceptual distinction between observed behaviour, underlying dispositions, and contextual constraints, enabling the analysis to move beyond surface-level modal shifts and to interrogate the processes through which behavioural change is initiated, facilitated, or inhibited.

The operationalisation of Mobility as a Service as a context-enabling intervention represents a further conceptual and methodological contribution of empirical design. In line with the theoretical framework, MaaS is not treated as an object of technological adoption or as an exogenous treatment, but as a structured modification of the mobility choice environment. This framing allows the empirical analysis to focus on how changes in informational accessibility, service integration, and perceived feasibility interact with individual attitudes, perceived behavioural control, and habitual routines. By embedding MaaS within a VTBC-oriented intervention logic, the empirical strategy directly tests the behavioural relevance of digitally mediated choice contexts within real-world policy settings.

The selection of the empirical context and target population further reinforces the coherence between theory and implementation. University campuses are conceptualised as institutional mobility attractors characterised by dense travel demand, high modal availability, and structured mobility routines, while university students represent a population undergoing a life-course transition associated with increased behavioural plasticity. This choice is analytically motivated by the theoretical emphasis on windows of opportunity and routine disruption, rather than by considerations of empirical convenience. As such, the empirical context functions as a theoretically informed testing ground for examining voluntary behavioural change under conditions that are conducive, yet not deterministic, of mobility reconfiguration.

At the same time, the empirical implementation is characterised by a reflexive and transparent engagement with methodological limitations. The quasi-experimental design adopted in this study explicitly acknowledges the constraints inherent to behaviour-oriented interventions in open and complex systems, including self-selection processes, heterogeneous engagement with the intervention, and context-specific effects. Rather than undermining the analytical value of the study, these limitations are incorporated into the research logic as conditions shaping the interpretation of empirical findings. Accordingly, the empirical strategy is oriented toward analytical generalisation, aiming to identify mechanisms, patterns, and scope conditions under which MaaS-enabled VTBC interventions may operate, rather than to produce decontextualised effect estimates.

Taken together, the empirical implementation and data collection strategy constitute a methodologically coherent and theoretically grounded foundation for the analytical phase of the study. By preserving consistency between conceptual assumptions, methodological logic, and empirical observation, this part establishes the necessary conditions for a robust interpretation of behavioural outcomes and underlying mechanisms. The following part builds on this foundation to analyse empirical results in light of the overarching research question, assessing how and under which conditions a MaaS-enabled choice context can support voluntary travel behaviour change within complex metropolitan urban mobility systems.

Part 4: Analysis and results

Analytical strategy and reading guide

This section defines the analytical strategy adopted in the empirical analysis and provides a structured reading guide for the results presented in this part. Its purpose is not to anticipate empirical findings, but to clarify how empirical evidence is organised, interpreted, and mobilised in relation to the overarching research question, the specific research questions, and the hypotheses formulated in Part 2. In particular, this section makes explicit the analytical logic through which results are ordered and the criteria used to assess their evidentiary value.

The empirical analysis is explicitly structured according to the diagnosis–intervention–evaluation sequence underpinning both the Voluntary Travel Behaviour Change (VTBC) framework and the research design developed in Parts 2 and 3. This sequence constitutes the organising principle of the empirical results presented in this part. Accordingly, findings are articulated across analytically distinct stages that correspond to the diagnostic baseline, the intervention exposure, and the evaluation of behavioural responses over time.

The diagnosis phase establishes the *baseline analytical reference*. Evidence derived from contextual analysis, revealed preference data (RP survey), and stated preference survey (SP survey) is used to characterise existing mobility practices, structural constraints, and perceived trade-offs prior to intervention. The analytical function of this phase is to delineate the behavioural opportunity space within which voluntary change may plausibly occur. Baseline results are not interpreted as indicators of behavioural change and do not support causal claims.

The intervention phase builds on the randomised assignment to treated and control conditions. Exposure to the MaaS-enabled choice context constitutes the central experimental contrast, and comparative analyses examine differences in behavioural outcomes between groups over time. Although participation and engagement with the intervention may vary, the randomised structure provides a robust basis for attributing observed differences to the intervention, subject to the limits imposed by attrition and heterogeneous uptake.

The evaluation phase extends the analysis beyond immediate behavioural responses by adopting a longitudinal perspective. Behavioural changes observed shortly after intervention exposure are analytically distinguished from early indications of persistence or decay. This temporal dimension allows the analysis to differentiate between short-term experimentation effects and the potential stabilisation of new mobility routines.

Across these phases, three analytically distinct forms of evidence are presented and should be interpreted accordingly.

First, descriptive patterns document observed mobility behaviours, usage distributions, and participation dynamics, providing empirical grounding without constituting evidence of intervention effects.

Second, comparative effects assess differences in behavioural outcomes between treated and control groups, leveraging the randomised design while remaining attentive to real-world implementation constraints.

Third, mechanism-oriented interpretations integrate behavioural outcomes with psycho-attitudinal measures and engagement indicators to examine how and under which conditions behavioural change occurs, prioritising explanatory coherence over effect magnitude alone.

Throughout the analysis, participant attrition and heterogeneous engagement with the intervention are explicitly documented and incorporated into the interpretation of results. These dynamics are treated as analytically relevant features of voluntary behaviour change processes, shaping both the observability and the durability of behavioural responses.

Finally, the interpretation of results is guided by a bounded but robust logic of inference. While the randomised design strengthens causal interpretation, findings are not read as universally generalisable estimates of intervention effectiveness. Instead, they are interpreted in terms of behavioural mechanisms and scope conditions relevant to complex metropolitan urban mobility systems.

Taken together, this analytical strategy establishes a transparent and rigorous framework for reading the results presented in the remainder of this part. By explicitly aligning the organisation of empirical findings with the diagnosis–intervention–evaluation logic and clarifying the role of randomisation, it defines what constitutes evidence at each analytical stage and under which assumptions and limitations the results should be interpreted.

Contextual and behavioural baseline diagnosis

This section develops the baseline diagnosis that informs the empirical analysis of voluntary travel behaviour change.

Baseline evidence is constructed through the integrated analysis of three complementary components: the urban mobility context and its structural constraints, revealed mobility patterns derived from observed behaviour, and stated preference data capturing perceived trade-offs and behavioural sensitivities. Each component contributes to a distinct analytical perspective, and their integration allows the baseline to move beyond descriptive inventories toward a structured diagnosis of behavioural constraints and opportunity space.

The purpose of this diagnostic exercise is twofold. First, it establishes an empirically grounded understanding of existing mobility practices and the systemic conditions within which they are embedded. Second, it identifies the types of behavioural adjustments that can be plausibly expected from context-enabled interventions, distinguishing between changes that are structurally constrained, cognitively inhibited, or potentially attainable through modifications of the choice environment.

Importantly, baseline results are not interpreted as indicators of behavioural change, nor are they used to derive causal inferences. Their analytical role is instead to inform the interpretation of subsequent empirical findings by clarifying the conditions under which exposure to a MaaS-enabled choice context may or may not translate into observable behavioural responses.

The section is organised as follows. It first examines the urban mobility context and the structural constraints relevant to daily travel practices. It then presents baseline revealed mobility patterns, followed by the analysis of stated preferences and perceived trade-offs. The section concludes with an integrated behavioural diagnosis that synthesises these elements and directly informs the transition from diagnosis to intervention in the subsequent analytical sections.

Urban mobility context and structural constraints

This section develops the first component of the baseline diagnosis by examining the structural characteristics of the urban mobility system and transport supply context of the Milan metropolitan mobility system in which daily travel behaviour unfolds. In line with the diagnostic purpose of the baseline outlined in section Phase 1: Context and baseline diagnosis, the analysis does not aim to evaluate transport system performance nor to assess policy effectiveness. Rather, it identifies the systemic conditions, accessibility patterns, and structural constraints that shape the feasibility of alternative mobility practices prior to intervention.

Situating the empirical analysis within the Milan metropolitan mobility system is a necessary analytical step for two reasons. First, it allows behavioural patterns observed in the following sections to be interpreted in relation to the spatial scale, functional organisation, and multimodal complexity of the system. Second, it clarifies which dimensions of mobility behaviour are structurally constrained and therefore unlikely to be affected by behaviour-oriented interventions, and which dimensions may instead be responsive to changes in the choice context.

From this perspective, the urban mobility system is treated not as a background setting, but as an active component of the behavioural processes under investigation. Transport supply, accessibility, and intermodal integration define the opportunity structure within which individual choices are made and routines are stabilised. Analysing these elements at the metropolitan and campus scales therefore provides the necessary foundation for the revealed and stated preference analyses that follow.

The Milan metropolitan mobility system: structure, scale, and accessibility patterns

The Milan metropolitan mobility system constitutes a paradigmatic example of a large-scale, functionally integrated urban region in which daily travel behaviour is shaped by interactions across multiple spatial and institutional scales. Mobility patterns extend well beyond the administrative boundaries of the core city, reflecting long-standing processes of residential dispersion, employment concentration, and functional specialisation that characterise the wider Lombardy region (OECD, 2015; Regione Lombardia, 2020).

Rather than operating as a compact urban system dominated by short-distance trips, the Milan area exhibits a polycentric spatial structure in which housing, employment centres, educational institutions, healthcare facilities, and services are widely distributed across municipalities and provinces (Camagni & Capello, 2016; Bertolini, 2017). As a consequence, a substantial share of daily mobility consists of medium- and long-distance trips, particularly for work and study purposes, generating recurrent commuting flows that connect peripheral and semi-peripheral areas to the metropolitan core. These patterns introduce strong structural dependencies on specific transport corridors and modes, thereby constraining the range of feasible behavioural adjustments at the individual level.

From a transportation system perspective, this spatial configuration is supported by a dense but heterogeneous and multi-layered transport supply. Rail-based services, including regional, suburban, and metropolitan railways, provide the structural backbone for medium- and long-distance commuting, particularly along radial corridors oriented toward Milan. These services are complemented by an extensive urban public transport network comprising metro, tram, and bus lines, which supports intra-urban accessibility and enables intermodal connections with the regional rail system. Road infrastructure organised around a dense network of primary and secondary roads

and a radial–ring motorway structure continues to play a significant role, especially for orbital movements and trips between peripheral areas that are less efficiently served by rail-based modes (Regione Lombardia, 2022; Agenzia TPL Bacino Milano, 2021).

The metropolitan mobility system is further characterised by high levels of demand intensity and temporal concentration, with pronounced peak periods associated with work, education, and service-related activities. This concentration amplifies congestion phenomena on both road and public transport networks, generating reliability issues and increasing the generalised cost of travel. At the same time, the coexistence of multiple transport modes, services, and operators creates a complex choice environment in which users continuously adapt their travel behaviour in response to accessibility conditions, service performance, and personal constraints.

Within this context, accessibility, rather than mobility alone, emerges as the key analytical dimension. While the Milan area is endowed with a rich transport supply, access to opportunities is unevenly distributed across the territory, reflecting differences in service coverage, network connectivity, and land-use patterns. Central and semi-central areas benefit from high levels of multimodal accessibility, whereas peripheral zones and interstitial areas often rely more heavily on private motorised transport or on limited and less reliable public transport options. These spatial disparities play a critical role in shaping travel behaviour, modal choice, and the feasibility of sustainable mobility alternatives.

The metropolitan scale is also particularly relevant from a behavioural perspective. Travel behaviour in the Milan area is influenced not only by local accessibility conditions, but also by regional commuting patterns, institutional arrangements, and long-established mobility routines. Daily mobility practices are frequently the outcome of long-term decisions related to residential location, employment, and education, which tend to lock individuals into specific travel patterns and modal dependencies. This structural dimension limits the effectiveness of purely infrastructural or regulatory interventions and reinforces the relevance of demand-side and behaviour-oriented approaches capable of acting on the choice context and on moments of behavioural flexibility.

Within metropolitan mobility systems characterised by strong functional integration and spatial dispersion, universities operate as structurally significant mobility poles. They generate large volumes of recurrent trips with high temporal regularity, linked to rigid institutional schedules and concentrated peak periods. At the same time, the spatial distribution of trip origins associated with university-related mobility is highly fragmented, extending across metropolitan and regional catchment areas. This asymmetry between concentrated destinations and dispersed origins produces distinctive commuting patterns that intensify peak demand, reinforce dependence on specific transport corridors, and increase sensitivity to intermodal continuity and reliability.

From an analytical perspective, these characteristics make university-related mobility particularly revealing of the interaction between structural accessibility conditions and behavioural constraints.

The feasibility of alternative mobility practices in this context depends less on the mere availability of transport services and more on their integration across scales, the quality of first- and last-mile connections, and the organisational effort required to coordinate complex trip chains. As a result, mobility behaviour associated with university campuses is strongly shaped by structural factors that precede individual choice, including regional commuting structures, service hierarchies, and institutional temporal rhythms.

In this sense, campuses function as critical observation points within the metropolitan mobility system. They concentrate behavioural responses to system-level constraints and amplify the effects of accessibility asymmetries, intermodal frictions, and cognitive complexity. Analysing mobility behaviour in relation to such attractors therefore allows structural constraints to be observed with particular clarity, highlighting the conditions under which behavioural flexibility is limited, selectively enabled, or contingent upon interventions capable of reducing organisational and cognitive burdens rather than expanding transport supply.

Public transport accessibility as a behavioural feasibility condition: Milano-Bicocca vs Monza

Within the metropolitan mobility system described above, public transport accessibility constitutes a central structural dimension shaping the feasibility of everyday mobility practices. From a behavioural perspective, the presence of public transport services does not in itself guarantee diversified or sustainable travel behaviour. What matters analytically is how transport supply is configured, connected, and experienced in relation to specific mobility attractors, and how these configurations translate into effective accessibility under everyday constraints.

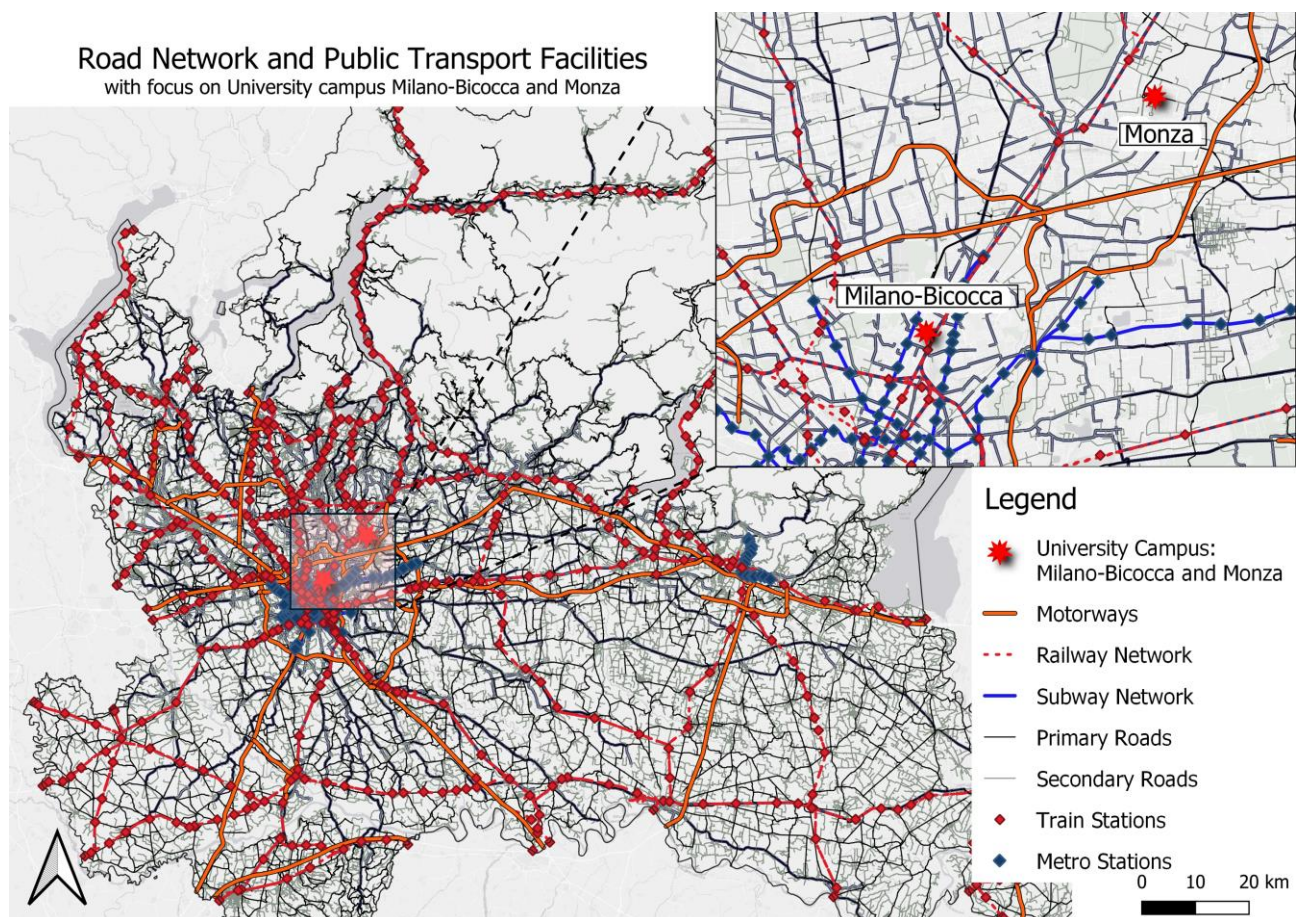
In complex urban regions such as the Milan metropolitan area, public transport systems combine multiple layers of provision, regional and suburban rail, metropolitan rapid transit, and surface services, within an institutionally integrated but operationally heterogeneous framework. While this configuration generates high aggregate levels of accessibility, it also produces differentiated accessibility conditions across locations, depending on intermodal integration, first- and last-mile continuity, service frequency, and the organisational effort required to coordinate multimodal trips. These elements are analytically relevant because they define whether public transport functions as a realistic behavioural alternative or remains a theoretically available but practically costly option.

From a Voluntary Travel Behaviour Change (VTBC) perspective, analysing public transport accessibility in relation to university campuses serves a diagnostic purpose. It allows structural accessibility constraints to be distinguished from behavioural or informational barriers and clarifies the extent to which observed mobility practices are shaped by system-level conditions rather than by individual preferences alone. In this sense, campus accessibility operates as an empirical lens

through which the interaction between transport supply, behavioural feasibility, and routine formation can be examined.

Against this analytical background, the public transport accessibility of the main University of Milano-Bicocca campuses is examined with specific attention to the Milano-Bicocca and Monza campuses. The analysis considers the configuration and integration of rail-based services, metropolitan lines, surface public transport, interurban connections, and institutionally provided shuttle services (Figure 9). In line with established accessibility assessment practices in urban mobility planning, catchment areas of approximately 600 meters around bus stops and 2 kilometers around railway stations are used as behaviourally meaningful thresholds for daily commuting, reflecting distances that are realistically walkable or cyclable under routine conditions.

Figure 9 Road network and public transport facilities in the Milan metropolitan area, with focus on the Milano-Bicocca and Monza campuses



Source 30 author's elaboration based on institutional transport data and public network datasets

Figure 9 provides a synthetic representation of the road and public transport networks at the metropolitan scale, highlighting the spatial position of the Milano-Bicocca and Monza campuses within the broader mobility system. Read analytically, the map illustrates the multi-scalar organisation of accessibility in the Milan metropolitan area and the structural conditions under which campus-related mobility is embedded.

At the metropolitan scale, the campuses are clearly located within the dense core of the regional rail and motorway networks, confirming their integration into the main mobility corridors that structure medium- and long-distance commuting flows. The concentration of railway lines and stations along radial axes converging toward Milan reflects the central role of rail-based services in supporting regional accessibility, while the ring–radial motorway structure underscores the continued relevance of road infrastructure for orbital and inter-peripheral movements.

At the urban scale, the map highlights marked differences in the configuration of public transport accessibility. The Milano-Bicocca campus appears embedded within a highly articulated urban transport network, characterised by a dense mesh of metro stations, surface public transport corridors, and intermodal nodes. This configuration suggests relatively low structural barriers in terms of physical access, while simultaneously implying high levels of network complexity and intermodal choice. By contrast, the Monza campus, although strongly connected at the regional rail level, appears more weakly integrated into the fine-grained urban transport network, with accessibility relying more heavily on transfers between regional rail services and surface transport connections.

These spatial patterns are analytically relevant because they make visible the distinction between aggregate accessibility and effective behavioural accessibility, highlighting how the mere presence of transport infrastructure does not necessarily translate into feasible or perceived mobility options for users (Geurs & van Wee, 2004; Martens, 2017; Schwanen et al., 2012). While both campuses are well positioned within the metropolitan transport system in terms of network reach, the quality of access differs substantially in terms of intermodal continuity, proximity to high-frequency services, and reliance on transfer-based trip chains. The map thus reinforces the interpretation of accessibility as a relational and scale-dependent property, shaped not only by the presence of transport infrastructure, but by how different network layers intersect around specific mobility attractors.

In this sense, Figure 9 functions as a spatial diagnostic tool rather than as a descriptive overview. It provides visual evidence of the structural asymmetries and intermodal configurations that condition everyday mobility practices and delimit the scope for voluntary behavioural change in campus-related travel. These system-level characteristics form a key part of the baseline diagnosis against which observed mobility patterns and subsequent behavioural responses are interpreted.

Building on this spatial diagnostic perspective, campus accessibility can be read as two distinct configurations of behavioural feasibility within the same metropolitan system. In one case, accessibility is extensive and highly multimodal, with dense overlaps between rail, metro, and surface services. In the other, regional reach remains strong, but effective access is shaped by discontinuities at the local scale and by dependence on intermodal transfers. This distinction is analytically crucial: it shifts attention from aggregate supply levels to the concrete conditions under which daily routines can be reliably reproduced, and therefore to the mechanisms through which structural accessibility becomes, or fails to become, behavioural accessibility.

For the Milano-Bicocca campus, a key accessibility node is Milano Greco-Pirelli railway station, served by several suburban rail lines connecting the campus to both the metropolitan area and the wider regional catchment. These include suburban services with regular headways as well as regional lines linking Milan to surrounding provinces, with peak-period frequencies generally ranging between half-hourly and hourly depending on the service.

Most of the academic buildings along Viale dell'Innovazione and Piazza della Scienza fall within approximately 600 meters of Milano Greco-Pirelli station, while the wider campus area remains within the broader 2 km rail catchment area. This spatial proximity significantly reduces first- and last-mile barriers and enables direct rail-based access for students commuting from a wide regional catchment area and reduces the need for intermediate motorised modes.

Rail accessibility is complemented by direct integration with the metropolitan metro network. The M5 metro line serves the campus area through the Bicocca, Ponale and Bignami stations, ensuring high-frequency connections to other parts of the city. Additional metro-based access is provided via interchange opportunities with other lines, including M1 and M3, which allow campus access through combined metro–tram or metro–bus trips depending on the specific destination building. Although not directly serving the campus area, the M4 contributes to overall network connectivity by strengthening cross-city accessibility and interchange opportunities within the metropolitan system.

Surface public transport further reinforces accessibility, playing a crucial role in fine-grained accessibility. The campus is served by multiple tram lines, notably the tram line connecting Precotto to piazzale Lagosta, with stops directly serving key university buildings. Additional tram services run along viale Fulvio Testi, providing intermediate-capacity connections between metro nodes and campus frontages. A dense network of urban bus lines operates within and around the campus, including routes traversing internal campus corridors and others connecting the area to major interchange nodes such as Milano Centrale and Villa San Giovanni. An interurban bus service extends accessibility beyond the municipal boundary, strengthening the role of the campus as a metropolitan-scale attractor.

In addition to mainstream public transport, the University provides a dedicated shuttle service for users with disabilities, operating on teaching days, and covering multiple municipalities in the northern metropolitan area. The service supports both origin–destination travel and internal campus transfers, highlighting the differentiated nature of accessibility needs and the role of institutional measures in mitigating behavioural and physical barriers.

Table 22 Public transport services serving the Milano-Bicocca campus

<i>Service type</i>	<i>Line / service designation</i>	<i>Main station or stop (interchanges)</i>	<i>Indicative peak-hour frequency</i>
<i>Suburban rail</i>	S8 Lecco–Carnate–Milano P.ta Garibaldi	Milano Greco-Pirelli	~30 minutes
	S9 Saronno–Seregno–Milano– Albairate	Milano Greco-Pirelli	~30 minutes
	S11 Milano–Chiasso–Como– Milano P.ta Garibaldi	Milano Greco-Pirelli	~30 minutes
<i>Regional rail</i>	R4 Brescia–Treviglio–Milano	Milano Greco-Pirelli	30–60 minutes
	R14 Bergamo–Carnate– Milano	Milano Greco-Pirelli	30–60 minutes
	R34 Stradella–Pavia–Milano	Milano Greco-Pirelli	30–60 minutes
	R38 Piacenza–Lodi–Milano	Milano Greco-Pirelli	30–60 minutes
<i>Metro</i>	M5	Bicocca – Ponale – Bignami	high-frequency service
	M1	Precotto; Sesto Marelli; Villa San Giovanni (bus/tram interchange)	high-frequency service
	M3	Zara (tram interchange); Comasina (student housing access)	high-frequency service
	M4	Dateo (student housing access)	high-frequency service
<i>Tram</i>	Line 7 (Precotto–P.le Lagosta)	Arcimboldi Ateneo Nuovo; Università Bicocca Scienza	~7 minutes
	Line 31 (Bicocca–Cinisello 1° Maggio)	San Glicerio; Fulvio Testi corridor	~6 minutes
<i>Urban bus</i>	Line 87	Internal campus corridors	~7 minutes
	Line 51	Ponale–Testi	~7–10 minutes
	Lines 81, 86	Breda–Rucellai (pedestrian underpass access)	~10–12 minutes
<i>Interurban bus</i>	Line 728	Sarca–Bignami (M5 interchange)	~12 minutes
<i>University service</i>	Accessible shuttle for users with disabilities	Door-to-campus / intermodal access	On demand (teaching days)

Source 31 Author's elaboration based on regional rail services, and local public transport operators.

Read analytically, Table 22 confirms a condition of high structural multimodality and dense network integration surrounding the Milano-Bicocca campus. The coexistence of multiple suburban and regional rail services, high-frequency metro lines, tramways, and a dense urban bus network

produces an access environment characterised by extensive formal availability and numerous intermodal combinations.

However, the analytical relevance of this configuration lies not in the abundance of services per se, but in the behavioural implications of their overlap. Accessibility to the campus is rarely achieved through a single, linear mode, but instead relies on the coordination of multiple services, schedules, and transfer interfaces. As a result, high aggregate accessibility coexists with elevated organisational and cognitive costs, particularly for users engaged in routine, time-constrained commuting.

In this context, behavioural feasibility is constrained by complexity rather than by scarcity. The density of available options expands theoretical choice, yet simultaneously increases uncertainty, coordination effort, and sensitivity to disruption. These conditions favour the stabilisation of habitual travel routines and limit adaptive experimentation, even in the presence of a structurally rich and diversified public transport supply.

Against this backdrop, the accessibility configuration of the Monza campus follows a markedly different structural logic.

The railway station of Monza is one of the most important nodes in the regional rail network, served by multiple suburban and regional services offering frequent connections with Milan and other major urban centers. From a purely infrastructural perspective, this ensures a high level of regional accessibility. Along the Milan–Monza corridor, peak-period frequencies are particularly high, with trains operating at intervals of approximately 5–10 minutes, providing strong rail accessibility at the metropolitan scale.

However, unlike the Milano-Bicocca campus, the main university buildings and the associated San Gerardo hospital area are located at a distance greater than 2 km from the railway station exceeding typical walking thresholds. As a result, effective access to the Monza campus relies heavily on intermodal transfers requiring interchange with surface public transport services, making last-mile connectivity a critical component of overall accessibility.

The campus is served by a set of urban and interurban bus lines serving stops located within walking distance of the main buildings and connecting the station area and other metropolitan nodes to the campus district. These services link the campus not only with Monza itself but also with neighbouring municipalities and railway stations along the metropolitan corridor such as Sesto San Giovanni, Lissone and Seregno, integrating the Monza campus into the wider metropolitan mobility system. These services typically provide travel times of 15–30 minutes from the station and stop within approximately 600 meters of the main campus buildings. Nevertheless, travel times and service frequencies introduce an additional layer of effort compared to the Milan campus, particularly for users unfamiliar with the local bus network.

To address this structural discontinuity, the university operates a dedicated shuttle bus service between the Monza railway station and Monza campus. This service is organised through scheduled morning, and afternoon runs and is specifically designed to support systematic commuting by

students. From a behavioural perspective, this service plays a compensatory role by reducing transfer complexity, perceived effort and travel uncertainty functioning as an institutional mechanism that supports multimodal travel in a manner conceptually aligned with MaaS principles. From a VTBC perspective, the shuttle service is analytically relevant because it acts as an institutional mechanism that reduces transfer friction and perceived uncertainty, thereby partially expanding behavioural feasibility without altering infrastructure provision.

Table 23 Public transport services serving the Monza campus

<i>Service type</i>	<i>Line / service designation</i>	<i>Main station or stop (interchanges)</i>	<i>Indicative peak-hour frequency</i>
<i>Suburban rail</i>	S7 Lecco–Molteno–Monza–Milano	Monza FS	~30 minutes
	S8 Lecco–Carnate–Milano P.ta Garibaldi	Monza FS	~30 minutes
	S9 Saronno–Seregno–Milano–Albairate	Monza FS	~30 minutes
	S11 Milano–Chiasso–Como–Milano P.ta Garibaldi	Monza FS	~30 minutes
<i>Regional / RegioExpress rail</i>	RE8 Milano–Lecco–Sondrio–Tirano	Monza FS	~5–10 minutes (Milano–Monza section)
	RE80 Milano–Como–Chiasso–Locarno	Monza FS	~5–10 minutes
	R4 Brescia–Treviglio–Milano	Monza FS	~5–10 minutes
<i>Interurban bus</i>	Z204 Vedano–Muggiò	Via Pergolesi / Ospedale San Gerardo	~20–30 minutes
	Z206 Monza–Ospedale San Gerardo	Via Pergolesi / Ospedale San Gerardo	~20–30 minutes
	Z221 Sesto S.G.–Monza–Carate	Via Pergolesi / Ospedale San Gerardo	~20–30 minutes
	Z225–Z227 Cinisello–Sesto FS/M1	Via Pergolesi / Ospedale San Gerardo	~20–30 minutes
	Z228 Seregno–Lissone–Monza	Via Pergolesi / Ospedale San Gerardo	~20–30 minutes
<i>Urban bus</i>	Z211 Monza Circular Line A	Via Pergolesi / Ospedale San Gerardo	~20 minutes
<i>University service</i>	UniMiB shuttle bus	Monza FS – Biomedical Campus	Scheduled peak-hour runs

Source 32 Author's elaboration based on regional rail services, and local public transport operators.

Read analytically, Table 23 reveals a structurally different configuration of accessibility at the Monza campus, characterised by high regional rail connectivity combined with limited local integration.

While the railway station of Monza constitutes a major metropolitan and regional node, effective access to the campus depends on a restricted set of intermodal sequences, primarily involving transfers from rail services to urban or interurban bus lines or to the university shuttle.

Unlike the Milano-Bicocca campus, accessibility in this context is not shaped by an abundance of overlapping services, but by a narrow and functionally critical set of access routes. Behavioural feasibility is therefore constrained by low redundancy and strong dependence on specific intermodal transitions, particularly along the last-mile segment. Disruptions, delays, or unfamiliarity with local connections can disproportionately affect travel reliability and perceived control.

In this configuration, behavioural rigidity emerges not from cognitive overload, but from structural scarcity. The limited number of viable access combinations reduces flexibility and increases reliance on compensatory modes, such as private car use or institutionally provided shuttle services, which offer greater predictability and autonomy within an otherwise fragmented accessibility environment.

Overall, the Monza campus illustrates how accessibility is not solely determined by the presence of high-capacity transport infrastructure, but by the quality of its integration with local access modes. This configuration provides an instructive contrast with the Milan campus and reinforces the importance of analysing intermodal interfaces and last-mile conditions when assessing the potential for voluntary behavioural change.

Taken together, the two campus contexts illustrate how structurally different configurations of public transport accessibility generate distinct constraints on behavioural feasibility within the same metropolitan mobility system. In the Milano-Bicocca area, the density and diversity of public transport services substantially reduce physical access barriers and expand the set of theoretically available mobility options. However, this abundance of supply is accompanied by a high degree of organisational and cognitive complexity. Users are required to navigate multiple modes, lines, fare structures, and interchange possibilities, often under time pressure and within rigid daily schedules. Under such conditions, behavioural feasibility is not limited by the absence of alternatives, but by the effort required to evaluate, coordinate, and reliably reproduce multimodal travel choices. These dynamics tend to favour routinised behaviour and the persistence of familiar modes, even in contexts of high structural accessibility.

In contrast, the Monza campus is characterised by a configuration in which high levels of regional rail accessibility coexist with pronounced local access constraints. While the metropolitan and regional reach of the campus is strong, effective accessibility depends critically on intermodal transfers and last-mile connections that introduce additional effort, uncertainty, and time variability. The need to coordinate rail services with surface transport or institutional shuttle services narrows the range of behaviourally feasible options, particularly for users with limited flexibility or limited familiarity with the local transport system. In this context, behavioural constraints emerge less from choice overload and more from dependence on specific intermodal sequences, whose reliability and perceived effort play a decisive role in shaping everyday mobility practices.

From a behavioural and VTBC-oriented perspective, these contrasting configurations highlight that constraints on voluntary behavioural change are not reducible to simple measures of transport supply or service frequency. Instead, constraints emerge from the interaction between structural accessibility conditions and the organisation of daily routines, including temporal rigidity, perceived reliability, and the cumulative effort associated with complex trip chains. Accessibility thus operates as a selective filter, determining which mobility options are not only available in principle but also feasible and sustainable in practice over time.

Importantly, these findings underscore that different forms of structural constraint may coexist within the same urban system and require differentiated analytical and policy responses. In contexts characterised by high supply density, behavioural feasibility is primarily constrained by complexity, cognitive load, and the costs of coordinating multiple services. In contexts characterised by fragmented local integration, feasibility is constrained by intermodal dependence, last-mile friction, and heightened sensitivity to service disruptions. Recognising these differentiated constraint profiles is essential for interpreting observed mobility behaviour and for assessing the potential scope and limits of interventions that seek to act on the choice context rather than on transport supply itself.

As a component of the baseline diagnosis, this analysis establishes the structural boundaries within which voluntary behavioural change can realistically occur. It clarifies that the effectiveness of MaaS-enabled choice environments and VTBC interventions cannot be evaluated independently of the accessibility configurations and constraint structures in which they are embedded. Behavioural change, where observed, must therefore be interpreted in relation to these pre-existing feasibility conditions, rather than as a simple response to the introduction of new informational or organisational tools.

Active and shared mobility as micro-scale conditions of behavioural feasibility

Beyond public transport accessibility, active and shared mobility infrastructures play a critical role in shaping the behavioural feasibility of everyday travel choices. From a behavioural and VTBC-oriented perspective, these infrastructures do not function as marginal complements to the transport system, but as enabling or constraining interfaces that condition how public transport can be accessed, combined, and sustained in daily routines.

In complex metropolitan urban contexts, the effectiveness of sustainable mobility alternatives is often determined at the level of the first and last mile. Discontinuities in cycling networks, the absence of secure parking, or the limited reliability of shared mobility services can substantially increase perceived effort and uncertainty, thereby reducing perceived behavioural control even where high-capacity public transport is available. Conversely, well-integrated active and shared mobility systems can lower organisational and cognitive barriers, expanding the set of behaviourally feasible mobility options without altering transport supply itself.

On this basis, the analysis examines active mobility infrastructure and shared mobility services in the areas surrounding the University of Milano-Bicocca campuses, focusing on cycling and walking conditions, bicycle parking and secure storage, and the availability and operational characteristics of shared mobility services. Spatial catchments of 1 km and 2 km around the main university buildings are used as behaviourally meaningful thresholds, reflecting distances that can realistically be integrated into daily routines.

In the Milano-Bicocca area, active and shared mobility infrastructures create a condition of partial behavioural enablement. Cycling corridors, parking facilities, and shared services are widely present, yet their effectiveness as everyday access options is uneven and highly contingent on network continuity, local safety conditions, and operational reliability, which represent a critical barrier to the uptake of cycling as a systematic access mode, particularly for less confident cyclists and for trip chains that require reliable continuity.

From an accessibility standpoint, the most relevant cycling connections include:

- a radial corridor toward the city center along Viale Pirelli–Via Venosta–Via De Marchi, connecting further to Via Melchiorre Gioia and the metropolitan cycling corridor aligned with the Martesana itinerary (including the BI20/Ciclovia AIDA);
- a second radial direction involving Via Sesto San Giovanni and Via Cozzi, partially supported through marked cycling lanes, also connecting to the Pirelli–Venosta–De Marchi axis;
- an east–west corridor that partly runs on separate lanes and bridges connecting the campus area with the Parco Nord system and further toward larger cycling corridors.

Taken together, these corridors provide directional connectivity rather than a continuous local network. From a behavioural standpoint, this means that cycling is feasible along specific axes, but fragile as a routine access mode, particularly when trips require transversal movements, crossings of rail infrastructure, or adaptation to variable traffic conditions.

Beyond network continuity, the availability and quality of bicycle parking constitute a second-order but decisive condition for behavioural feasibility. Secure and predictable storage is particularly relevant when cycling functions as a connector to public transport, as it directly affects perceived commitment, risk, and reversibility of choice. Table 24 summarises the main bicycle parking locations and capacities.

Table 24 Bicycle parking facilities in Milano-Bicocca campus

<i>Parking facility</i>	<i>Address</i>	<i>Municipality</i>	<i>Bicycle capacity</i>	<i>Location</i>
<i>PARK U1–U2</i>	Via Pirelli, near Piazza della Scienza 3	Milan	36	External (on square)
<i>PARK U3–U4</i>	Viale dell’Innovazione, near Piazza della Scienza 2	Milan	37	External (on square)
<i>PARK U5</i>	Via Polvani	Milan	~68 (planned)	Underground parking
<i>PARK U5/U9</i>	Viale dell’Innovazione	Milan	15	On-street
<i>PARK U6/U7</i>	Viale dell’Innovazione	Milan	178	Underground parking
<i>PARK U12</i>	Via Vizzola	Milan	24	Underground parking
<i>PARK U14</i>	Viale Sarca	Milan	15	On-street
<i>PARK U42</i>	Via Forni	Milan	7	External parking
<i>PARK U62</i>	Via Beato Carino	Cinisello Balsamo	6	External parking

Source 33 University of Milano-Bicocca, PSCL 2025

Beyond the existing racks, the University is implementing a structured program of secure bicycle storage facilities (velostations) between 2025 and 2028, with a planned capacity exceeding 500 bicycle spaces (and additional provision for e-scooters), reserved for the university community. From a behavioural perspective, this planned expansion is analytically significant not primarily because of the increase in capacity, but because it addresses a critical threshold condition for the stabilisation of cycling within daily routines.

Secure and dedicated storage directly reduces perceived risks related to theft and damage and lowers what can be defined as the commitment cost of cycling. By increasing predictability and reducing the need for precautionary strategies (such as carrying heavy locks or allocating additional time to search for secure parking), velostations enhance perceived behavioural control and reduce the irreversibility associated with choosing cycling as part of a multimodal trip chain. In VTBC terms, this intervention acts on the feasibility dimension of behaviour rather than on motivation, making cycling a more reversible, lower-risk option within routine mobility practices.

Table 25 summarises the main velostation facilities currently in use, under construction, or planned across the Milano-Bicocca campus. The spatial distribution of these facilities, largely integrated within academic buildings and major access points, further reinforces their behavioural relevance, as secure storage is co-located with daily activity anchors rather than treated as a peripheral or ancillary service.

Table 25 Planned and ongoing velostations (Campus of Milano-Bicocca)

<i>Facility / building</i>	<i>Address</i>	<i>Bicycle CAPACITY</i>	<i>Location</i>	<i>Status (timing)</i>
<i>U6 AGORA'</i>	Piazza Ateneo Nuovo 1	64	Ground floor under portico	In use
<i>PARK U6/U7</i>	Viale dell'Innovazione	110	Underground parking (-1)	Completion phase (2025)
<i>U2 QUANTUM</i>	Piazza della Scienza 3	112	Ground floor	Under construction (2025)
<i>PARK U5</i>	Via Polvani	68	Underground parking (-1)	Planned (2026)
<i>U10.1 LOGOS</i>	Viale dell'Innovazione	124	Underground parking (-1)	Under construction (2026)
<i>U10.2 (Residence)</i>	Viale dell'Innovazione	104	Underground parking (-1)	Under construction (2026)

Source 34 University of Milano-Bicocca, PSCL 2025

In addition to these infrastructural investments, the campus area hosts a university-promoted cycling facility (the “Marco Bondi” cycling station), managed through internal university associations. While limited in scale, this initiative plays a complementary role by supporting cycling culture, peer-based knowledge exchange, and social normalisation of active mobility. From a behavioural standpoint, such community-based facilities can amplify the effects of physical infrastructure by reducing informational barriers and reinforcing positive expectations around cycling as a viable everyday practice.

While the continuity and safety of cycling infrastructure define the physical feasibility of active mobility, they do not exhaust the conditions under which non-car options can be integrated into everyday travel routines. In the Milano-Bicocca context, shared mobility services constitute a complementary layer of accessibility, operating not at the level of network continuity, but at the level of organisational flexibility and modal integration within complex trip chains.

The Milano-Bicocca campus area is served by a wide range of shared mobility services, including station-based bike sharing, free-floating bicycles and e-scooters, scooter sharing, and car sharing. This diversity expands theoretical option availability and supports multimodal trip chaining. However, behavioural feasibility is conditioned by operational variability, spatial coverage limits, and the cognitive effort required to navigate multiple platforms and rules. In this context, shared mobility increases choice only to the extent that it remains legible, reliable, and easily combinable with public transport.

Finally, pedestrian accessibility has been analysed through a dedicated campus-scale walkability assessment developed within the MUSA project context. The results highlight spatial variability, with pockets of high walkability concentrated in the central campus area and weaker conditions along major road axes (with particular criticalities along a key arterial that operates as an internal barrier).

From a behavioural perspective, walking quality affects both direct access and the last-mile connection to public transport, thus indirectly shaping mode choices and perceived feasibility of non-car alternatives.

While the Milano-Bicocca campus illustrates a context in which active and shared mobility operate within a dense but fragmented urban fabric, the Monza campus is characterised by a structurally different configuration. Here, the feasibility of active and shared mobility is shaped less by network density and more by spatial discontinuity and corridor dependence, which fundamentally alter the role that these modes can play as systematic last-mile solutions within everyday commuting routines.

From an infrastructural perspective, active mobility in the Monza area is organised around a limited number of longitudinal corridors. A primary south–north cycling itinerary connects the railway station area to the historic center and the Parco di Monza, extending toward northern municipalities and partially aligning with a broader regional corridor associated with the Lambro river system.

However, this corridor-based configuration does not translate into effective accessibility for the main university buildings and the San Gerardo hospital. Dedicated cycling infrastructure does not extend into the campus area itself, with the exception of a short and locally disconnected segment serving parking areas and specific facilities. As a result, cycling access remains spatially discontinuous and weakly integrated into the campus access structure, limiting its capacity to function as a reliable last-mile solution within everyday commuting routines.

This configuration is analytically significant because access to the Monza campus is already structurally dependent on intermodal transfers from the railway station. In such a context, the absence of continuous and legible cycling connections does not merely limit the uptake of active mobility, but actively constrains the set of behaviourally feasible last-mile solutions for rail-based commuters.

Cycling, which could theoretically operate as a flexible and low-cost connector between the station and the campus, is effectively excluded from routine travel chains by infrastructural discontinuity and perceived unreliability. As a result, access options are functionally narrowed to surface public transport and institutionally provided shuttle services, increasing dependence on scheduled modes and reducing individual control over travel time and route choice.

Bicycle parking provision around the Monza campus remains limited in scale and strategically peripheral, amounting to approximately 90 bicycle racks primarily located near university parking areas. While this supply satisfies basic accommodation needs for occasional use, it does not constitute a strong enabling condition for systematic cycling or for the stabilisation of bike–rail intermodal routines. Table 26 summarises the main bicycle parking locations and capacities serving the Monza campus.

Table 26 Bicycle parking facilities (Campus of Monza)

<i>Parking facility</i>	<i>Address</i>	<i>Municipality</i>	<i>Bicycle capacity</i>	<i>Location</i>
<i>PARK U8 (external)</i>	Via Cadore 25	Monza	32	External parking
<i>PARK U8 (semi-underground)</i>	Via Cadore 25	Monza	24	Underground
<i>PARK U8</i>	Via Cadore 48	Monza	24	External parking
<i>PARK U18</i>	Via Podgora	Vedano al Lambro	2	External parking
<i>PARK U28</i>	Via Raoul Follerau	Vedano al Lambro	10	External parking

Source 35 University of Milano-Bicocca, PSCL 2025

In addition to conventional bicycle parking, a velostation with approximately 40 bicycle spaces is available near the hospital parking area and is accessible through an app-based system operated by a municipal mobility provider. While limited in capacity, this facility introduces an important qualitative distinction: it offers secure, managed storage that lowers theft risk and uncertainty, thereby reducing one of the key psychological and practical barriers to cycling. The presence of individual bicycle boxes for hospital staff, currently implemented as a pilot initiative, further illustrates how targeted micro-infrastructure can selectively expand behavioural feasibility for specific user groups. Analytically, these measures point to the relevance of secure storage not merely as an accessory service, but as a critical enabling condition for stabilising cycling within intermodal routines.

Shared mobility services partially compensate for the structural limitations of active mobility at the Monza campus. A station-based municipal bike sharing system operates through a distributed network of docking stations located near the hospital area and the railway station, supporting short-distance trips and potential last-mile connections. However, its effectiveness as a systematic access mode is conditioned by station density, bicycle availability, and the need to align shared-bike access with rail arrival times.

Free-floating e-scooter services are also available, operating under a controlled model that restricts parking and return to designated virtual zones covering the historic center, the railway station, and the Parco di Monza area. While this operational design improves order, safety, and public acceptability, it simultaneously constrains spatial flexibility, particularly for destinations located outside the core service zone. As a result, e-scooter use remains feasible primarily for specific, spatially bounded trip chains rather than as a generalised last-mile solution for campus access.

Electric car sharing integrated with the regional rail system is available through designated parking and charging points near the railway station and selected locations closer to the campus–hospital district. Behaviourally, this option plays a distinct role compared to active or micromobility services. Rather than functioning as a routine access mode, rail-integrated car sharing operates as a form of “contingency mobility”, providing a fallback option in situations of time pressure, service disruption,

or complex trip chaining. By reducing the perceived risk of being unable to complete a journey, such services may indirectly support public transport use as a primary mode, even if they do not themselves substitute for car ownership or generate significant modal shift.

The comparison between the two campus contexts confirms that active and shared mobility infrastructures generate differentiated configurations of behavioural feasibility within the same metropolitan mobility system. In the Milano-Bicocca area, the presence of multiple cycling corridors, extensive bicycle parking facilities, and a wide range of shared mobility services substantially expands the theoretical availability of non-car options. However, this abundance is accompanied by fragmentation in cycling infrastructure, discontinuities at critical junctions, and operational variability in free-floating services. These features introduce reliability, safety, and predictability concerns that directly affect effective behavioural accessibility. As a result, active and shared mobility options are formally present but not uniformly usable, and their integration into daily routines depends heavily on individual confidence, system familiarity, and tolerance for risk and uncertainty.

In the Monza context, constraints are structurally different and more directly rooted in the limited continuity between regional accessibility and local active mobility provision. The absence of direct cycling connections to the campus, combined with the systematic reliance on intermodal transfers, reduces the capacity of active modes to function as stable last-mile connectors for rail-based commuting. Shared mobility services partially compensate for these gaps, but their effectiveness remains contingent on spatial coverage, operational rules, and the need to coordinate multiple services within a single trip chain. Consequently, behavioural feasibility in Monza is narrower, more fragile, and more unevenly distributed across user groups, particularly disadvantaging those with lower flexibility or lower familiarity with local mobility systems.

From a behavioural perspective, these findings indicate that active and shared mobility infrastructures influence mobility choices not simply by expanding modal availability, but by reshaping the effort, risk, and organisational demands associated with multimodal travel. Where infrastructures are fragmented or operationally constrained, they tend to reinforce habitual behaviour even in the presence of sustainable alternatives. Conversely, where they stabilise first- and last-mile access and reduce uncertainty, they can meaningfully widen the space for voluntary behavioural change without requiring radical shifts in primary mode choice.

From transport supply to behavioural feasibility: structural constraints and boundary conditions for change

Taken together, the analysis of the Milan metropolitan mobility system and of the transport supply serving the University of Milano-Bicocca delineates a context in which high levels of modal availability coexist with structurally embedded constraints that delimit the space of feasible behavioural adjustment. Although both the Milano-Bicocca and Monza campuses are embedded within a dense

and multimodal transport environment, accessibility conditions differ markedly in their configuration, continuity, and behavioural implications. Intermodal integration remains uneven, last-mile accessibility is imperfect, and the effort required to translate formal transport supply into effective daily mobility options varies substantially across locations, trip structures, and user profiles.

From a behavioural perspective, these constraints are neither marginal nor incidental. They shape the conditions under which mobility routines are formed, stabilised, and reproduced over time. Long-distance commuting patterns, spatial asymmetries between dispersed origins and concentrated destinations, reliance on transfer-dependent trip chains, and fragmentation in active and shared mobility infrastructures collectively reinforce habitual travel practices, even in contexts where sustainable alternatives are formally present. In such conditions, the persistence of car dependence or reliance on a narrow set of modes cannot be interpreted as a simple expression of individual preference, but must be understood as an adaptive response to a structurally demanding and cognitively costly choice environment.

Importantly, these structural conditions delimit the scope of voluntary behavioural change in analytically consequential ways. They indicate that behaviour-oriented interventions cannot be expected to compensate for constraints rooted in spatial organisation, commuting distance, or the geography of transport networks, nor to override rigid temporal schedules and transfer-dependent access structures. Rather, the potential for voluntary change appears selective and conditional, concentrated in those dimensions of mobility behaviour where constraints are primarily organisational, cognitive, or informational, and where alternative practices can be integrated into existing routines without disproportionate increases in effort, risk, or uncertainty.

At the same time, the analysed context is characterised by a high degree of behavioural complexity. The coexistence of multiple modes, services, operators, fare systems, and access rules increases the cognitive and organisational burden associated with everyday travel decisions, encouraging the stabilisation of routines as a rational coping strategy. This complexity constitutes a structural constraint in its own right, as it limits the behavioural uptake of available alternatives even in highly supplied environments and reduces the likelihood of sustained experimentation with unfamiliar or multimodal options.

In analytical terms, the transport supply context examined in this section therefore functions as a set of boundary conditions for behavioural change. It specifies which forms of behavioural adjustment are structurally implausible, which are conditionally feasible, and which may become attainable only through interventions capable of reducing complexity and lowering the non-material costs of mobility choices. These boundary conditions provide a necessary interpretative frame for the empirical analysis that follows, ensuring that observed behavioural responses, or their absence, are interpreted as situated outcomes shaped by pre-existing structural constraints rather than as abstract indicators of individual willingness to change.

Baseline mobility patterns under spatial and systemic constraint

Structural and socio-demographic anchoring of everyday mobility

The baseline diagnosis begins with an examination of the socio-demographic and academic structure of the student population captured by the revealed preference (RP) survey at the University of Milano-Bicocca. This step is not intended as a descriptive profiling exercise. Rather, it serves to identify the structural anchoring conditions under which everyday mobility practices are formed, stabilised, and reproduced prior to any behavioural intervention.

From a behavioural perspective, socio-demographic and academic attributes do not directly determine mobility choices, but they shape the temporal rigidity, organisational autonomy, and degree of routinisation that characterise daily travel. These dimensions are analytically relevant because they condition both the formation of habitual behaviour and the scope for voluntary adjustment within existing routines.

Table 27 reports on the age distribution of students. The sample is strongly concentrated in younger cohorts: 36.6% of respondents are under 21 years of age, and a further 22.5% fall within the 22–24 age group. Students over the age of 30 represent only a marginal share of the population.

Table 27 Age distribution of students

<i>Age group</i>	<i>Share</i>
< 21	36.6%
22–24	22.5%
25–30	12.4%
31–35	2.3%
36–45	2.9%
46–55	1.1%
> 56	0.4%
Absent / wrong	22.0%

Source 36 author's elaboration based on RP sampling data.

This age structure is analytically significant because it corresponds to a population predominantly engaged in full-time education, with limited control over daily schedules and high exposure to externally imposed temporal constraints. In behavioural terms, such conditions tend to favour stable, repetitive mobility patterns, as daily travel must be synchronised with fixed class timetables, examination periods, and institutional rhythms. Under these circumstances, mobility choices are less likely to be continuously re-evaluated and more likely to become routinised responses to recurring constraints.

The academic composition of the sample further reinforces this interpretation. As shown in Table 28, bachelor's students constitute the majority of respondents (53.5%), followed by students enrolled in master's programs (22.5%) and single-cycle degrees (14.3%).

Table 28 Degree program distribution of students

<i>Degree program</i>	<i>Share</i>
<i>Bachelor's degree</i>	53.5%
<i>Master's degree</i>	22.5%
<i>Single-cycle master's</i>	14.3%
<i>Other courses</i>	2.4%
<i>Absent / wrong</i>	7.3%

Source 37 author's elaboration based on RP sampling data

This distribution implies that most respondents are subject to highly structured academic schedules, characterised by fixed weekly rhythms and limited flexibility in attendance requirements. Such institutional arrangements play a decisive role in shaping mobility behaviour, as they constrain departure times, arrival windows, and acceptable travel durations. In this context, the feasibility of alternative mobility options is evaluated primarily in relation to their reliability and predictability rather than to marginal differences in cost or comfort.

The relevance of institutional anchoring is further confirmed by the distribution of academic years reported in Table 29.

Table 29 Academic year distribution of students

<i>Academic year</i>	<i>Share</i>
<i>First year</i>	43.4%
<i>Second year</i>	28.0%
<i>Third year</i>	18.0%
<i>Fourth year</i>	1.8%
<i>Fifth year</i>	2.3%
<i>Sixth year</i>	0.2%
<i>Out-of-course</i>	6.1%

Source 38 author's elaboration based on RP sampling data

A large share of respondents is at an early stage of their academic trajectory: 43.4% are first-year students and 28.0% second-year students, while out-of-course students represent only a limited fraction of the sample (6.1%). Early-stage students typically display lower spatial and organisational autonomy: they are less likely to have optimised residential location choices in relation to campus accessibility and more likely to rely on inherited, socially transmitted, or opportunistic mobility arrangements.

At the same time, first-year students have recently experienced a major life event associated with the transition to university, a phase that is commonly characterised by elevated behavioural plasticity and heightened openness to change. In this condition, established routines are weaker and behavioural patterns are still in the process of consolidation, increasing receptiveness to self-regulatory mechanisms and action planning strategies.

From a behavioural standpoint, this condition simultaneously strengthens short-term dependence on pre-existing or opportunistic routines and increases the potential for behavioural adaptation. Mobility behaviour in this phase is often shaped by necessity and adaptation rather than by deliberate optimisation; however, the ongoing reorganisation of daily practices may facilitate the formation of new habits and the effectiveness of goal-setting, self-monitoring and implementation intentions in guiding emerging travel routines.

Taken together, the socio-demographic and academic profile of the RP sample delineates a population whose everyday mobility is deeply embedded in institutionalised temporal structures and recurrent organisational constraints. This configuration is particularly conducive to the stabilisation of habitual travel practices and constitutes a critical boundary condition for any process of voluntary behavioural change.

In analytical terms, baseline mobility at University of Milano-Bicocca must therefore be interpreted as behaviour formed under high structural anchoring, where the scope for change is conditioned not only by transport supply, but by the limited flexibility inherent in students' daily life organisation. This diagnosis provides an essential foundation for interpreting subsequent evidence on modal choice, intermodality, and responsiveness to MaaS-enabled interventions.

Importantly, the RP data indicate that these practices are not only socially and institutionally anchored, but also structurally stable over time. As shown in Table 30, average one-way commuting distance and travel time remain remarkably consistent across survey waves conducted in different years. Mean commuting distance oscillates between approximately 33 and 36 kilometers, while average travel time remains close to one hour per trip.

Table 30 Average commuting distance and travel time of students

<i>Year</i>	<i>Avg. distance (km)</i>	<i>Avg. travel time (min)</i>
2016	32.8	58.0
2020	36.3	56.2
2023	33.8	62.4

Source 39 author's elaboration based on RP sampling data

From an analytical perspective, this stability is highly significant, particularly because the figures refer to three independent surveys conducted in different years (2016, 2020, 2023) on distinct student samples. The observed convergence therefore does not reflect the persistence of individual

trajectories, but the reproduction of structurally similar mobility configurations across cohorts. In other words, despite changes in student composition, external conditions, and broader mobility contexts, the spatial and temporal burden of commuting remains effectively unchanged.

This pattern strongly suggests that everyday mobility among University of Milano Bicocca students is not characterised by progressive optimisation, experimentation, or gradual adjustment, but by long-standing configurations linking residential location, transport infrastructure, and institutional schedules. Baseline behaviour thus reflects consolidated responses to a stable opportunity structure rather than weakly anchored, transient, or opportunistic choices.

This finding has direct implications for the interpretation of behavioural change. First, it implies that any observed deviation from baseline patterns cannot be plausibly attributed to random fluctuation or short-term variability, but must be assessed against a background of deeply entrenched commuting arrangements. Second, it reinforces the analytical relevance of interventions that operate on organisational, cognitive, and informational dimensions of mobility choice, such as coordination, reliability, predictability, and perceived usability of existing options, rather than on infrastructural transformation or residential relocation, which lie largely outside the feasible scope of short- to medium-term behavioural change.

In this sense, the socio-demographic and academic anchoring of mobility practices identified in this section does not merely contextualise subsequent analyses, but defines a demanding analytical baseline against which empirical evidence on behavioural response, adaptation, and resistance to change must be interpreted.

While the socio-demographic and academic profile of the RP sample clarifies the temporal and institutional anchoring of everyday mobility practices, it does not yet explain how these practices are spatially organised within the metropolitan system. To fully characterise baseline mobility patterns, it is therefore necessary to shift the analytical focus from who travels and under which constraints to from where mobility originates and along which spatial structures it is channelled.

Given the marked stability of commuting distances and travel times observed across survey waves, spatial organisation emerges as a critical explanatory dimension. Long-standing residential locations, combined with rigid academic schedules, imply that daily mobility is not the outcome of short-term optimisation, but the expression of structurally embedded spatial relations between origins, transport corridors, and campus locations.

For this reason, the analysis now turns to the spatial anchoring of baseline mobility, examining the geographic distribution of trip origins and the main access corridors to the Milano-Bicocca and Monza campuses. Using trip origins maps, shortest-path network analyses, and frequency-weighted flow representations, this step makes it possible to visualise how institutionalised routines materialise in space, and to distinguish between contexts characterised by dispersed catchment areas and those reliant on a more limited and rigid set of access routes.

This spatial perspective provides a necessary bridge between the socio-demographic anchoring of behaviour and the subsequent analysis of modal choices. By revealing the structure of mobility basins and dominant corridors, it establishes the spatial boundary conditions within which modal decisions and intermodal combinations take place, and against which the feasibility of voluntary behavioural change must be assessed.

Spatial structure of commuting flows and territorial anchoring

Building on the socio-demographic and temporal anchoring of everyday mobility practices outlined in the previous section, this block shifts the analytical focus to the spatial organisation of baseline mobility. The objective is not to map travel behaviour per se, but to identify how commuting routines are territorially structured, how mobility basins are formed, and to what extent access to the Milano-Bicocca and Monza campuses relies on dispersed catchment areas or on a limited set of dominant corridors.

From an analytical perspective, spatial organisation constitutes a critical layer of the baseline diagnosis. Given the observed stability of commuting distances and travel times, daily mobility cannot be interpreted as the outcome of short-term optimisation or flexible adjustment. Rather, it reflects long-standing spatial relations between residential locations, transport infrastructures, and campus destinations. These relations define the opportunity structure within which individual modal choices are made and routines are reproduced, thereby constraining the range of behaviourally feasible alternatives prior to any intervention.

To capture this dimension, the analysis combines origin-based mapping with network-based flow representations. Geographic distributions of trip origins are used to delineate the effective mobility basins associated with the Milano-Bicocca and Monza campuses, while shortest-path and frequency-weighted network analyses make visible the spatial concentration of flows, the degree of corridor dependence, and the presence, or absence, of redundancy in access routes. Read together, these representations allow baseline mobility to be interpreted not as a collection of individual trips, but as a structured spatial configuration characterised by varying degrees of dispersion, concentration, and rigidity.

A comparative perspective between the Milano-Bicocca and Monza campuses is central to this analysis. Although both campuses are embedded within the same metropolitan mobility system, their spatial anchoring differs substantially in terms of catchment scale, corridor structure, and reliance on specific access routes. These differences are analytically relevant because they shape the margin of manoeuvre available to users, conditioning not only current modal choices but also the potential responsiveness to interventions acting on the choice context rather than on transport supply.

In this sense, the spatial analysis developed in this block does not aim to explain mobility behaviour through spatial factors alone. Instead, it establishes the spatial boundary conditions within which

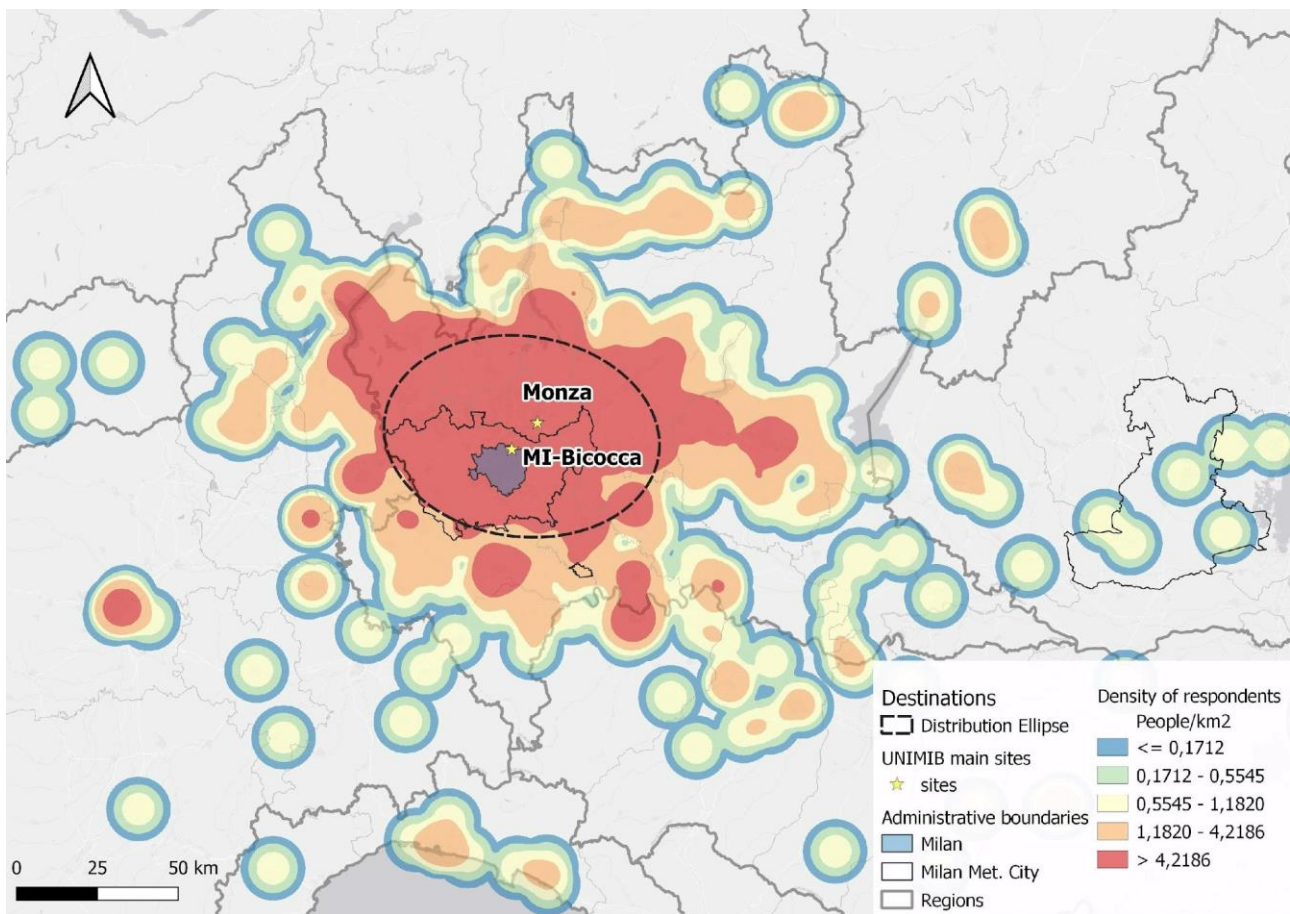
baseline mobility practices are formed and stabilised. By making visible the geography of origins and the structure of dominant access corridors, it provides the necessary foundation for the subsequent examination of modal shares, intermodality, and perceived constraints, ensuring that these dimensions are interpreted as situated responses to a given spatial configuration, rather than as abstract expressions of individual preference.

The revealed preference data enable the spatial structure of university-related mobility to be analysed by explicitly linking individual trip origins to campus destinations within the metropolitan and regional context. In this perspective, spatial analysis operates not as a descriptive or illustrative exercise, but as an analytical device to uncover the structural conditions under which everyday mobility decisions are formed, routinised, and reproduced over time.

Rather than treating commuting as a collection of individual trajectories, the analysis reconstructs mobility as a system of recurrent spatial relations between residential locations, transport corridors, and institutional destinations. These relations define mobility basins and dominant access structures, which in turn delimit the set of behaviourally feasible options available to users prior to any behavioural or organisational intervention.

The first level of analysis therefore considers the overall mobility basin associated with the University of Milano-Bicocca, jointly examining the Milano-Bicocca and Monza campuses. This system-level perspective makes it possible to identify the combined spatial reach of university-related mobility, to distinguish between proximal and long-distance origin patterns, and to assess the degree to which commuting demand is dispersed across the metropolitan territory or concentrated along specific regional axes. By doing so, it establishes a common spatial frame against which campus-specific differences can subsequently be interpreted.

Figure 10 Overall mobility basin of students (Milano-Bicocca and Monza campuses)



Source 40 MOST, Spoke-8, WP1, elaboration based on RP sampling data

The spatial distribution of trip origins reveals a highly asymmetric and polycentric mobility basin (Figure 10). While a strong concentration of origins is observed within the Milan metropolitan area, the basin clearly extends well beyond the core city, incorporating large portions of Lombardy and several provincial capitals. This configuration confirms that university-related mobility is structurally embedded in medium- and long-distance commuting patterns, rather than being confined to local or neighbourhood-scale movements. From an analytical perspective, this implies that everyday mobility to the university is shaped by spatial relations that are largely fixed prior to individual travel decisions, reflecting long-term residential choices and regional accessibility structures rather than short-term optimisation.

The substantial overlap between the Milano-Bicocca and Monza catchments further indicates that the two campuses operate within a single, integrated mobility system rather than as functionally independent attractors. Although they differ in scale and accessibility configuration, both campuses draw from a shared metropolitan and regional pool of origins, reinforcing the interpretation of University of Milano-Bicocca-related mobility as a system-level phenomenon embedded in the wider Lombardy urban region.

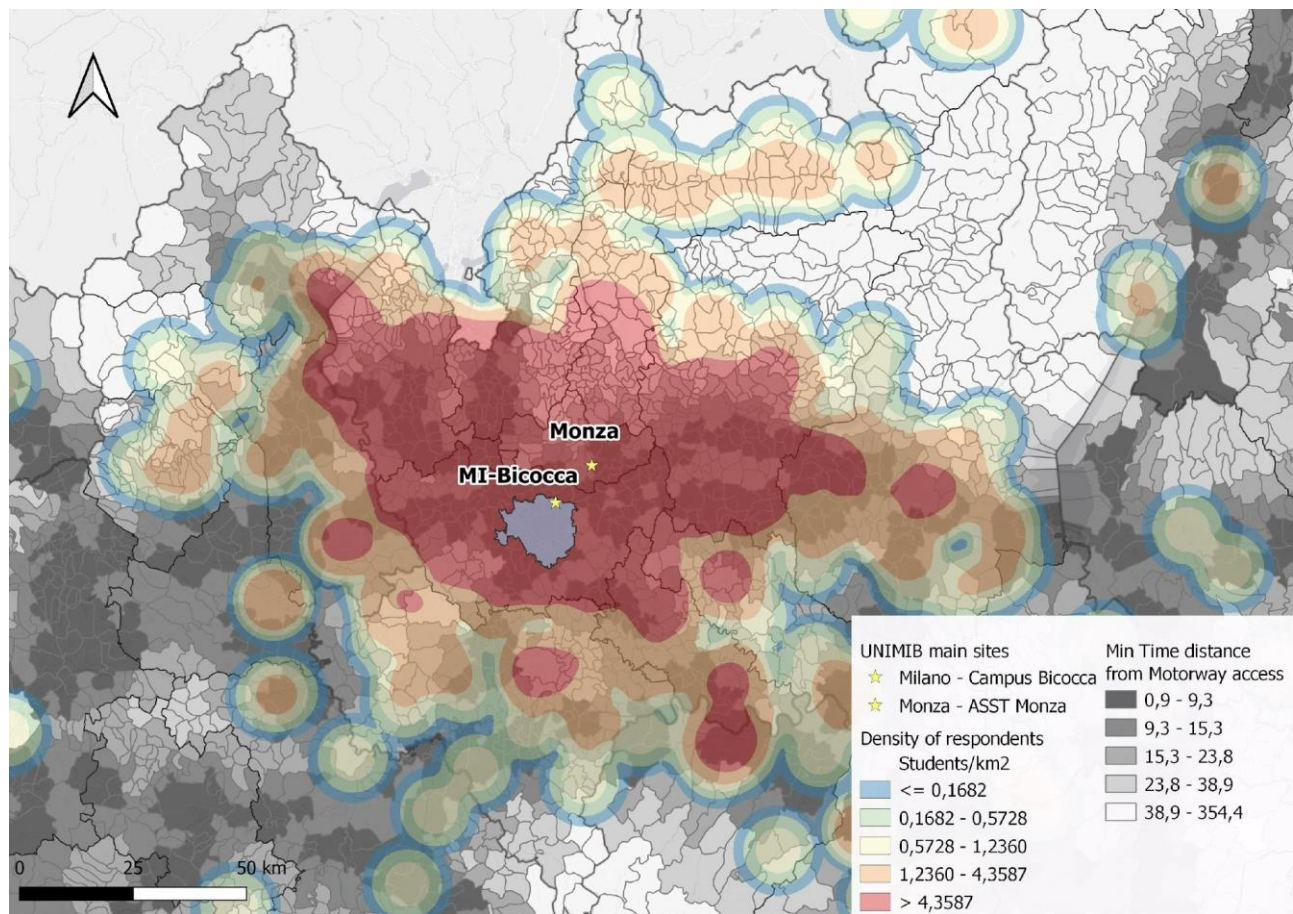
Within this common basin, however, the two campuses exhibit markedly different spatial logics. For the Milano-Bicocca campus, origins are distributed across multiple spatial scales. A substantial share of trips originates within the city of Milan itself and in the immediately adjacent municipalities of Monza, Sesto San Giovanni, and Cinisello Balsamo, which are functionally integrated with the Bicocca district. Beyond this inner belt, a second layer of origins emerges along the main metropolitan and regional corridors, including the provincial capitals of Bergamo, Lecco, Como, Varese, and Brescia, all directly connected through the regional rail system. Additional clusters of origins are observed in the northern and eastern sectors of the Milan conurbation and along radial metropolitan axes served by high-capacity public transport, such as the M2 corridor towards Gorgonzola, the Milan–Brescia railway towards Treviglio, and the Milan–Novara and Milan–Varese rail lines. With the exception of the most distant polarities, the majority of origins remain concentrated within a radius of approximately 15–20 km from the Milano campus, confirming the coexistence of metropolitan proximity and regional reach within a highly articulated catchment structure.

By contrast, the Monza campus displays a more compact and spatially concentrated mobility basin. Origins are largely confined to the municipality of Monza and neighbouring areas, particularly along the Milan–Monza–Seregno–Saronno railway axis. Most commuting trips originate within approximately 10 km from the campus, although a limited number of longer-distance origins, such as Lecco, Bergamo, Brescia, and Varese, are also present. Compared to Milano-Bicocca, the Monza basin is characterised by lower spatial dispersion but stronger alignment along a restricted set of regional directions. This configuration implies a different form of structural rigidity: fewer origins translate into a stronger dependence on a limited number of access corridors and a narrower set of viable travel options, particularly for last-mile connections.

Crucially, these spatial patterns cannot be interpreted independently of the broader accessibility conditions of the metropolitan transport system discussed in context analysis. While the structural characteristics of public transport supply, intermodal integration, and network hierarchy are examined in the previous chapter, the present spatial analysis focuses on how territorial accessibility differentials intersect with the geography of origins.

This relationship is explored explicitly in Figure 11, which relates the spatial distribution of commuting origins to minimum travel time from motorway access points. Rather than representing the full structure of the transport system, the map provides a synthetic indicator of territorial accessibility, highlighting differences in ease of access to the metropolitan mobility network across space. In analytical terms, this allows spatial dispersion and corridor dependence to be interpreted not merely as descriptive features, but as boundary conditions that interact with accessibility gradients to shape everyday mobility practices.

Figure 11 Overall mobility basin of students and accessibility (Milano-Bicocca and Monza campuses)



Source 41 MOST, Spoke-8, WP1, elaboration based on RP sampling data

Read analytically, this representation reinforces the distinction, established in the context analysis, between aggregate accessibility and effective behavioural accessibility. Although many origins are located within areas that are formally accessible in terms of network proximity, accessibility becomes uneven once territorial position, access effort, and reliance on specific corridors are taken into account. Areas characterised by shorter access times to the motorway network tend to align more closely with dominant commuting corridors, while more peripheral or interstitial zones experience longer access times and reduced flexibility in route choice.

The spatial coincidence between high-density origin areas and zones of relatively low access time highlights the structural coupling between residential location and specific access axes, rather than a uniform integration into the metropolitan transport system. Conversely, origins located in areas with higher access times, even when included within the broader mobility basin, are more likely to depend on indirect routes, additional transfers, or less reliable access sequences. This pattern reinforces the interpretation of accessibility as a relational and conditional property, shaped by territorial position and network access conditions rather than by transport supply alone.

From a behavioural perspective, these territorial accessibility differentials have direct implications for feasibility. Sustainable mobility options are not evenly distributed across space, but are selectively

enabled or constrained depending on the alignment between residential location, access to major mobility corridors, and campus destinations. As a result, mobility choices are pre-structured by spatial and territorial conditions that delimit the range of realistically viable alternatives for different groups of users, well before individual preferences or attitudinal factors enter into play.

To synthesise these spatial differences, Table 31 summarises the dominant origin typologies associated with each campus. Rather than providing an exhaustive classification of residential locations, these typologies capture the prevailing spatial logic through which commuting patterns are organised. As such, they function as an interpretative device that links the geography of origins to the structure of mobility basins and to the constraints shaping behavioural feasibility, offering a concise lens through which the subsequent flow and modal analyses can be read.

Table 31 Dominant origin typologies of Milano-Bicocca and Monza campuses

<i>Campus</i>	<i>Dominant origin typologies</i>
<i>Milano-Bicocca</i>	City + metropolitan belt + Lombardy provincial capitals
<i>Monza</i>	Monza-Brianza corridor + Milan + selective long-distance poles

Source 42 author's elaboration based on RP sampling data

This typological distinction is analytically significant because it reflects two distinct configurations of structural constraint shaping baseline mobility within the same metropolitan system.

For the Milano-Bicocca campus, the coexistence of urban, metropolitan, and regional origins generates a highly dispersed mobility basin anchored to a limited number of high-capacity corridors. In principle, spatial dispersion expands the set of potentially available modal combinations; in practice, it produces a travel environment in which access is strongly mediated by network hierarchy, corridor alignment, and intermodal coordination. Structural constraint therefore takes the form of corridor dependence combined with elevated organisational and cognitive demands, particularly where daily routines require reliable connections across multiple spatial scales.

In contrast, the Monza campus exhibits a more compact and corridor-based origin structure. Lower spatial dispersion reduces the number of distinct directional flows, but simultaneously increases dependence on a restricted set of access routes and transfer-dependent sequences, especially where last-mile connectivity is required. In this configuration, structural rigidity arises less from choice overload than from limited redundancy: fewer viable access chains imply higher sensitivity to disruptions and narrower margins for adaptive reconfiguration of everyday mobility practices.

Having established these differentiated basin logics, the analysis moves from the geography of origins to the networked organisation of mobility demand. While basin structures indicate where commuting demand is generated and how spatial dispersion or concentration is configured, they do not yet reveal how this demand is channelled, constrained, and stabilised by the topology and hierarchy of

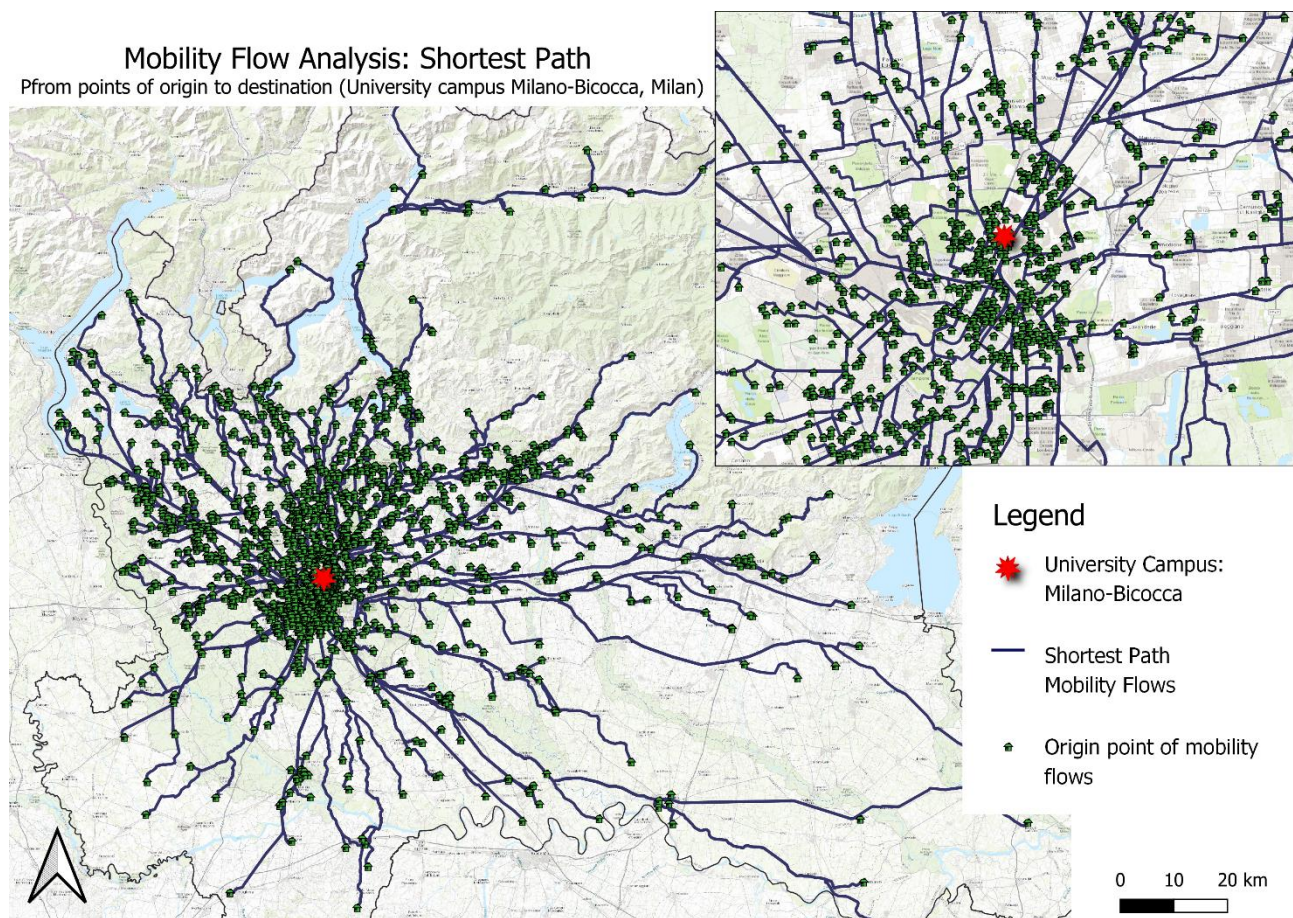
the transport system. To address this analytical gap, the focus now shifts to the organisation of revealed mobility flows within the multi-infrastructure transport network.

The purpose of the flow analysis is therefore not to reconstruct individual route choices or to infer behavioural optimisation at the trip level. Rather, it aims to make visible the structural channeling of demand induced by network topology, hierarchy, and intermodal connectivity across road, rail, and metropolitan transit systems. In this sense, flows are analysed as emergent properties of the interaction between spatially anchored demand and infrastructural structure, rather than as the outcome of individual decision-making alone.

Two complementary representations are adopted. First, shortest-path analysis, used as a network-based benchmark, translates observed origin–destination relations into the most direct network connections and highlights the corridors and nodes through which mobility is structurally likely to concentrate. Second, a frequency-weighted representation aggregates these paths by road and rail segment usage, making visible the segments that repeatedly concentrate flows and therefore operate as structural bottlenecks or critical connectors. Both analyses are conducted separately for the Milano-Bicocca and Monza campuses, allowing a comparative assessment of how different basin structures are translated into corridor concentration, redundancy, and network reliance.

The shortest-path and frequency-weighted flow maps are computed on a multi-layer transport network including road infrastructure, regional and suburban railways, and metropolitan rapid transit lines. The resulting patterns capture network-induced concentration and corridor dependence, rather than behavioural optimisation at the individual level.

Figure 12 Shortest-path mobility flows to Milano-Bicocca campus



Source 43 author's elaboration on RP sampling data

For the Milano-Bicocca campus (Figure 12), shortest-path flows exhibit a pronounced radial configuration converging toward the campus area, closely aligned with the primary metropolitan access corridors across road and rail-based infrastructures. While origins are widely dispersed across the metropolitan and regional basin, paths rapidly concentrate along a limited number of structurally dominant routes. This pattern reflects both the central position of the campus within the metropolitan system and the hierarchical organisation of the transport network, which channels heterogeneous origin–destination relations into a small set of high-capacity axes.

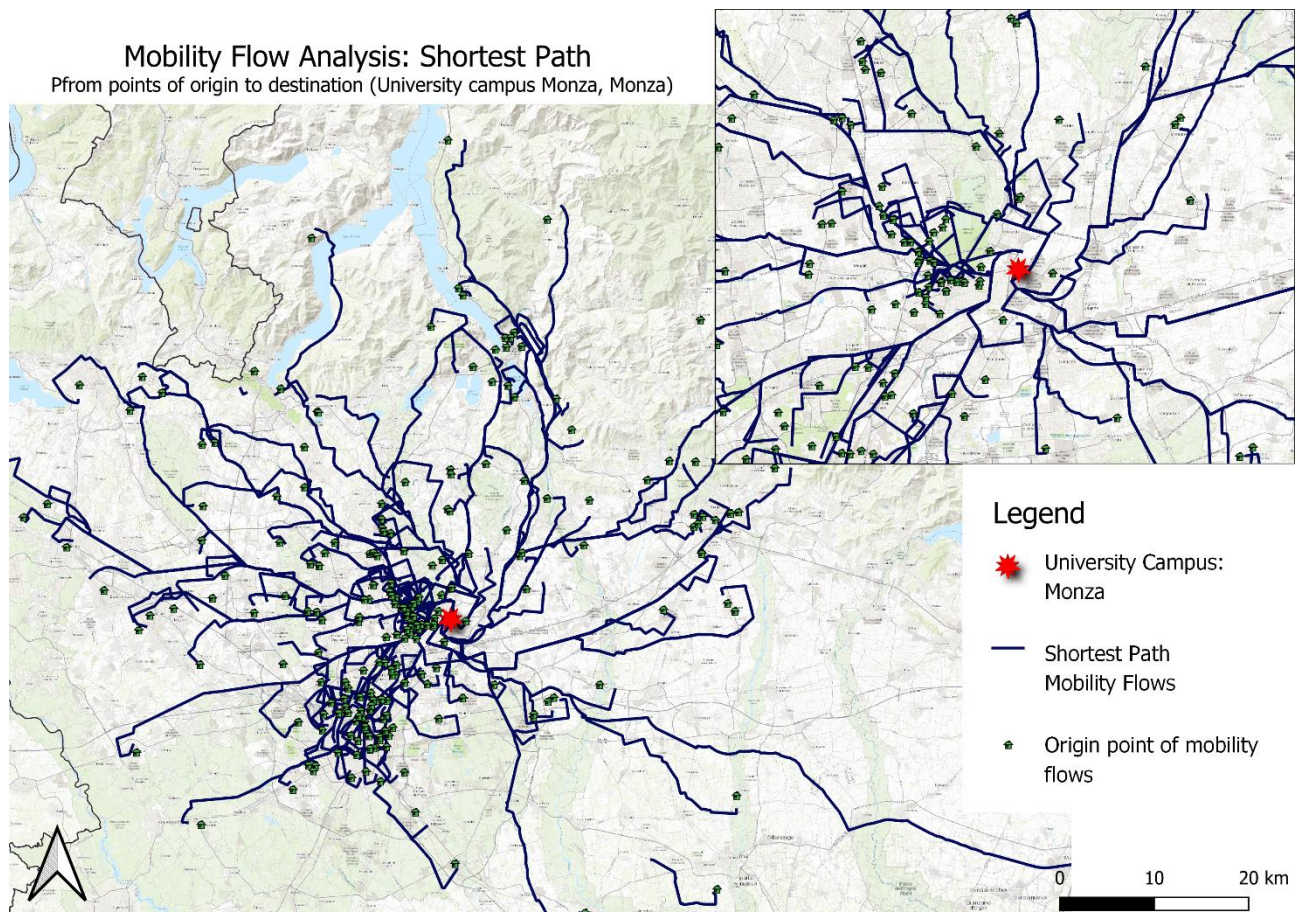
Importantly, this spatial dispersion produces diversity primarily at the level of the first mile. Residential heterogeneity shapes how users initially access the transport system, through different local feeders, access modes, or neighbourhood-level connections, but this diversity is rapidly reabsorbed once trips enter the main network. Beyond the initial access stage, mobility paths converge onto the same dominant corridors, compressing heterogeneous origin conditions into a shared downstream travel experience.

From a behavioural perspective, this strong corridor concentration implies that everyday mobility is shaped by collective structural constraints affecting large portions of the commuting population simultaneously. Exposure to common bottlenecks, capacity limits, and reliability conditions along

these axes favours the stabilisation of routinised access patterns and limits the behavioural feasibility of route diversification or adaptive reconfiguration, even in the presence of multiple theoretical modal options. Behavioural flexibility is therefore constrained not by lack of choice at origin, but by the rapid standardisation of travel conditions imposed by network hierarchy.

A different configuration emerges for the Monza campus (Figure 13).

Figure 13 Shortest-path mobility flows to Monza campus



Source 44 author's elaboration on RP sampling data

Shortest-path flows display a compact and strongly corridor-dependent structure, with origins clustering within a relatively limited spatial radius and paths aligning along a small number of dominant regional access directions. Compared to the Milano-Bicocca campus, overall spatial dispersion is lower, but network convergence is sharper, indicating that access is structured around a restricted set of infrastructural axes rather than distributed across multiple alternative corridors.

This pattern reveals a fundamentally different spatial logic. Whereas the Milano-Bicocca campus absorbs heterogeneous origins into shared high-capacity corridors after an initial phase of local diversification, the Monza campus exhibits limited diversification even at the early stages of the trip. Both origin distribution and network structure reinforce each other in producing a narrow set of viable access paths, reducing spatial redundancy from the outset (Figure 13).

Flows align predominantly along the Milan–Monza–Seregno–Saronno corridor, complemented by a small number of secondary regional directions, while transversal connections remain weak or fragmented. This configuration reflects the peripheral position of the campus within the metropolitan system and its structural reliance on intermodal sequences linking regional rail services to local access modes. Access to the campus is therefore less a matter of navigating a complex network than of successfully reproducing a specific and tightly coupled sequence of connections.

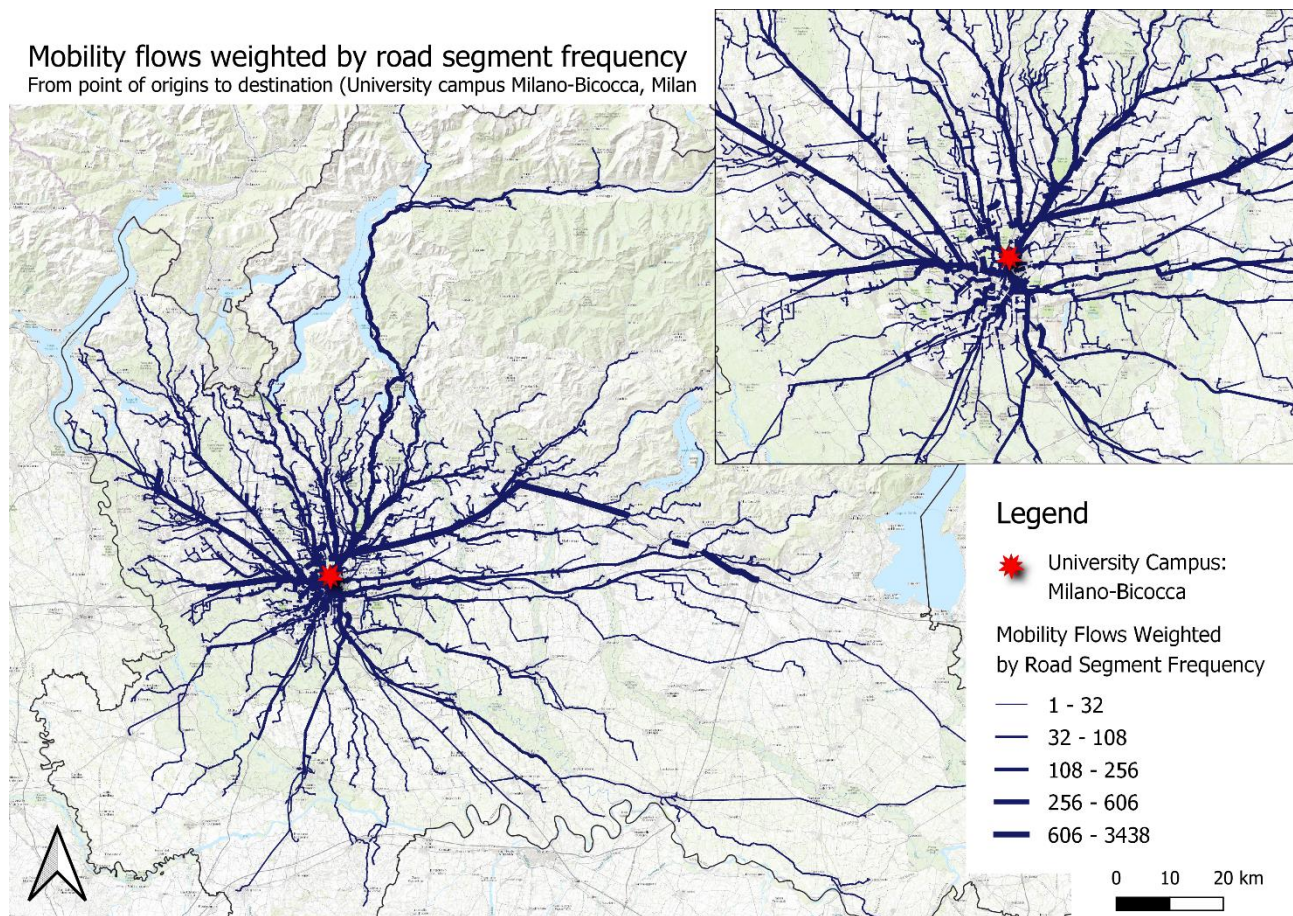
From a behavioural perspective, this spatial structure generates a distinct form of rigidity. Reduced dispersion may simplify route choice cognitively, but the limited redundancy of access corridors and intermodal sequences increases sensitivity to disruptions, transfer reliability, and last-mile conditions. Behavioural feasibility in this context is constrained less by choice overload and more by path dependency: the continuity and coordination of a narrow set of viable access chains become critical for the reproduction of everyday mobility routines.

As a result, adaptive experimentation is constrained not by complexity, but by scarcity. Fewer alternative routes and limited flexibility in access sequences reduce the scope for incremental behavioural adjustment, reinforcing stable, compensatory, and strongly path-dependent commuting practices, particularly in contexts where public transport unreliability or last-mile friction is perceived as high.

Moving from shortest-path to frequency-weighted flows shifts the analytical focus from structural possibility to structural reliance. While the shortest-path logic shows how the network could channel demand under minimum-cost connections, the weighted representation reveals which segments become recurrently indispensable once the entire basin of observed origins is projected onto the same infrastructural hierarchy. By weighting network segments according to how often they are traversed across individual trips, this approach reveals how spatial dependence is translated into effective concentration in practice, highlighting path dependence, bottlenecks, and the infrastructural segments on which the functioning of the system is most heavily relied. In other words, it operationalises the transition from corridor dependence as a geometric property to corridor criticality as a systemic condition shaping everyday behavioural feasibility.

Against this backdrop, the frequency-weighted flow map for the Milano-Bicocca campus provides a direct diagnostic of how dispersed commuting demand is translated into concentrated reliance on a limited set of metropolitan and regional corridors (Figure 14).

Figure 14 Frequency-weighted mobility flows to Milano-Bicocca campus



Source 45 author's elaboration based on RP sampling data

The frequency-weighted flow representation for the Milano-Bicocca campus reveals a pronounced hierarchical structuring of mobility within the metropolitan and regional network. While origins are spatially dispersed across a wide catchment area, actual movement concentrates disproportionately along a limited number of network segments, which emerge as dominant conduits of university-related mobility.

Compared to the shortest-path representation, this map highlights not merely where flows could occur, but where they are systematically reproduced in practice. A small subset of radial and tangential corridors, largely corresponding to high-capacity metropolitan and regional infrastructures, absorbs a substantial share of total movements, revealing strong path dependence in the organisation of everyday access.

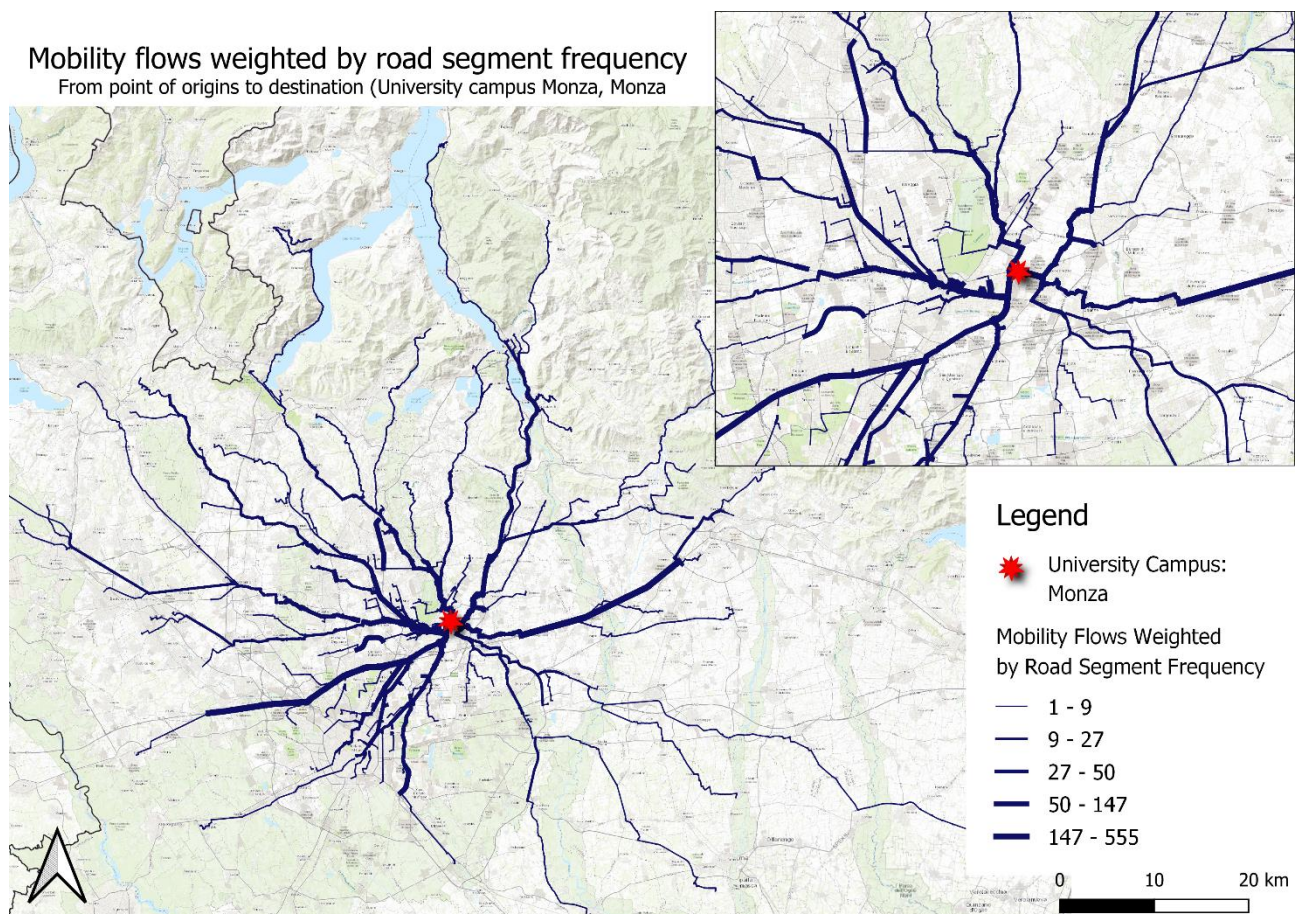
Analytically, this pattern points to a condition of systemic exposure: although the mobility basin is extensive, the effective functioning of daily university access depends on the performance of a restricted set of infrastructural elements. Disruptions, congestion, or reliability issues affecting these segments are therefore likely to propagate widely, impacting users with otherwise heterogeneous origins and trip structures.

From a behavioural perspective, the frequency-weighted flows suggest that route stabilisation is not merely an individual response to complexity, but a collective outcome produced by the interaction between dispersed demand and network hierarchy. Even in a context characterised by high modal availability and dense transport supply, repeated convergence onto the same corridors compresses behavioural margins for route diversification and adaptive reconfiguration.

In this sense, the Milano-Bicocca mobility system combines spatial dispersion at the origin level with functional concentration at the network level. This configuration expands the nominal set of accessible options while simultaneously constraining behavioural feasibility through shared exposure to congestion, coordination demands, and cumulative vulnerability along critical infrastructural axes.

A similar but more constrained pattern is observed for the Monza campus (Figure 15).

Figure 15 Frequency-weighted mobility flows to Monza campus



Source 46 author's elaboration based on RP sampling data

The frequency-weighted flow map reveals an even stronger concentration of movements along a limited set of network segments compared to the Milano-Bicocca campus. Although the overall mobility basin is more compact, the effective organisation of flows is highly corridor-dependent, with a small number of access routes absorbing a disproportionate share of total movements.

The most heavily weighted segments align closely with the main road and rail corridors connecting Monza to Milan and to the western and northern parts of the Brianza area. In contrast to the Milano campus, where multiple high-capacity axes coexist and partially overlap, the Monza campus exhibits a more polarised spatial structure, characterised by fewer dominant paths and markedly lower network redundancy.

Analytically, this configuration points to a distinct form of structural rigidity. Reduced spatial dispersion of origins does not translate into greater flexibility; instead, it intensifies dependence on specific corridors and junctions. Effective accessibility is therefore highly sensitive to disruptions, congestion, or inefficiencies affecting these key segments, with limited opportunities for rerouting or adaptive reconfiguration within the surrounding network.

From a behavioural perspective, the frequency-weighted flows suggest that routine stabilisation for Monza-based commuters is driven less by complexity-induced inertia and more by necessity. The scarcity of alternative high-quality routes reinforces repetitive use of the same access paths, compressing behavioural margins for adjustment and increasing the salience of last-mile conditions, transfer reliability, and mode continuity.

Compared to Milano-Bicocca, where systemic exposure emerges from the interaction between dispersed demand and network hierarchy, the Monza campus displays a more tightly constrained configuration in which compactness, limited redundancy, and corridor dependence jointly restrict behavioural adaptability. In this context, spatial compactness operates not as a source of resilience, but as a reinforcing mechanism of structural lock-in, shaping mobility behaviour through necessity rather than through choice.

Read comparatively, the frequency-weighted flow analyses identify two distinct morphologies of structural constraint shaping baseline mobility behaviour. In both cases, university-related mobility depends disproportionately on a restricted subset of network segments, but the mechanisms through which constraint is produced differ fundamentally.

For the Milano-Bicocca campus, constraint emerges from the interaction between high spatial dispersion of origins and strong convergence along a limited number of metropolitan and regional corridors. This configuration generates systemic exposure to congestion and reliability issues while simultaneously sustaining elevated organisational and cognitive complexity associated with multimodal travel chains. Behavioural rigidity here is not driven by lack of options, but by the cumulative effort required to navigate, coordinate, and stabilise complex access sequences.

For the Monza campus, constraint takes a more concentrated and scarcity-driven form. Lower spatial dispersion is coupled with pronounced corridor dependence and limited network redundancy, producing a mobility structure that is narrower, more polarised, and highly sensitive to disruptions. Behavioural feasibility is tightly bound to a small number of viable access routes and last-mile connections, reducing margins for adaptation and reinforcing path-dependent routines.

What differentiates the two campuses is therefore not the presence of structural constraint, but its morphology: diffuse and complexity-driven in Milano, concentrated and rigidity-driven in Monza. This distinction is analytically crucial, as it implies that behavioural stability arises through different mechanisms and that the scope for voluntary adjustment is shaped by qualitatively different forms of constraint within the same metropolitan system.

Taken together, the spatial basin analysis and the network-based flow representations establish the structural boundary conditions within which everyday mobility to the University of Milano-Bicocca campuses takes place. They show that baseline mobility is not characterised by free recombination of origins and routes, but by highly regularised patterns shaped by long-standing spatial relations, corridor dependence, and network hierarchies.

Importantly, these patterns constrain the scope of feasible behavioural change in analytically precise ways. Where mobility is organised around a limited number of dominant corridors and repeatedly used network segments, behavioural adjustment is restricted not only by infrastructure availability, but by exposure to congestion, transfer reliability, and the cumulative cognitive and organisational effort required to reconfigure established routines. In VTBC terms, perceived behavioural control is therefore bounded less by attitudinal resistance than by the anticipated costs and risks associated with deviation from stabilised practices.

This interpretation has direct implications for behaviour-oriented and MaaS-based interventions. Rather than aiming to alter spatial structures or redistribute demand, dimensions that remain largely fixed in the short to medium term, interventions can plausibly act only on the margins of this system, by reducing organisational friction, improving reliability across intermodal chains, enhancing the legibility of available options, and lowering the non-material costs of coordination embedded in everyday travel.

The baseline spatial organisation of mobility thus operates as a selective filter: it delineates which behavioural changes are structurally implausible, which are conditionally feasible, and which may emerge only where complexity, uncertainty, and rigidity can be meaningfully reduced. This framework provides the necessary foundation for interpreting the modal patterns analysed in the following section, ensuring that observed choices are read as situated responses to constrained opportunity structures rather than as abstract expressions of individual preference.

Modal structure of revealed behaviour

The spatial analyses developed in the preceding section establish that university-related mobility at University of Milano-Bicocca is produced within a highly structured opportunity space, defined by differentiated mobility basins, strong corridor dependence, and uneven accessibility conditions. However, spatial configuration alone does not explain how these constraints are enacted in everyday

practice. What remains analytically decisive is how such structural conditions are translated into stable, reproducible patterns of behaviour.

This section therefore examines the modal structure of revealed behaviour as the behavioural articulation of the spatial and systemic constraints identified above. Modal choices are not approached as isolated or preference-driven decisions, but as the operational form through which spatial anchoring, network hierarchy, and institutional temporalities are rendered actionable in daily mobility routines. In this sense, modal structure constitutes the point at which abstract accessibility conditions become concrete behavioural commitments.

From a Voluntary Travel Behaviour Change (VTBC) perspective, analysing modal structure serves as a diagnostic function rather than a descriptive one. Revealed modal shares do not simply indicate what modes are used, but which mobility options are behaviourally feasible under conditions of long commuting distances, rigid schedules, intermodal dependence, and cumulative organisational effort. Persistence of dominant modes should therefore be interpreted as the outcome of bounded optimisation within a constrained feasibility space, rather than as inertia, resistance, or lack of motivation.

Accordingly, this chapter treats modal split, intermodality, and the role of specific modes not as separate analytical dimensions, but as interrelated components of a single behavioural configuration. Examined jointly, they allow baseline mobility to be conceptualised as a stabilised behavioural equilibrium, shaped by structural constraints, perceived behavioural control, and the need to minimise uncertainty and coordination costs.

By framing modal behaviour in this way, the analysis establishes a critical baseline against which subsequent behavioural responses can be meaningfully interpreted. Any observed change, or absence of change, in later phases must be read not as a direct expression of altered preferences, but as an adjustment occurring within, or constrained by, this pre-existing modal equilibrium. This provides the necessary analytical foundation for evaluating the scope, limits, and selectivity of MaaS-enabled and VTBC-oriented interventions.

Table 32 reports on the overall modal split for students, classified according to the main transport mode used for the longest portion of the trip. This operational definition is analytically relevant, as it captures the mode that structurally anchors the journey, even when trips are embedded within broader intermodal chains.

Table 32 Main transport mode

<i>Aggregate transport mode</i>	<i>2016</i>	<i>2020</i>	<i>2023</i>
<i>Train</i>	56.0%	56.0%	51.3%
<i>Local public transport</i>	24.7%	26.6%	26.9%
<i>Public transport (total)</i>	80.7%	82.6%	78.2%
<i>Car / motorcycle</i>	13.3%	12.4%	14.3%
<i>Active mobility</i>	6.0%	5.0%	7.5%

Source 47 author's elaboration based on RP sampling data

The observed modal structure confirms the structural centrality of rail-based mobility in university-related travel. Across all survey waves, train and suburban rail services consistently account for the majority of trips, with local public transport modes (metro, tram, and bus) playing a substantial complementary role. Taken together, public transport represents nearly four-fifths of all reported journeys in each wave, underscoring the dominant role of collective transport within the baseline mobility configuration.

From an analytical perspective, this pattern reflects a mobility system fundamentally anchored to medium- and long-distance commuting and to the availability of high-capacity corridors rather than to short-range, locally optimised travel. Modal choice emerges here not as a flexible or situational decision, but as a structurally embedded response to the spatial organisation of origins and to the positioning of the campuses within the metropolitan and regional rail network. The prevalence of rail-based modes is therefore best interpreted as an outcome of spatial feasibility rather than of modal preference.

Equally significant is the temporal stability of this modal structure. Despite differences in survey years and samples, the relative shares of public transport, car-based mobility, and active modes remain remarkably consistent. This stability indicates that baseline mobility is not characterised by progressive modal transition or experimentation, but by a consolidated equilibrium in which existing modes continue to satisfy minimum requirements of reliability, predictability, and temporal compatibility with institutional schedules.

Car and motorcycle use, while secondary in aggregate terms, remains persistently present across all waves. This persistence suggests that private motorised mobility functions not as a dominant alternative to public transport, but as a structurally embedded residual option, likely activated where public transport fails to meet specific feasibility thresholds related to travel time, last-mile access, or schedule coordination. Active mobility, by contrast, appears marginal as a main mode, reflecting the combined effect of long commuting distances and the limited capacity of walking and cycling to function as primary modes within a predominantly regional mobility basin.

Taken together, the aggregate modal split delineates a baseline behavioural configuration characterised by high public transport dependence, selective car use, and limited scope for fully active commuting. Crucially, this configuration should not be read as a transitional state open to

spontaneous rebalancing, but as a stabilised outcome of spatial anchoring, infrastructural hierarchy, and institutional constraint. As such, it provides a demanding reference point against which subsequent analyses of intermodality, compensatory mode use, and behavioural feasibility must be interpreted.

The aggregate modal split provides a useful overview of baseline mobility patterns, but it risks obscuring structurally important differences across campus contexts. As the analysis of accessibility conditions and commuting flows has shown, the Milano-Bicocca and Monza campuses are embedded within the same metropolitan mobility system but operate under markedly different spatial, infrastructural, and intermodal constraints.

From an analytical perspective, it is therefore necessary to disaggregate modal choices by campus in order to assess whether and how these contextual differences are translated into concrete travel decisions. Disaggregating the modal split allows baseline behaviour to be interpreted not as a homogeneous outcome, but as a set of campus-specific adaptations to differentiated conditions of accessibility, corridor dependence, and behavioural feasibility.

Disaggregating modal split by campus reveals important structural differences.

Table 33 Main transport mode by campus

<i>Aggregate transport mode</i>	<i>Milano-Bicocca campus</i>	<i>Monza campus</i>
<i>Train</i>	51.3%	20.5%
<i>Local public transport</i>	29.3%	13.9%
<i>Public transport (total)</i>	<i>80.6%</i>	<i>33.9%</i>
<i>Car / Motorcycle</i>	10.2%	48.0%
<i>Active mobility</i>	9.2%	17.6%

Source 48 author's elaboration based on RP sampling data

Table 33 reports the main transport mode by campus, highlighting pronounced divergences in baseline mobility behaviour between the Milano-Bicocca and Monza campuses.

The Milano-Bicocca campus exhibits a very strong reliance on public transport, with rail-based modes alone accounting for over half of all trips and public transport overall exceeding 80% of the modal split. This configuration is fully consistent with the campus's integration into the metropolitan and regional rail network and with the highly dispersed spatial structure of origins identified in the previous section. Local public transport plays a substantial complementary role, enabling first- and last-mile access within a dense urban environment and supporting complex intermodal chains. Behaviourally, this pattern reflects a context in which sustainable modes are structurally dominant, but where feasibility is shaped by intermodality, coordination costs, and exposure to congestion rather than by modal scarcity.

By contrast, the Monza campus displays a sharply different modal equilibrium. Car and motorcycle use account for nearly half of all trips, while public transport, despite the presence of strong regional rail connections, plays a much more limited role as the main mode. Active mobility also assumes greater relative importance, although within a context characterised by short local movements rather than full-trip substitution. This modal structure reflects the campus's distance from the railway station and its reliance on transfer-based access, in which last-mile discontinuities and limited redundancy reduce the behavioural attractiveness of public transport as a standalone solution. In this context, private motorised mobility and the university shuttle function as compensatory modes, enabling predictability, autonomy, and control where public transport integration is incomplete.

Analytically, these contrasts confirm that modal split is not the outcome of individual preference alone, but the expression of campus-specific accessibility conditions and spatial constraints. In Milano-Bicocca, high modal density expands theoretical choice but increases organisational complexity, reinforcing public transport dominance within stabilised routines. In Monza, fewer access routes reduce complexity but simultaneously narrow the set of behaviourally feasible alternatives, increasing reliance on compensatory modes. Modal structure thus emerges as a context-dependent adaptation to differentiated forms of structural constraint rather than as a neutral indicator of modal preference.

Importantly, these campus-specific modal equilibria mask a substantially higher level of behavioural complexity once intermodality is taken into account. While the main mode captures the dominant backbone of commuting, it does not reflect the full organisational effort required to complete everyday trips, particularly in contexts characterised by transfer dependence, first- and last-mile discontinuities, and corridor-based access. To fully assess behavioural feasibility at baseline, it is therefore necessary to move beyond primary modal choice and examine how additional modes are combined within daily travel chains.

Table 34 reports the additional transport modes used alongside the declared main mode. The values do not represent exclusive modal shares; rather, each percentage expresses the likelihood that a given mode is incorporated as an additional component within a single commuting trip. As multiple complementary modes may be involved in the same trip chain, percentages do not sum to 100%.

Analytically, this representation shifts attention away from dominant modes toward the organisational architecture of everyday mobility. Instead of focusing on what mode is chosen for the longest segment, it reveals how commuting trips are assembled as sequences of interconnected stages that must be coordinated in space and time. In this sense, additional modes operate as indicators of behavioural effort, making visible the degree to which baseline mobility relies on intermodality rather than on self-contained modal solutions.

Table 34 Additional transport modes used in combination with the main mode

<i>Additional means used</i>	<i>Total student n (%)</i>	<i>Milano-Bicocca campus n (%)</i>	<i>Monza campus n (%)</i>
<i>No additional means</i>	320 (12.0%)	271 (11.0%)	38 (19.4%)
<i>On foot (≥ 5 minutes)</i>	1172 (44.0%)	1091 (44.2%)	63 (32.1%)
<i>Active mobility (bike, bike sharing, micromobility)</i>	118 (4.4%)	99 (4.0%)	14 (7.1%)
<i>Car / motorcycle</i>	734 (27.5%)	687 (27.8%)	34 (17.3%)
<i>Local public transport</i>	1106 (41.5%)	1005 (40.7%)	92 (46.9%)
<i>Train</i>	306 (11.5%)	274 (11.1%)	25 (12.8%)

Source 49 author's elaboration based on RP sampling data

At the aggregate level, the first critical result is that strictly monomodal commuting is relatively rare. Only a small minority of students report no additional means, while the large majority combine the main mode with at least one complementary component. Walking for at least five minutes emerges as the most widespread additional element, underscoring the structural importance of access and egress stages. Walking thus appears not as a discretionary or lifestyle-driven choice, but as a necessary connective layer enabling the functioning of the overall trip.

More generally, the distribution of additional modes points to a high density of intermodality embedded in everyday mobility. Local public transport, private motorised modes, and rail services all appear frequently as complementary components, indicating that commuting is commonly structured as a multi-stage chain rather than as a single-mode journey. This confirms that baseline mobility is organisationally complex, even before considering potential behavioural change.

However, as already observed for the main modal split, the aggregate picture masks important campus-specific differences. Disaggregating the use of additional modes by campus is therefore analytically necessary, as the Milano-Bicocca and Monza campuses operate under distinct accessibility configurations and spatial constraints.

For the Milano-Bicocca campus, the use of additional modes is characterised by very high levels of walking and local public transport integration. This reflects the dense urban environment and the high degree of intermodal overlap documented in the context and flow analyses. The high incidence of walking as an additional component of the trip chain is consistent with the spatial accessibility conditions identified in the context analysis. As shown earlier, the majority of academic buildings are located within a radius of approximately 2 km from the Milano Greco-Pirelli railway station, a distance that is behaviourally compatible with walking and cycling as routine first- and last-mile solutions.

This spatial configuration structurally favours the integration of active mobility within rail-based commuting patterns, not as a substitute for high-capacity public transport, but as a connective layer enabling effective access to the campus from metropolitan and regional corridors. Walking therefore

emerges as a systemic component of intermodality rather than as a marginal or discretionary choice, reinforcing the interpretation of baseline mobility as inherently hybrid and segment-based.

From a behavioural perspective, this proximity reduces physical access barriers while simultaneously increasing the organisational relevance of active modes within complex trip chains. Active mobility at Milano-Bicocca thus functions as a stabilising element within highly multimodal routines, supporting access continuity while simultaneously anchoring routines to specific spatial and temporal sequences, and contributing to the cumulative effort that characterises everyday travel in a dense and intermodal urban environment.

Here, intermodality is driven primarily by complexity: a wide range of services and access points expands potential choice, but requires frequent transfers and careful coordination. Additional modes thus function as mandatory connectors within extended and transfer-dependent trip chains, increasing organisational and cognitive load even in a highly supplied environment.

By contrast, the Monza campus exhibits a different intermodal profile. A higher share of students reports no additional means, while the use of local public transport and rail as complementary components remains substantial but is organised around a smaller number of access sequences. Active mobility appears as an additional element in a non-negligible share of trips, but its role is more selective and strongly conditioned by last-mile constraints.

As highlighted in the context analysis, the main university and hospital buildings are located at distances exceeding 2 km from the Monza railway station, beyond thresholds that are routinely walkable for most users. This spatial separation limits the capacity of active mobility to function as a generalised first- or last-mile connector for rail-based commuting. Instead, walking and cycling operate in a more conditional and segmented manner, often in combination with local public transport or institutional shuttle services rather than autonomous connectors.

In this configuration, active mobility does not stabilise intermodality through proximity, as observed at the Milano-Bicocca campus, but functions as a compensatory and situational element within transfer-dependent trip chains. Intermodality at Monza is therefore less pervasive but more functionally critical: fewer viable access sequences increase dependence on specific combinations of rail, bus, shuttle, and occasional active segments. This pattern is consistent with the compact and corridor-dependent accessibility structure of Monza, where behavioural feasibility is constrained not by complexity saturation, but by spatial discontinuity and limited redundancy in last-mile access.

From a behavioural perspective, these differences delineate two distinct intermodal regimes characterised by different sources of behavioural effort.

At the Milano-Bicocca campus, behavioural effort arises primarily from complexity saturation. A wide range of modes and access options are formally available, but their effective use requires the coordination of multiple services, schedules, and interfaces. Stable routines therefore emerge as a

necessary strategy to manage cognitive load, timing uncertainty, and transfer reliability within dense and highly intermodal trip chains.

At the Monza campus, by contrast, behavioural effort stems from structural scarcity and spatial discontinuity. Fewer viable access chains, greater distance from the railway station, and dependence on specific intermodal sequences concentrate behavioural risk on a limited set of connectors. Here, routines are stabilised not to cope with choice overload, but to minimise exposure to last-mile uncertainty and disruption within narrowly defined access paths.

In both contexts, the configuration of additional modes reveals that baseline mobility operates close to a behavioural feasibility threshold. Routines are stabilised not by modal preference or attitudinal resistance, but by the need to manage cumulative effort, uncertainty, and the fragility of interdependent trip components.

In VTBC terms, behavioural inertia therefore emerges as a rational coping strategy within an already demanding mobility system. Any change to a single element of the trip chain risks destabilising the overall configuration unless compensatory adjustments are simultaneously available. Accordingly, the effectiveness of MaaS-based interventions depends less on expanding nominal choice and more on their capacity to stabilise, simplify, and de-risk existing intermodal practices, particularly at points of transfer, last-mile connection, and service coordination.

At this stage, the analysis is conducted on the aggregate student population. Although important campus-specific differences have emerged in previous sections, a further disaggregation of additional modes by both main transport mode and campus is not analytically robust due to the limited sample size associated with the Monza campus. The following results should therefore be interpreted as capturing the structural logic of intermodality at the system level, rather than campus-specific behavioural regimes.

This pattern becomes even clearer when additional modes are analysed in relation to the main transport mode. Values represent the probability that a given additional mode is used in combination with the declared main transport mode. Percentages do not sum to 100% within columns, as multiple additional modes may be involved within the same trip chain. Table 35 therefore captures the structure of intermodal coordination rather than modal substitution.

Table 35 Additional modes by main transport mode

<i>Additional mode used</i>	<i>Active mobility</i>	<i>Car / Motorcycle</i>	<i>Local public transport</i>	<i>Train</i>
<i>No additional means</i>	36%	42%	7%	5%
<i>On foot (≥ 5 minutes)</i>	13%	20%	54%	56%
<i>Bicycle</i>	5%	5%	3%	4%
<i>Bike sharing</i>	1%	1%	0%	0%
<i>Micromobility</i>	1%	0%	0%	0%
<i>Motorcycle / scooter</i>	1%	2%	0%	1%
<i>Car as driver</i>	8%	7%	7%	30%
<i>Car as passenger</i>	4%	4%	5%	13%
<i>Urban bus</i>	20%	8%	15%	12%
<i>Extra-urban bus</i>	1%	2%	7%	5%
<i>University shuttle</i>	2%	2%	1%	2%
<i>Tram / trolleybus</i>	8%	3%	16%	3%
<i>Subway / light rail</i>	13%	13%	15%	23%
<i>Train</i>	19%	20%	19%	5%
<i>Other</i>	0%	0%	1%	0%

Source 50 author's elaboration based on RP sampling data

Train-based trips show the highest degree of multimodality, with extensive reliance on walking and local public transport for access and distribution. This reflects the spatial logic of rail-based commuting and the necessity of coordinating services across multiple scales. Car-based trips exhibit lower, but still significant, levels of modal combination, indicating that even behaviours commonly perceived as monomodal are frequently embedded within broader intermodal practices.

The prevalence of intermodality is further corroborated by the distribution of transfers reported in Table 36. Nearly 80% of students perform at least one transfer during their commuting trip, and more than one third are required to coordinate two or more transfers. This confirms that baseline mobility is not organised around direct or linear trajectories, but around multi-stage trip chains that require repeated transitions between modes, services, and network layers.

Table 36 Number of transfers per trip

<i>Number of transfers</i>	<i>Share of trips</i>
<i>0 transfers</i>	20.5%
<i>1 transfer</i>	45.2%
<i>2 transfers</i>	24.5%
<i>3 or more transfers</i>	9.6%

Source 51 author's elaboration based on RP sampling data

From a behavioural perspective, the number of transfers represents a critical indicator of organisational and cognitive load. Each transfer introduces additional requirements in terms of timing precision, spatial orientation, reliability assessment, and contingency management. As transfers

accumulate, so does the exposure to uncertainty and disruption, increasing the perceived cost of deviating from established routines. Under such conditions, behavioural feasibility is shaped less by the nominal availability of alternatives and more by the ability to reliably reproduce complex sequences under everyday constraints.

In this sense, the high incidence of transfers helps explain the strong routinisation observed in baseline mobility patterns. Stable travel practices emerge not because they minimise effort in absolute terms, but because they provide predictability within an already demanding intermodal environment. Spontaneous experimentation or incremental reconfiguration of trips becomes behaviourally costly, as any change to one segment risks destabilising the coordination of the entire chain.

Analytically, the transfer distribution therefore reinforces the interpretation of baseline mobility as operating close to a behavioural feasibility threshold. The observed persistence of established practices should be understood as an adaptive response to cumulative coordination demands, rather than as inertia or resistance to change. This insight is central for interpreting subsequent evidence on perceived obstacles and for assessing the realistic scope of interventions aimed at modifying the choice context rather than the underlying transport supply.

An additional and analytically decisive layer emerges when revealed behaviour contrasts with perceived availability. As shown in Table 37, rail-based modes (train and metro/light rail) are perceived as the most widely available options, in line with their dominant role in the revealed modal structure. This convergence confirms the centrality of rail accessibility in structuring everyday university-related mobility.

However, the perceived availability of private motorised modes remains substantial despite their more limited use as main modes. Cars, both as driver and as passenger, are perceived as available by a significant share of students, even though they account for a minority of revealed trips. Analytically, this divergence suggests that car-based mobility does not function primarily as a default choice, but as a latent fallback option: a reserve mode that remains cognitively and practically available and can be activated selectively in response to breakdowns, constraints, or excessive effort within intermodal public transport chains.

A similar gap emerges for active and shared mobility. Walking, cycling, micromobility and shared services are perceived as being available by non-negligible proportions of the student population, yet remain marginal as main modes. This discrepancy reinforces a core analytical distinction: formal availability does not coincide with behavioural feasibility. The presence of infrastructure or services is insufficient to generate systematic use when organisational effort, reliability concerns, safety perceptions, and integration costs remain high. In this sense, perceived availability captures the outer boundary of the choice set, while revealed behaviour reflects its behaviourally viable core.

Table 37 Perceived availability of transport modes

<i>Transport mode perceived as available</i>	<i>Share of students</i>
<i>On foot (≥ 5 minutes)</i>	38.7%
<i>Bicycle</i>	14.5%
<i>Bike sharing</i>	8.5%
<i>Skateboard / micromobility</i>	2.0%
<i>Skateboard sharing</i>	6.7%
<i>Motorcycle / scooter</i>	2.4%
<i>Motorcycle / scooter sharing</i>	4.0%
<i>Car as driver</i>	28.3%
<i>Car as passenger</i>	13.3%
<i>Car sharing</i>	6.3%
<i>Urban bus</i>	28.3%
<i>Extra-urban bus</i>	11.9%
<i>University shuttle</i>	3.7%
<i>Tram / trolleybus</i>	17.9%
<i>Subway and light rail</i>	33.9%
<i>Train</i>	40.9%
<i>Ferry boat</i>	0.1%
<i>Funicular</i>	0.1%
<i>Other</i>	1.7%

Source 52 author's elaboration based on RP sampling data

Taken together, modal split, intermodality, transfer intensity, and perceived availability converge toward a coherent interpretation of baseline mobility at university of Milano-Bicocca. University-related travel is structurally multimodal, strongly rail-oriented, and embedded in complex, transfer-dependent trip chains. Behaviour unfolds within a context characterised by elevated organisational effort, limited redundancy, and constrained flexibility, rather than by modal scarcity or lack of sustainable options.

These characteristics define a demanding baseline for voluntary behavioural change. They indicate that interventions cannot plausibly operate by expanding nominal choice or promoting modal substitution in the abstract. Instead, any realistic scope for change lies in addressing the organisation, coordination, legibility, and reliability of existing intermodal practices. From this perspective, the baseline does not reflect a deficit of sustainable behaviour, but a condition of structurally constrained sustainability, within which MaaS-enabled solutions may reduce friction and perceived risk without fundamentally altering entrenched spatial and infrastructural relations.

More broadly, the revealed preference evidence delineates a mobility system that is dense rather than deficient. Everyday mobility at University of Milano-Bicocca emerges as highly routinised, spatially anchored, and organisationally demanding. Long commuting distances, strong dependence on rail-based accessibility, systematic intermodality, and frequent transfers are not residual features, but constitutive elements of the baseline condition.

Analytically, this configuration challenges simplified interpretations of travel behaviour based on individual preference, awareness, or attitudinal resistance. Modal choices observed in the RP data are best understood as adaptive responses to a complex opportunity structure, in which feasibility is shaped by spatial dispersion, corridor dependence, and the cumulative effort required to coordinate multiple services. Behavioural stability, in this sense, does not signal resistance to change, but the rational consolidation of routines under conditions of high organisational cost and limited redundancy.

Crucially, the coexistence of high perceived availability and selective revealed use exposes the structural gap between accessibility in principle and accessibility in practice. While many transport modes are technically available, only a subset is behaviourally viable within the constraints of time, reliability, transfer burden, and cognitive effort. This gap constitutes a central structural constraint on voluntary behavioural change, limiting the scope for spontaneous adaptation and reinforcing the persistence of established travel patterns even in highly supplied environments.

The baseline reconstructed through RP data therefore defines a behaviourally demanding starting point. It delineates the boundary conditions within which any behavioural response must occur, distinguishing between dimensions of mobility that are structurally locked in and those that remain conditionally malleable. In this context, the potential for change does not reside in shifting aggregate modal shares, but in intervening on the non-material costs of mobility (coordination effort, uncertainty, and perceived behavioural risk) embedded in everyday intermodal chains.

By making visible the spatial, modal, and organisational architecture of everyday mobility, this baseline analysis establishes a rigorous empirical reference frame. It ensures that subsequent evidence on behavioural responses, preferences, and stated intentions is interpreted not as abstract attitudinal variation, but as situated behaviour unfolding within a tightly constrained and structurally differentiated mobility system.

Baseline mobility as structurally constrained sustainability

This section does not introduce new empirical evidence. Rather, it integrates the results of the revealed preference analyses into a coherent diagnostic interpretation of baseline mobility, consolidating the socio-demographic, spatial, network-based, and modal findings into a unified analytical frame. Its purpose is to clarify the structural conditions under which everyday mobility behaviour at the University of Milano-Bicocca is formed, stabilised, and reproduced, and to define the boundary conditions within which any voluntary behavioural change can realistically occur.

Taken together, the revealed preference evidence analysed in this section defines baseline mobility at the University of Milano-Bicocca as a structurally anchored and behaviourally demanding system, rather than as a collection of loosely coordinated individual choices. Socio-demographic

characteristics, spatial organisation of origins, network-based flow structures, and modal configurations converge toward a consistent interpretation: everyday mobility is shaped by long-standing institutional, spatial, and infrastructural constraints that precede and delimit individual decision-making.

The stability of commuting distances and travel times over time confirms that baseline behaviour is not characterised by incremental optimisation or spontaneous experimentation, but by consolidated adaptations to a given opportunity structure. Residential locations, academic schedules, and accessibility hierarchies jointly lock individuals into recurrent mobility arrangements, within which choice is exercised primarily at the margins rather than through radical reconfiguration. In this sense, behavioural stability does not signal inertia or resistance per se, but reflects rational accommodation to persistent structural conditions.

Spatial analyses further reinforce this interpretation. Dispersed and polycentric mobility basins, combined with strong corridor dependence and limited route redundancy, translate spatial anchoring into concrete movement patterns along the transport network. Whether through highly concentrated radial flows toward the Milano-Bicocca campus or more corridor-bound access to the Monza campus, revealed mobility is characterised by structural path dependency and exposure to shared reliability constraints. These spatial configurations reduce the scope for adaptive re-routing and amplify the consequences of congestion, disruption, or transfer failure for large segments of the commuting population.

Modal evidence does not contradict this picture, but deepens it. The dominance of rail-based modes, the systematic reliance on intermodality, and the high incidence of transfers indicate that sustainable mobility is already embedded in everyday practice, yet under conditions of elevated organisational and cognitive effort. Behavioural feasibility is therefore not constrained by the absence of sustainable options, but by the complexity, fragility, and coordination costs associated with their routine use. Everyday mobility emerges as environmentally oriented but operationally demanding.

The contrast between revealed behaviour and perceived availability of transport modes is particularly revealing in this respect. While multiple transport options are formally available within the system, only a subset proves behaviourally viable on a routine basis. This gap underscores the analytical distinction between accessibility as system provision and accessibility as effective behavioural control, highlighting why the presence of infrastructure or services alone is insufficient to induce sustained behavioural change.

In analytical terms, baseline mobility at university di Milano-Bicocca can thus be understood as a condition of structurally constrained sustainability. Behavioural change is neither absent nor implausible, but inherently selective, bounded, and contingent upon interventions capable of reducing non-material costs, such as uncertainty, fragmentation, and cognitive burden, rather than simply expanding transport supply. Within this framework, the potential leverage of MaaS-enabled

solutions lies not in substituting dominant modes, but in stabilising, simplifying, and de-risking existing intermodal practices.

Crucially, this diagnosis reframes how subsequent evidence on perceived obstacles and motivations should be interpreted. Reported barriers and drivers of mobility choice are not external explanations layered onto otherwise flexible behaviour, but subjective articulations of underlying structural constraints that already shape feasibility and routine formation. Understanding these perceptions therefore requires situating them within the constrained opportunity structure reconstructed through the revealed preference analysis.

By consolidating the spatial, modal, and organisational architecture of everyday mobility, this baseline diagnosis establishes a rigorous empirical and conceptual reference frame. It ensures that subsequent analyses of stated preferences, perceived constraints, and MaaS-related behavioural responses are interpreted not as abstract expressions of individual willingness to change, but as situated responses unfolding within a tightly constrained and structurally differentiated mobility system.

Perceived constraints vs motivational drivers: interpreting behavioural feasibility

Building on the spatial and modal analyses presented in the previous sections, this subsection advances the baseline diagnosis by explicitly confronting what motivates observed mobility choices with what constrains them in everyday practice. The aim is not to introduce a new explanatory layer detached from revealed behaviour, but to complete the baseline interpretation by examining how structural conditions are perceived, evaluated, and internalised by users.

Rather than treating motivations and obstacles as separate or competing explanations, the analysis adopts a behavioural feasibility perspective, in which travel behaviour is understood as the outcome of a continuous negotiation between enabling drivers and constraining conditions embedded in the mobility system. Accordingly, the focus is not on explaining behaviour through individual preferences, but on reconstructing the boundary conditions within which preferences can become behaviourally operative under everyday constraints.

In line with Voluntary Travel Behaviour Change (VTBC) theory, motivations are not interpreted as abstract or freely expressed preferences, nor obstacles as isolated or contingent frictions. Instead, both are conceptualised as context-dependent signals that reflect how individuals adapt to structural constraints, institutional arrangements, and accessibility configurations when forming and stabilising daily mobility routines. Perceived motivations and obstacles thus provide insight into the subjective articulation of feasibility, effort, and control within an already demanding mobility environment.

Importantly, this perspective allows perceived constraints to be read not simply as barriers to change, but as indicators of where behavioural flexibility is structurally limited and where it may still exist.

Similarly, motivations are interpreted not as latent desires awaiting activation, but as conditional drivers whose behavioural relevance depends on the degree to which organisational effort, uncertainty, and coordination costs can be managed within existing routines.

The joint analysis of motivations and perceived obstacles therefore enables baseline mobility behaviour to be interpreted not merely as a distribution of modes or routes, but as a bounded optimisation process, operating within clearly defined structural and cognitive limits. This perspective is essential for assessing whether, where, and through which mechanisms voluntary behavioural change toward more sustainable mobility can plausibly occur, and for evaluating the realistic scope of MaaS-enabled interventions that act on the choice context rather than on transport supply itself.

Table 38 Reasons for main mode choice

<i>Reason for choosing main mode</i>	<i>All students n (%)</i>	<i>Milano campus n (%)</i>	<i>Monza campus n (%)</i>
<i>Travel time</i>	1,097 (41.1%)	1,020 (41.3%)	77 (39.3%)
<i>Cost-effectiveness</i>	911 (34.2%)	855 (34.6%)	56 (28.6%)
<i>Lack of viable alternatives</i>	876 (32.9%)	809 (32.8%)	67 (34.2%)
<i>Less stressful alternative</i>	787 (29.5%)	731 (29.6%)	56 (28.6%)
<i>Autonomy of movement</i>	560 (21.0%)	494 (20.0%)	66 (33.7%)
<i>Environmental concern</i>	444 (16.7%)	428 (17.3%)	16 (8.2%)
<i>Comfort</i>	401 (15.0%)	374 (15.1%)	27 (13.8%)
<i>Parking difficulties</i>	201 (7.5%)	187 (7.6%)	14 (7.1%)
<i>Inefficient public service</i>	195 (7.3%)	159 (6.4%)	36 (18.4%)
<i>Safety of transport mode</i>	183 (6.9%)	172 (7.0%)	11 (5.6%)
<i>Personal safety</i>	131 (4.9%)	124 (5.0%)	7 (3.6%)
<i>Health</i>	75 (2.8%)	70 (2.8%)	5 (2.6%)
<i>Lack of cycling paths</i>	63 (2.4%)	62 (2.5%)	1 (0.5%)
<i>Leisure / extra-academic activities</i>	39 (1.5%)	37 (1.5%)	2 (1.0%)
<i>Accompanying people</i>	34 (1.3%)	30 (1.2%)	4 (2.0%)

Source 53 author's elaboration based on RP sampling data

A first analytically salient result emerging from Table 38 is that the dominant motivations for main mode choice are overwhelmingly functional and constraint-oriented, rather than normative or value-driven. Travel time, cost-effectiveness, and lack of viable alternatives consistently rank as the most frequently reported reasons across both campuses, while motivations related to environmental concern, health, or safety remain clearly secondary.

From a behavioural perspective, this distribution should not be interpreted as evidence of weak pro-environmental attitudes or low awareness of sustainability issues. Rather, it reflects a hierarchy of decision criteria shaped by feasibility constraints. In a mobility context characterised by long commuting distances, rigid academic schedules, frequent transfers, and high organisational effort, motivations linked to efficiency, predictability, and effort minimisation systematically dominate over aspirational or ethical considerations. Behaviour is therefore guided less by what individuals would ideally prefer and more by what can be reliably integrated into daily routines.

Particularly revealing is the prominence of lack of viable alternatives, reported by approximately one third of students in both campuses. This item does not signal satisfaction with the chosen mode, nor a positive attachment to it. Instead, it points to a condition of constrained choice, in which behaviour reflects adaptation to a limited and uneven opportunity structure rather than the outcome of active selection among equivalent options. In this sense, reported motivations function less as expressions of intrinsic preference and more as ex post justifications of structurally constrained decisions.

In VTBC terms, this pattern exemplifies a condition of bounded voluntariness. Mobility choices are formally voluntary, but substantively restricted by spatial anchoring, accessibility configurations, and the cumulative effort associated with intermodal coordination. Under such conditions, motivations related to speed, cost, and stress reduction do not operate as independent drivers of behaviour, but as pragmatic criteria for coping with an already demanding mobility system.

The relative marginality of normative motivations, such as environmental concern or health, should therefore be read not as a lack of disposition toward sustainable mobility, but as an indication that normative drivers are subordinated to feasibility considerations. Where the baseline mobility system already operates close to a behavioural feasibility threshold, value-oriented motivations struggle to translate into actual behaviour unless enabling conditions are sufficiently stabilised and simplified.

This interpretation reinforces the analytical distinction between motivation and capacity for action. What Table 38 captures is not simply why students choose a given mode, but how motivations are filtered, reordered, and constrained by the structural conditions reconstructed in the previous sections. This insight provides a critical bridge toward the analysis of perceived obstacles, where these feasibility constraints become explicit and articulated as barriers to alternative behaviours.

A closer inspection of campus-level differences further reinforces this structural interpretation. While the overall hierarchy of motivations is largely consistent across Milano-Bicocca and Monza, their relative salience varies in ways that closely mirror the differentiated accessibility and spatial configurations reconstructed in the context analysis.

At the Milano-Bicocca campus, motivations related to travel time, cost-effectiveness, and lower stress dominate, alongside a comparatively higher incidence of environmental concern. This pattern is consistent with a context of high structural accessibility combined with high organisational complexity. As shown in the previous sections, Milano-Bicocca is embedded within a dense and highly multimodal transport environment, characterised by extensive rail accessibility, multiple overlapping services, and frequent intermodal transitions. In such a setting, behavioural constraints arise less from the absence of alternatives and more from the effort required to coordinate them. Consequently, motivations reflect a need to manage complexity efficiently rather than to compensate for outright scarcity. Environmental concern, while still secondary, is more likely to surface as a relevant driver precisely because basic feasibility conditions are relatively satisfied.

By contrast, the Monza campus displays a distinct motivational profile that reflects a more structurally constrained accessibility regime. Here, autonomy of movement and inefficiency of public services emerge as comparatively more salient motivations, while environmental concern plays a noticeably weaker role. This configuration aligns with the campus's peripheral position within the metropolitan system and its reliance on transfer-dependent access from the railway station to the campus and hospital district. As documented in the context analysis, the distance between the Monza railway station and the main university buildings exceeds typical walking thresholds for a significant share of users, increasing dependence on buses, shuttles, or private motorised modes.

In this context, autonomy functions as a compensatory motivation. It reflects the value attributed to modes, particularly private cars, that reduce dependence on fragile intermodal sequences and mitigate uncertainty associated with last-mile connectivity. Similarly, the higher salience of inefficient public service does not simply express dissatisfaction, but signals the structural vulnerability of access chains that rely on a limited set of connections with low redundancy. Behavioural choice in Monza is therefore shaped less by complexity overload and more by structural scarcity and reliability concerns, which systematically privilege modes offering greater control over timing and routing.

These campus-specific differences confirm that motivations cannot be interpreted independently of structural context. The same motivational category, such as autonomy, efficiency, or stress reduction, takes on different behavioural meanings depending on whether individuals operate in an environment of dense but complex supply (Milano-Bicocca) or in one characterised by narrower access corridors and transfer dependence (Monza). In both cases, motivations act as context-sensitive signals of feasibility, revealing how individuals adapt to distinct configurations of constraint rather than expressing stable or universal preferences.

From a VTBC perspective, this finding is analytically crucial. Where feasibility constraints differ, the same behavioural intervention may encounter fundamentally different motivational logics and limits. Recognising these differentiated motivational–structural alignments is therefore essential for assessing the realistic scope of voluntary behavioural change and for designing MaaS-enabled interventions that respond to context-specific constraints rather than abstract behavioural ideals.

From a behavioural feasibility perspective, motivations therefore cannot be fully understood without simultaneously examining the obstacles that students perceive in their everyday travel. While motivations indicate why a given mode is selected within a constrained choice set, perceived obstacles reveal how structural and systemic frictions are experienced at the level of daily practice. Together, they form two sides of the same behavioural process: motivations reflect the optimisation criteria adopted under constraint, while obstacles make explicit the limiting conditions that shape and bound such optimisation.

This analytical shift is central to VTBC-oriented interpretation. Obstacles are not treated here as exogenous barriers acting on otherwise unconstrained behaviour, but as integral components of the

behavioural environment within which routines are formed and stabilised. Examining perceived obstacles therefore allows the baseline mobility system to be read from the perspective of lived feasibility, highlighting which elements of the transport system generate friction, uncertainty, and effort, and how these elements interact with the motivations previously identified.

For this reason, the analysis now turns to perceived obstacles to mobility, with the aim of clarifying the concrete sources of behavioural constraint that underpin the functional motivations observed above and delimit the scope for voluntary behavioural change toward more sustainable practices.

Table 39 Perceived obstacles to commuting

<i>Perceived obstacle</i>	<i>All students n (%)</i>	<i>Milano campus n (%)</i>	<i>Monza campus n (%)</i>
<i>Poor punctuality of public transport</i>	1,385 (52.0%)	1,288 (52.1%)	88 (44.9%)
<i>Excessive overcrowding of public transport</i>	1,059 (39.7%)	1,002 (40.6%)	57 (29.1%)
<i>High travel expenses</i>	540 (20.3%)	497 (20.1%)	43 (21.9%)
<i>Traffic congestion</i>	508 (19.1%)	434 (17.6%)	74 (37.8%)
<i>Poor travel comfort</i>	420 (15.8%)	396 (16.0%)	24 (12.2%)
<i>Difficulty finding parking</i>	215 (8.1%)	159 (6.4%)	56 (28.6%)
<i>Lack of safe cycling paths</i>	82 (3.1%)	72 (2.9%)	10 (5.1%)
<i>High parking costs</i>	62 (2.3%)	56 (2.3%)	6 (3.1%)
<i>Poor security of bicycle racks</i>	50 (1.9%)	48 (1.9%)	2 (1.0%)
<i>Lack of bicycle parking spaces</i>	46 (1.7%)	42 (1.7%)	4 (2.0%)
<i>Presence of physical barriers</i>	28 (1.1%)	26 (1.1%)	2 (1.0%)
<i>No difficulties</i>	151 (5.7%)	141 (5.7%)	10 (5.1%)

Source 54 author's elaboration based on RP sampling data

The obstacle profile reported in Table 39 reinforces and sharpens the interpretation developed in the previous sections by making explicit the constraint structure within which baseline mobility behaviour is produced. The predominance of poor punctuality and overcrowding of public transport, followed by high travel expenses and congestion-related difficulties, delineates a mobility environment characterised by systemic and recurrent frictions, rather than by occasional or situational disruptions. These obstacles represent persistent features of everyday commuting conditions and therefore operate as background constraints shaping behaviour over time.

Crucially, the configuration of perceived obstacles closely mirrors the hierarchy of motivations identified above. This correspondence is analytically significant. Travel time minimisation, stress reduction, and cost-effectiveness emerge as dominant motivations precisely because reliability deficits, overcrowding, and congestion constitute structurally embedded sources of uncertainty and effort within daily travel chains. In this sense, motivations and obstacles cannot be treated as independent explanatory layers. Motivations express the optimisation criteria adopted under constraint, while obstacles reveal the structure of those constraints. Behaviour thus reflects bounded optimisation rather than unconstrained preference.

The fact that only a very small minority of students report no difficulties at all further reinforces this reading. Baseline mobility operates under conditions of permanent friction, not episodic disruption. From a behavioural perspective, this implies that observed routines are stabilised not because they are optimal in absolute terms, but because they represent the least fragile configurations within a system characterised by limited reliability and high coordination demands. Stability, in this context, is a defensive property rather than an aspirational one.

Campus-level differentiation further clarifies how distinct constraint regimes shape behavioural outcomes.

At the Milano-Bicocca campus, motivations are dominated by travel time, cost-effectiveness, and, more marginally, environmental concern. This pattern reflects the context of high modal availability and dense intermodal overlap, as documented in the accessibility and flow analyses. Here, behavioural constraint arises primarily from complexity saturation. The coexistence of multiple services, transfer points, and access possibilities expands theoretical choice, but generates cumulative organisational and cognitive costs. Obstacles such as poor punctuality and overcrowding therefore function as complexity multipliers, reinforcing reliance on established routines and discouraging experimentation despite high nominal accessibility.

In contrast, the Monza campus exhibits a stronger emphasis on autonomy of movement and lack of viable alternatives, accompanied by a markedly higher salience of traffic congestion and parking-related obstacles. This configuration reflects a structurally different constraint regime, characterised by spatial discontinuity, limited redundancy, and strong dependence on a narrow set of access routes and transfer-dependent sequences. Crucially, this regime is also reinforced by the significantly higher incidence of car-based commuting observed for the Monza campus.

In this context, reliance on the private car functions less as an expression of preference than as an adaptive response to constrained accessibility and weak local integration of high-capacity public transport. However, car-based commuting does not eliminate structural friction; rather, it reconfigures them. Congestion, parking availability, and parking costs emerge as salient obstacles precisely because car use operates within a saturated and spatially constrained access environment. Behavioural rigidity therefore arises less from excessive complexity, as in the Milano case, and more from structural scarcity combined with car dependence, which narrows the set of viable access chains and increases sensitivity to disruption.

Importantly, the relatively marginal role of environmental concern, health, and safety as primary motivations should not be interpreted as indifference toward these dimensions. Rather, it indicates a hierarchy of feasibility. When everyday mobility requires long travel times, multiple transfers, and tight temporal coordination, behavioural priorities systematically shift toward reliability, predictability, and control. Normative and value-based motivations remain behaviourally secondary unless embedded within options that satisfy these foundational functional requirements.

The contrast between perceived availability of transport modes and revealed behaviour further strengthens this interpretation. While trains, metro services, private cars, and even active or shared mobility options are perceived as being available by substantial shares of students, revealed choices remain strongly concentrated on a limited subset of options. This gap underscores the analytical distinction between formal accessibility and effective behavioural accessibility. Constraints related to access effort, transfer reliability, temporal alignment, and cognitive load operate as filtering mechanisms, excluding many theoretically available modes from the set of routinely usable ones.

Taken together, the joint analysis of motivational drivers and perceived obstacles leads to a critical analytical conclusion: baseline mobility behaviour at University of Milano-Bicocca is not characterised by resistance to sustainable mobility, but by structural saturation of constraint. Students do not refrain from adopting alternative or more sustainable modes because of lack of awareness, weak attitudes, or insufficient value alignment. Rather, everyday mobility already operates close to the upper threshold of acceptable effort, uncertainty, and organisational burden.

Under such conditions, behavioural stability emerges as a rational coping strategy in response to systemic fragility, rather than as inertia or conservatism. This diagnosis has direct implications for voluntary behavioural change strategies. Interventions that merely expand formal availability or appeal to normative motivations are unlikely to produce significant effects, as they do not modify the underlying feasibility structure. Conversely, interventions that selectively relieve constraints where motivations already align, by reducing uncertainty, improving coordination, and lowering cognitive and organisational costs, can expand the effective choice set without increasing behavioural burden.

From this perspective, Mobility as a Service should be interpreted not as a tool to reshape preferences, but as a context-enabling mechanism capable of rebalancing the constraint–motivation relationship. Behavioural change, where it occurs, is best understood as a process of re-optimisation under relaxed boundary conditions, rather than as a transformation of values or attitudes.

This section therefore concludes the baseline diagnostic phase of the analysis by identifying the behavioural, contextual, and systemic constraints within which everyday mobility at University of Milano-Bicocca is currently produced. The following phase builds on this diagnosis to assess whether MaaS-based interventions can selectively relax these constraints and enable behavioural reconfiguration without increasing overall effort.

Structural constraints and behavioural feasibility in university mobility: answering RQ1

This section consolidates the baseline diagnostic phase of the analysis and provides an explicit and integrated answer to Research Question 1 (RQ1), which investigates the behavioural, contextual, and

structural conditions that constrain voluntary mobility change among the University of Milano-Bicocca population.

Drawing together the results of the context analysis, spatial and network-based examinations, revealed behavioural patterns, and perceptual evidence on motivations and obstacles, the section moves beyond fragmented interpretations of travel behaviour. Rather than attributing observed mobility choices to individual preferences or attitudinal resistance, it reconstructs everyday mobility as the outcome of structurally constrained decision-making embedded in a complex metropolitan mobility system.

In this perspective, baseline mobility is interpreted as a condition of behavioural feasibility under constraint, in which routines emerge as adaptive responses to persistent spatial, infrastructural, and organisational frictions. The purpose of this concluding synthesis is therefore not merely to summarise empirical findings, but to articulate a coherent analytical diagnosis of the boundary conditions within which voluntary behavioural change is currently possible, implausible, or selectively feasible.

By doing so, this section establishes the conceptual and empirical reference frame against which subsequent analyses of MaaS-related preferences and behavioural responses (RQ2) must be interpreted, ensuring continuity between the diagnostic phase and the intervention-oriented assessment that follows.

Across all analytical dimensions (spatial distribution of origins, network-based flow structures, modal split, intermodality, perceived obstacles, and motivational drivers) everyday mobility emerges as highly stabilised, effort-intensive, and strongly conditioned by external constraints. Behavioural routines are not weakly anchored or opportunistic, but instead reflect long-standing adaptations to persistent frictions related to distance, time, reliability, and coordination. In this sense, baseline mobility does not represent a neutral starting point for change, but a high-cost behavioural equilibrium, already optimised under constrained conditions.

The spatial analysis of origins and flows has shown that University of Milano-Bicocca-related mobility is embedded within medium- and long-distance commuting patterns extending well beyond the metropolitan core. The Milano-Bicocca and Monza campuses operate within a single integrated mobility basin, yet exhibit markedly different spatial logics. The Milano-Bicocca campus is characterised by a highly dispersed catchment area combined with strong dependence on high-capacity metropolitan and regional corridors. This configuration expands formal modal availability but generates elevated organisational and cognitive complexity, particularly through transfer-based access and dense intermodal chains. Behavioural rigidity in this context arises not from scarcity of options, but from cumulative frictions that increase uncertainty and effort.

By contrast, the Monza campus displays a more compact but structurally rigid accessibility configuration. Origins are more concentrated and flows more corridor-dependent, resulting in fewer viable access routes and limited redundancy. Here, behavioural constraint stems less from complexity than from structural discontinuity and restricted choice sets, particularly in relation to last-mile access and dependence on specific modes. These differences demonstrate that behavioural feasibility is campus-specific and deeply shaped by spatial organisation rather than by individual characteristics alone.

Baseline modal patterns further reinforce this interpretation by revealing distinct modal equilibria between the two campuses. While rail-based public transport dominates overall, its behavioural meaning varies substantially across contexts. At the Milano-Bicocca campus, the modal structure is strongly anchored to train and metropolitan public transport, reflecting dense service availability and corridor accessibility. However, this dominance coexists with elevated intermodality and organisational effort, as access and egress stages frequently require multiple transfers and tight temporal coordination.

At the Monza campus, a significantly higher share of car-based commuting is observed. This pattern does not reflect a stronger preference for private vehicles, but rather a structurally induced adaptation to weaker rail integration, spatial discontinuities, and limited last-mile accessibility. In this context, car use functions as a compensatory mode, enabling autonomy, predictability, and time control where public transport alternatives are fragmented or unreliable.

Across both campuses, modal dominance does not imply simplicity. Intermodality is pervasive, with the majority of trips involving one or more transfers and extensive coordination across modes. Even behaviours often perceived as monomodal, such as car use, are frequently embedded within broader intermodal chains that include walking or local public transport. High levels of transfer dependency and organisational effort therefore constitute a defining feature of everyday mobility, reinforcing behavioural inertia and limiting the scope for adaptive experimentation.

Beyond the identification of constraints and patterns, the baseline analysis enables a clear behavioural diagnosis of university-related mobility. Table 40 does not summarise empirical indicators, but synthesises the behavioural diagnosis emerging from the baseline analysis, translating heterogeneous evidence into analytically comparable constraint profiles.

Table 40 Behavioural diagnosis of baseline mobility by campus

<i>Analytical dimension</i>	<i>Milano-Bicocca campus</i>	<i>Monza campus</i>
<i>Spatial structure of origins</i>	Highly dispersed, multi-scalar (urban, metropolitan, regional)	Compact and corridor-based, limited spatial dispersion
<i>Dominant accessibility logic</i>	High-capacity rail and metropolitan corridors	Dependence on a restricted set of access routes
<i>Modal equilibrium</i>	Strong dominance of rail-based public transport	Mixed equilibrium with high share of car-based commuting
<i>Role of private car</i>	Marginal and complementary	Compensatory and enabling (autonomy, reliability)
<i>Degree of intermodality</i>	Very high; multiple transfers common	Moderate but structurally necessary
<i>Main sources of behavioural friction</i>	Intermodal complexity, unreliable transfers, overcrowding	Spatial discontinuity, congestion, parking-related constraints
<i>Dominant motivational drivers</i>	Travel time, cost-effectiveness, stress reduction, environmental concern	Autonomy of movement, lack of viable alternatives, travel time
<i>Nature of behavioural constraint</i>	Complexity-induced (high cognitive and organisational load)	Scarcity-induced (limited redundancy and choice sets)
<i>Behavioural profile (VTBC)</i>	Highly habitual, high-effort, low-flexibility behaviour	Structurally constrained, compensatory, low-redundancy behaviour
<i>Potentially malleable dimensions</i>	Intermodal friction, reliability, coordination costs	Access continuity, integration with public transport, predictability
<i>Non-malleable dimensions</i>	Residential location, commuting distance, rail dependence	Residential location, spatial separation, corridor dependence
<i>Implications for behavioural change</i>	Selective re-optimisation within existing routines	Reduction of structural dependence and compensatory car use

Source 55 author's elaboration

The comparison highlights that behavioural feasibility is constrained through different mechanisms at the two campuses. In analytical terms, behavioural constraint at Milano-Bicocca operates primarily through complexity saturation, whereas at Monza it operates through structural scarcity. Both configurations limit behavioural feasibility, but through fundamentally different mechanisms. This distinction is critical for interpreting subsequent behavioural responses to MaaS-based interventions.

Observed behaviour can be characterised as predominantly habitual, high-effort, and low-flexibility mobility. Travel routines appear to stabilise not primarily through continuous deliberation, but through repeated adaptation to a demanding and fragile system in which deviations from established routines are associated with significant cognitive, organisational, and reliability costs.

From a Voluntary Travel Behaviour Change (VTBC) perspective, this configuration may be interpreted as reflecting behaviour that is structurally habitual rather than attitudinally rigid. In this context, habits seem to be sustained less by strong affective attachment to specific modes, such as private

car use, than by the high perceived risk and effort associated with managing complex and uncertain travel conditions. Behavioural stability thus tends to emerge as a rational coping strategy in the presence of systemic fragility, rather than necessarily as inertia or resistance to change.

Importantly, this diagnosis implies that baseline behaviour is neither fully locked-in nor easily malleable. It occupies an intermediate zone in which change is theoretically possible, but only if interventions reduce effort, uncertainty, and coordination costs rather than add new layers of complexity.

The joint analysis of motivational drivers and perceived obstacles provides a crucial interpretative lens for understanding this configuration. Dominant motivations (travel time, cost-effectiveness, stress reduction, and lack of viable alternatives) are overwhelmingly functional and closely aligned with the most widely reported obstacles, including poor punctuality, overcrowding, congestion, and high travel expenses. Motivations thus emerge not as expressions of aspirational preference, but as rationalisations of constraint.

Differences between campuses further qualify this interpretation. At the Milano-Bicocca campus, motivations related to efficiency and environmental concern coexist with strong perceptions of public transport unreliability, indicating that behavioural stability results from complexity-induced friction rather than ideological resistance. At the Monza campus, greater emphasis on autonomy of movement and lack of alternatives, coupled with higher salience of congestion and parking-related obstacles, points to a constraint regime shaped by spatial scarcity and limited redundancy. In both cases, normative motivations such as environmental concern or health remain secondary unless embedded within options that meet basic requirements of reliability, predictability, and control.

The baseline diagnosis also allows a clear distinction between dimensions of mobility behaviour that are structurally constrained and those that remain potentially malleable within the scope of behaviour-oriented interventions.

Residential location patterns, commuting distances, and dependence on regional rail infrastructure emerge as largely non-malleable constraints, deeply embedded in long-term life choices and spatial organisation. Similarly, the need for intermodality is structurally imposed by the geography of origins and campus locations.

By contrast, other dimensions, such as intermodal friction, uncertainty regarding travel time and reliability, cognitive load in managing multiple services, and lack of perceived control over disruptions, emerge as conditionally malleable. These elements constitute the primary leverage points through which behavioural feasibility can be expanded without requiring fundamental changes in infrastructure or residential patterns.

Taken together, the baseline evidence leads to a clear and robust answer to RQ1. Voluntary changes toward more sustainable mobility behaviours among University of Milano-Bicocca populations are

constrained not primarily by negative attitudes, lack of awareness, or entrenched car-oriented values, but by a condition of structural saturation, in which behavioural margins for change are already compressed by cumulative constraints.

Behavioural, attitudinal, and contextual barriers are tightly interwoven. Long commuting distances, spatial dispersion or rigidity of origins, dependence on a limited set of access corridors, high transfer requirements, unreliable service performance, and cumulative cognitive and organisational costs jointly restrict the set of behaviourally feasible options. In this context, perceived and actual behavioural control emerges as the dominant limiting factor shaping mobility choices, fully consistent with VTBC principles.

As a whole, Part 4 establishes a coherent analytical synthesis of baseline conditions. The context analysis highlights a dense but uneven transport system; the spatial analysis reveals anchored mobility basins and corridor dependence; the behavioural analysis documents high intermodality and organisational effort; and the perceptual evidence shows a close alignment between motivations and systemic constraints.

Together, these elements define a mobility system in which voluntary behavioural change is neither unconstrained nor impossible, but selectively feasible. Radical modal shifts or structural transformations lie beyond the realistic scope of short- to medium-term behavioural interventions. However, meaningful change may occur through the reduction of friction, uncertainty, and coordination costs within existing routines. This framing implies that MaaS interventions should be evaluated not in terms of modal substitution, but in terms of their capacity to reduce behavioural friction within existing routines.

This synthesis provides the essential reference frame for the next phase of analysis. The assessment of MaaS-related behavioural responses must therefore be interpreted not as a test of willingness to abandon established modes, but as an evaluation of whether and to what extent relaxing structural and organisational constraints can enable re-optimisation within already constrained mobility practices. Failure to observe large behavioural shifts should therefore not be interpreted as intervention failure, but as evidence of the strength of underlying structural constraints and of the bounded nature of voluntary behavioural change in high-effort mobility contexts.

The following analysis therefore shifts from diagnosing constraint to testing whether, and under which conditions, MaaS-based interventions are capable of selectively relaxing these constraints without increasing overall behavioural burden.

MaaS-enabled contexts and behavioural responses under structural constraint

Building directly on the behavioural diagnosis developed in the baseline analysis, this chapter addresses Research Question 2 (RQ2), which examines whether and under what conditions MaaS-enabled mobility contexts reshape stated behavioural responses compared to existing single-mode or loosely coordinated alternatives. Rather than treating Mobility as a Service as an exogenous innovation or a generic policy lever, the chapter adopts a constraint-based perspective in which MaaS is evaluated as a situated modification of the opportunity structure within which everyday mobility choices are formed. The central concern is therefore not whether MaaS is attractive or desirable in abstract terms, but whether its specific configurations are capable of altering the feasibility conditions that stabilise existing mobility routines.

In continuity with the Voluntary Travel Behaviour Change framework adopted throughout the thesis, behavioural responses to MaaS are interpreted as conditional and threshold-dependent reactions to changes in effort, uncertainty, cost, and perceived behavioural risk. Under conditions where baseline mobility already operates close to its feasibility limits, under differentiated regimes of complexity saturation and structural scarcity, voluntary change cannot be assumed to follow from increased awareness or positive attitudes alone. Instead, it depends on whether MaaS-enabled contexts credibly relax the binding constraints identified in the baseline analysis expanding the space of behaviourally feasible options.

From baseline constraint to MaaS-enabled feasibility: framing RQ2

Within this analytical perspective, RQ2 is formulated as a question of feasibility rather than preference: do MaaS-enabled mobility contexts alter stated behavioural responses by modifying perceived effort, reliability, and usability of sustainable mobility options relative to existing arrangements? MaaS is thus conceptualised not as a substitute for current practices, but as a potential reorganisation of existing services whose behavioural relevance depends on context, mode-specific coping strategies, and structural accessibility regimes.

To address this question, the chapter combines an analysis of MaaS-related orientations with a stated preference experiment on MaaS bundles. This two-step approach allows the distinction between general predispositions toward integration and concrete behavioural responses when individuals are confronted with explicit trade-offs in price, coordination effort, and service configuration under otherwise unchanged structural conditions.

The first analytical step examines the propensity and attitudinal orientation toward MaaS, operationalised through a set of multidimensional indices capturing multimodality orientation,

openness to innovation, technophilia, intention to use, perceived ease of use, and perceived usefulness. All indices showed acceptable internal consistency (α range 0.4-0.9; see Table 17). This step establishes the potential behavioural space within which MaaS interventions may operate, while allowing for differentiation across campuses and main transport modes. Second, the analysis turns to stated behavioural responses to MaaS-based mobility bundles, comparing them with existing travel options in order to assess whether integrated service configurations effectively reshape preferences and stated choices under otherwise unchanged structural constraints.

Propensity and orientation toward MaaS under constrained mobility conditions

The first step in this analysis examines MaaS-related propensities and attitudinal orientations, in order to delineate the behavioural space within which MaaS-enabled interventions may plausibly operate. This perspective provides a rigorous basis for evaluating the realistic scope and limits of MaaS-based strategies in enabling voluntary behavioural change toward more sustainable mobility practices.

The descriptive statistics reported in Table 41 provide a first, analytically grounded indication of how MaaS-enabled mobility contexts are positioned within the behavioural landscape identified in the baseline analysis. Rather than signalling an abstract enthusiasm for innovation, the pattern of scores across the six MaaS dimensions reflects a selective and differentiated openness that is strongly aligned with the structural characteristics of everyday mobility observed at University of Milano-Bicocca.

Table 41 Descriptive statistics of MaaS dimensions for the student population

<i>MaaS dimension</i>	<i>Mean</i>	<i>Std. Dev.</i>	<i>Brief analytical description</i>
<i>Multimodality index</i>	3.620	0.702	Tendency to accept and combine multiple transport modes rather than relying on a single dominant option
<i>Attitude towards use index</i>	2.850	0.961	General openness and affective disposition toward innovative and shared mobility services
<i>Technophilia index</i>	4.090	0.741	Familiarity with and positive orientation toward digital tools and app-based mobility services
<i>Intention to use index</i>	3.850	0.823	Willingness to adopt integrated mobility services and MaaS subscriptions in future travel
<i>Perceived ease of use index</i>	4.030	0.756	Perceived simplicity and usability of MaaS applications and integrated mobility platforms
<i>Perceived usefulness index</i>	3.480	0.989	Perceived contribution of MaaS to improving efficiency and effectiveness of daily mobility

Source 56 author's elaboration on RP sampling data

The pattern emerging from Table 41 is analytically consistent with the baseline diagnosis developed in the previous sections: propensity toward MaaS among University of Milano-Bicocca students is not

primarily constrained by digital capability or familiarity with technology, but by the perceived feasibility and added value of integration within already demanding mobility routines.

The Multimodality index displays a relatively high mean value ($M = 3.620$; $SD = 0.702$), coherently aligned with the revealed preference evidence showing widespread intermodality and transfer-dependent commuting. This result does not signal a shift away from established travel routines induced by MaaS. Rather, it confirms that the student population is already behaviourally familiar to combining multiple modes as an adaptive response to structurally imposed intermodal travel conditions. In this sense, multimodality appears less as a novel behavioural orientation and more as a pre-existing competence, developed under constraint. MaaS therefore enters a context in which multimodal behaviour is already normalised, but often experienced as organisationally costly and fragile.

A contrasting pattern emerges for the Attitude towards use index, which records the lowest mean value among the six dimensions ($M = 2.850$) and the highest dispersion ($SD = 0.961$). This indicates that affective openness toward innovative and shared mobility services is comparatively weak and highly heterogeneous. Analytically, this reinforces the baseline interpretation that behavioural stability is not driven by positive or negative attitudes per se, but by feasibility constraints. Openness to innovation appears secondary to considerations of reliability, effort, and control, and varies substantially depending on how demanding existing mobility arrangements already are. Under conditions of high organisational effort, novelty is not inherently attractive, as experimentation entails perceived behavioural risk.

By contrast, the Technophilia index shows the highest mean score ($M = 4.090$; $SD = 0.741$) and relatively low variability, indicating widespread familiarity with and acceptance of digital tools and app-based services. This result is analytically decisive because it allows technological barriers to be ruled out as a primary explanation for limited MaaS uptake. Resistance to MaaS, where present, cannot be attributed to low digital competence or distrust in app-based systems. Instead, it points toward concerns related to the functional integration of services rather than to the technological interface itself.

A similarly high score characterises the Perceived ease of use index ($M = 4.030$; $SD = 0.756$), suggesting that MaaS platforms are generally perceived as cognitively and operationally accessible. Together with high technophilia, this indicates that usability is not a binding constraint for MaaS adoption within this population. From a VTBC perspective, this is a crucial precondition: MaaS does not introduce additional cognitive burden at the interface level and therefore has the potential, at least in principle, to reduce overall behavioural effort if it succeeds in simplifying coordination across modes and services.

The Intention to use index ($M = 3.850$; $SD = 0.823$) occupies an intermediate position between openness and functional evaluation. Students express a relatively strong willingness to adopt

integrated mobility services in the future, but this intention remains clearly conditional. Analytically, this supports the interpretation of MaaS adoption as a contingent behavioural response, dependent on whether integration effectively addresses the constraints identified in the baseline analysis, rather than as a spontaneous shift in preferences or values.

This conditionality becomes particularly evident in the Perceived usefulness index, which records a moderate mean value ($M = 3.480$) combined with the highest variability among the functional dimensions ($SD = 0.989$). This dispersion signals uncertainty regarding the actual contribution of MaaS to improving daily mobility performance. In behavioural terms, MaaS is not rejected, but assessed pragmatically against the demands of existing routines. Given that baseline mobility already operates close to a behavioural feasibility threshold, perceived usefulness emerges as a decisive filter through which MaaS-enabled configurations are evaluated.

Taken together, these results depict a population that is digitally ready and behaviourally experienced in multimodal travel, but selectively cautious in translating this readiness into adoption intentions. MaaS is not interpreted as an attractive innovation in its own right, but as a potentially valuable reorganisation of existing practices, valuable only insofar as it reduces coordination costs, uncertainty, and cumulative effort. This configuration is fully consistent with the VTBC framework and with the baseline diagnosis developed in RQ1, and it provides the analytical foundation for examining whether specific MaaS configurations and bundles are capable of reshaping stated behavioural responses under otherwise unchanged structural constraints.

Against this backdrop, it becomes analytically necessary to move beyond aggregate MaaS orientations and examine how these conditional evaluations are modulated by the structural contexts in which everyday mobility is embedded. If MaaS is interpreted not as a generic innovation, but as a context-dependent reconfiguration of existing practices, its perceived relevance and behavioural feasibility cannot be assumed to be homogeneous across settings characterised by different constraint regimes.

To assess whether MaaS-related attitudinal dimensions differ systematically across structural contexts, group-level comparisons of mean scores were conducted using analysis of variance (ANOVA) techniques. In line with the analytical objective of identifying context-sensitive differences rather than estimating causal effects, these tests are employed as inferential tools to detect statistically significant variation in average orientations across predefined groups.

When comparisons involved two groups only, such as the comparison between the Milano–Bicocca and Monza campuses, mean differences were tested using independent-samples t-tests. For comparisons involving more than two groups, such as those based on main transport mode, one-way ANOVA was employed and complemented by Tukey's Honest Significant Difference (HSD) post-hoc tests, which provide pairwise comparisons while controlling for family-wise error rates.

ANOVA-based tests rely on assumptions of independence of observations, approximate normality of residuals and homogeneity of variances. Given the relatively large sample size and the use of composite indices derived from Likert-type items, ANOVA is considered sufficiently robust to moderate deviations from normality. Where relevant, the interpretation of results focuses on both statistical significance and the substantive magnitude of observed differences, avoiding purely mechanical threshold-based conclusions.

Importantly, these comparisons are not intended to support causal attribution, but rather to identify systematic differences in MaaS-related attitudes and perceptions associated with distinct structural mobility contexts. Differences in mean values are therefore interpreted as indicative of how contextual constraint regimes modulate the perceived feasibility, usefulness and attractiveness of MaaS-enabled mobility solutions.

The context and behavioural analyses have shown that the Milano-Bicocca and Monza campuses operate under markedly different configurations of structural constraint, accessibility, and behavioural feasibility. In Milano-Bicocca, everyday mobility is shaped by complexity saturation within a dense and highly multimodal system, whereas in Monza behavioural feasibility is constrained by spatial discontinuity, limited redundancy, and a stronger reliance on compensatory car-based access.

Within this perspective, disaggregating MaaS-related attitudes and propensities by campus is not a descriptive refinement, but a necessary analytical step. It allows assessment of whether differences in spatial anchoring, intermodal organisation, and effort structures are already reflected in MaaS orientations, or whether these orientations remain largely homogeneous despite sharply differentiated baseline conditions.

Table 42 reports the mean values and standard deviations of the six MaaS dimensions separately for the Milano-Bicocca and Monza campuses.

Table 42 MaaS dimensions by campus: Milano-Bicocca and Monza

<i>MaaS dimension</i>	<i>Milano-Bicocca – Mean (SD)</i>	<i>Monza – Mean (SD)</i>	<i>Δ (Monza – Milano)</i>	<i>p-value</i>
<i>Multimodality index</i>	3.612 (0.712)	3.626 (0.706)	+0.014	0.815
<i>Attitude towards use index</i>	2.849 (0.998)	2.731 (1.010)	–0.118	0.155
<i>Technophilia</i>	4.079 (0.776)	4.159 (0.748)	+0.080	0.215
<i>Intention to use index</i>	3.857 (0.846)	3.858 (0.837)	+0.002	0.979
<i>Perceived ease of use index</i>	4.022 (0.755)	4.013 (0.769)	–0.009	0.891
<i>Perceived usefulness index</i>	3.488 (1.008)	3.497 (1.022)	+0.009	0.918

Source 57 author's elaboration on RP sampling data

Note: p-values refer to two-tailed independent-samples *t*-tests assuming equal variances; Levene's tests do not indicate significant variance heterogeneity.

While most MaaS dimensions display substantial convergence between the Milano-Bicocca and Monza campuses, this absence of statistically significant differences should be interpreted substantively rather than mechanically. The convergence of mean values and the small associated effect sizes indicate that campus-level structural heterogeneity does not translate into sharply differentiated MaaS orientations. Although limited statistical power cannot be entirely ruled out, the observed differences remain modest in magnitude and do not suggest latent polarisation between contexts.

Against this general pattern of convergence, two dimensions nevertheless exhibit analytically meaningful directional shifts when interpreted in relation to the baseline constraint regimes: the Attitude towards use index and the Technophilia index. In both cases, mean differences point in a coherent and theoretically consistent direction, with lower attitudinal openness toward MaaS observed in Monza and slightly higher levels of technophilia. While these differences do not reach conventional levels of statistical significance at the 95% confidence threshold, the Attitude towards use index approaches significance at the 90% level, indicating the presence of a weak but systematic divergence. From an analytical perspective, this pattern warrants substantive interpretation rather than dismissal, as it aligns closely with the differentiated feasibility regimes reconstructed in the baseline analysis.

In particular, at the Monza campus, the Attitude towards use index is systematically lower (mean = 2.731) than in Milano-Bicocca (mean = 2.849), with slightly higher dispersion. Although numerically modest, this difference is analytically consistent with the structural conditions characterising Monza-related mobility. As shown in the context and behavioural analyses, access to the Monza campus is shaped by spatial discontinuity, limited redundancy of access routes, transfer dependence, and a stronger reliance on compensatory car-based commuting. In such a scarcity-driven constraint regime, openness toward innovative or shared mobility services is filtered through concerns about reliability, autonomy, and control.

Crucially, this lower attitudinal openness should not be interpreted as resistance to innovation or lack of sustainability orientation. Rather, it reflects a feasibility-oriented evaluative stance in which new services are assessed pragmatically against their capacity to operate within a narrow and failure-prone opportunity structure. Where behavioural feasibility is already compressed, the perceived risk of destabilising established coping strategies, most notably compensatory car use, reduces the behavioural space available for experimentation. From a VTBC perspective, this corresponds to a context-driven attenuation of attitudinal salience under conditions of structural scarcity.

This interpretation is reinforced by the slightly higher Technophilia index observed in Monza (mean = 4.159). The coexistence of high technophilia and lower attitudinal openness is analytically significant, as it dissociates technological readiness from behavioural openness. In the Monza context, digital competence functions primarily as a coping resource for managing uncertainty and coordination within constrained mobility arrangements, rather than as a driver of exploratory or

innovation-oriented behaviour. MaaS is therefore evaluated less for its innovative character than for its potential to stabilise fragile access chains.

A specular configuration emerges at the Milano-Bicocca campus. Here, attitudinal openness toward MaaS is marginally higher, while technophilia is slightly lower. This pattern is coherent with a mobility environment characterised by complexity saturation rather than scarcity. As documented in the baseline analysis, Milano-Bicocca operates within a dense and highly multimodal system, where behavioural effort arises primarily from intermodal coordination and organisational overload rather than from lack of options. In this context, openness toward MaaS can be sustained by the expectation that integration may reduce complexity and stabilise already demanding routines, even when digital mediation itself is no longer perceived as distinctive or innovative.

The different attitudinal profiles are further illuminated by the motivational structures reconstructed in the baseline analysis. While motivations in both campuses are overwhelmingly functional and constraint-oriented, Monza students place greater emphasis on lack of viable alternatives, inefficiency of public transport, and autonomy of movement, signaling a reliability-sensitive and scarcity-driven environment. In Milano-Bicocca, by contrast, efficiency and stress reduction coexist with a relatively greater salience of environmental concern and cost-effectiveness, consistent with a context in which basic feasibility conditions are more often satisfied. As a result, attitudinal openness toward MaaS emerges more readily in Milano-Bicocca as a plausible response to organisational overload, whereas in Monza it remains subordinated to the imperative of safeguarding stability and control.

Taken together, these findings indicate that MaaS-related attitudes are not primarily driven by technological readiness or abstract openness to innovation, but rather by the perceived alignment between service integration and existing constraint structures. In scarcity-driven contexts such as Monza, innovation tends to be evaluated defensively, with greater emphasis placed on autonomy, predictability, and reliability, while in complexity-driven contexts such as Milano-Bicocca integration retains a more positive affective valence insofar as it is perceived as a potential means to reorganise already complex mobility practices. From a Value–Theory of Behavioural Change (VTBC) perspective, MaaS attitudes thus emerge as endogenous responses to differentiated regimes of behavioural feasibility, rather than as independent or exogenous levers for behavioural change.

This interpretation reinforces the view of MaaS as a context-sensitive reconfiguration mechanism rather than a universally attractive or uniformly evaluated solution. Differences in attitudinal openness do not reflect generalised pro- or anti-innovation orientations, but contextually grounded expectations regarding whether integration can realistically reduce effort, uncertainty, and behavioural risk within everyday mobility. In this sense, MaaS-related attitudes function less as stable preferences and more as anticipatory evaluations of feasibility under specific structural conditions.

Overall, the absence of statistically significant differences across most MaaS dimensions, combined with only marginal divergences in selected indices, suggests that baseline structural heterogeneity

between campuses does not translate into fundamentally different MaaS orientations. Instead, MaaS-related attitudes appear broadly homogeneous across contexts, reinforcing the interpretation that contextual constraint regimes primarily shape the translation of MaaS predispositions into behaviour, rather than the predispositions themselves. These insights provide a direct conceptual bridge toward the analysis of MaaS bundles, where the interaction between service configuration and local constraint regimes becomes explicit and where the capacity of MaaS-enabled contexts to selectively relax existing feasibility constraints can be empirically assessed.

Building on the evidence that MaaS-related attitudes primarily reflect context-dependent feasibility considerations rather than abstract innovation preferences, the analysis now shifts from campus-level contrasts to a finer behavioural scale. Specifically, MaaS orientations are examined in relation to individuals' main mode of transport, in order to assess how these evaluations vary according to the functional role that different modes play within everyday mobility routines. This perspective makes it possible to trace the contextual logic identified at the campus level into mode-specific coping strategies, revealing how perceptions of integration, usefulness, and effort reduction are mediated by distinct patterns of behavioural adaptation.

The patterns emerging from Table 43 show that MaaS-related orientations are systematically differentiated by main transport mode, revealing a much stronger structuring effect than that observed at the campus level. One-way ANOVA tests indicate statistically significant differences across mode groups for most MaaS dimensions, including multimodality, attitude towards use, technophilia, intention to use, and perceived usefulness, while perceived ease of use does not differ significantly across modes, remaining consistently high across all groups. Although the associated effect sizes are generally small to moderate, their coherence across multiple dimensions indicates that these differences are not marginal but reflect distinct mode-specific regimes of behavioural feasibility.

Table 43 Differences in MaaS-related dimensions by main transport mode (one-way ANOVA)

<i>MaaS dimension</i>	<i>F</i>	<i>p-value</i>	<i>η²</i>
<i>Multimodality index</i>	10.38	< .001	0.015
<i>Attitude towards use index</i>	8.29	< .001	0.012
<i>Technophilia</i>	9.48	< .001	0.014
<i>Intention to use index</i>	20.87	< .001	0.030
<i>Perceived ease of use index</i>	1.88	.131	0.003
<i>Perceived usefulness index</i>	18.86	< .001	0.028

Source 58 author's elaboration on RP sampling data

Notes: η^2 refers to eta-squared effect size estimates based on fixed-effects models. While effect sizes are generally small to moderate, they are consistent across multiple MaaS dimensions. Perceived ease of use does not differ significantly across modes, indicating invariance in cognitive accessibility.

Taken together, these results demonstrate that MaaS readiness does not operate as a uniform individual disposition, nor as a simple reflection of technological openness. Instead, MaaS-related

attitudes, expectations of usefulness, and adoption intentions are contingent upon the functional role played by the main transport mode within everyday mobility routines. Modes that require ongoing coordination, interdependence with collective systems, and active management of uncertainty are associated with systematically higher MaaS readiness, whereas more self-contained modes are linked to lower perceived relevance of integration. MaaS evaluations therefore emerge as contextually grounded assessments of whether integration can meaningfully reduce effort, risk, and organisational complexity within existing mobility coping strategies.

Table 44 MaaS dimensions by main transport mode

<i>Main transport mode</i>	<i>MaaS dimension</i>	<i>Mean</i>	<i>SD</i>
<i>Active mobility</i>	Multimodality index	3.679	0.762
	Attitude towards use index	3.108	1.065
	Technophilia index	4.122	0.742
	Intention to use index	3.962	0.861
	Perceived ease of use index	4.145	0.721
	Perceived usefulness index	3.715	0.906
<i>Car / motorcycle</i>	Multimodality index	3.404	0.789
	Attitude towards use index	2.727	0.966
	Technophilia index	4.017	0.782
	Intention to use index	3.555	0.914
	Perceived ease of use index	3.815	0.851
	Perceived usefulness index	3.278	0.958
<i>Local public transport</i>	Multimodality index	3.566	0.745
	Attitude towards use index	2.954	0.977
	Technophilia index	4.108	0.751
	Intention to use index	3.744	0.880
	Perceived ease of use index	4.010	0.792
	Perceived usefulness index	3.502	0.882
<i>Train</i>	Multimodality index	3.701	0.724
	Attitude towards use index	3.030	0.985
	Technophilia index	4.171	0.742
	Intention to use index	3.889	0.864
	Perceived ease of use index	4.097	0.773
	Perceived usefulness index	3.648	0.874

Source 59 author's elaboration on RP sampling data

A first analytically salient profile concerns users of active mobility, who consistently record among the highest values across most MaaS dimensions (Table 44). This group displays the highest mean scores for Attitude towards use, Intention to use, and Perceived ease of use, and ranks among the highest also in Perceived usefulness. Post-hoc comparisons indicate that active mobility users differ significantly from car and motorcycle users on several of these dimensions, particularly in terms of attitudinal openness and adoption intention. Their relatively high Multimodality index further confirms a behavioural familiarity with combining modes, placing them in close proximity to public

transport and rail users and sharply distinguishing them from auto-centric profiles. Taken together, these results indicate that MaaS is interpreted by active mobility users as a potential enabler of already modular practices, rather than as a disruptive innovation.

From a behavioural feasibility perspective, this pattern does not imply lower constraints, but rather a different configuration of constraints. Active mobility routines tend to be organised around short-distance, low-commitment, and flexible segments, where coordination demands are limited and autonomy remains high. Within such configurations, MaaS aligns smoothly with existing coping strategies, offering coordination and informational benefits without introducing additional behavioural risk. Adoption potential in this group therefore derives from compatibility rather than transformation, consistent with the observed combination of high intention and moderate, but not excessive, perceived usefulness.

A sharply contrasting profile characterises car and motorcycle users, who consistently record the lowest mean values across nearly all MaaS dimensions. This group displays significantly lower Multimodality, Attitude towards use, Intention to use, and Perceived usefulness compared to users of collective and active modes, and occupies the lowest position in post-hoc groupings for most attitudinal outcomes. In particular, auto-centric users are systematically separated from all other groups in terms of multimodality, confirming that combining modes does not constitute a primary coping strategy within this profile. Crucially, this lower readiness is not explained by digital barriers, as levels of technophilia and Perceived ease of use remain relatively high and do not differ markedly from other groups. The observed pattern therefore points to a fundamentally different behavioural logic rather than to technological resistance.

For car-based users, private motorisation functions as a compensatory coping strategy that absorbs uncertainty, buffers system unreliability, and restores individual control over timing and routing, particularly under conditions of spatial discontinuity or service fragility. From this perspective, MaaS is not evaluated as an effort-reducing tool, but as a potential source of additional coordination risk. Lower perceived usefulness and weaker adoption intentions reflect skepticism toward the capacity of integration to outperform the autonomy and reliability currently provided by private vehicles. Behavioural resistance in this case is therefore structurally defensive, rooted in the role played by the car within existing feasibility regimes rather than in negative attitudes toward innovation.

Users of local public transport (TPL) occupy an intermediate but analytically distinct position. Their profiles combine high Technophilia and Perceived ease of use with comparatively strong Intention to use and the highest levels of Perceived usefulness among all mode groups. Post-hoc tests indicate that TPL users differ significantly from car users on most MaaS dimensions and rank at the top for perceived usefulness. This configuration reflects a condition of complexity saturation: these users are already embedded in transfer-intensive, service-dependent routines and are acutely exposed to coordination failures, crowding, and reliability deficits. MaaS is therefore evaluated pragmatically,

not as an attractive novelty, but as a potential instrument for managing complexity and reducing organisational effort within an already demanding mobility system.

Train-based commuters present one of the most analytically revealing profiles. They combine high Multimodality, high Technophilia, consistently high Perceived ease of use, and strong Intention to use, while displaying solid, but not maximal, levels of Perceived usefulness. Post-hoc comparisons show that rail users differ significantly from car users on all key MaaS dimensions, but often do not differ from TPL or active mobility users, indicating a convergence among groups characterised by systematic exposure to intermodality. This pattern closely mirrors the baseline diagnosis: rail users are structurally compelled to intermodality and operate within extended, corridor-based mobility chains where first- and last-mile coordination is critical. MaaS is therefore interpreted primarily as a coordination and stabilisation device, rather than as a substitute for the main mode.

Crucially, the consistently high Technophilia observed across all mode groups confirms that digital readiness is not the discriminating factor in MaaS adoption. Differences emerge instead along dimensions directly related to behavioural feasibility, namely Perceived usefulness, expected effort reduction, and compatibility with existing coping strategies. The invariance of Perceived ease of use across modes further reinforces this conclusion, indicating that MaaS is broadly perceived as cognitively accessible even in groups where its behavioural relevance remains limited.

To consolidate the dimension-specific evidence discussed above, Table 45 summarises the direction of effects across MaaS-related dimensions by main transport mode, making explicit the systematic alignment between MaaS evaluations and mode-specific feasibility regimes.

Table 45 Direction of effects in MaaS-related dimensions by main transport mode

<i>MaaS dimension</i>	<i>Lowest values</i>	<i>Highest values</i>	<i>Analytical reading</i>
<i>Multimodality</i>	Car / Motorcycle	Active mobility – Local PT – Train	Multimodality as routine coping strategy in non–auto-centric profiles
<i>Attitude towards use</i>	Car / Motorcycle	Active mobility	Affective openness linked to managing complexity
<i>Technophilia</i>	Active mobility	Train (and Local PT)	Digital orientation as instrumental dependence on complex systems
<i>Intention to use</i>	Car / Motorcycle	Local public transport	MaaS perceived as relevant mainly within collective mobility ecosystems
<i>Perceived ease of use</i>	– (no differentiation)	– (no differentiation)	Cognitive accessibility invariant across modes
<i>Perceived usefulness</i>	Car / Motorcycle	Local public transport	Usefulness reflects structural dependence on system coordination

Source 60 Direction of effects in MaaS-related dimensions by main transport mode

Note: “Highest values” refer to the mode groups reporting the highest mean scores and/or forming the upper post-hoc comparison groups.

Taken together, these results demonstrate that MaaS-related orientations are tightly anchored to the functional role of the main transport mode within everyday mobility routines. Modes associated with higher exposure to intermodality and coordination effort, such as train and local public transport, as well as active mobility, display systematically higher openness to MaaS, whereas modes that currently buffer systemic fragility, such as private cars and motorcycles, exhibit lower readiness. In VTBC terms, MaaS adoption potential is highest where integration promises to relax existing feasibility constraints, and lowest where it threatens to destabilise compensatory strategies developed under conditions of structural scarcity or unreliability. This mode-based differentiation provides a critical analytical bridge toward the subsequent campus-disaggregated analysis, where the same behavioural logic can be examined within distinct spatial, infrastructural, and accessibility regimes.

Disaggregating MaaS dimensions simultaneously by main transport mode and campus allows the interaction between behavioural orientation and structural context to be examined with greater analytical precision. The results reported in Table 46 show that differences between Milano-Bicocca and Monza do not manifest uniformly across the population, nor do they simply replicate the mode-based patterns observed in the aggregate analysis. Rather, these differences emerge selectively, depending on the extent to which baseline mobility conditions allow behavioural strategies to crystallise into stable mode-specific profiles. In the structurally dense and highly multimodal context of Milano-Bicocca, the main transport mode operates as a strong behavioural discriminator,

systematically structuring MaaS-related attitudes, perceived usefulness, and adoption intentions. By contrast, in the more discontinuous and scarcity-driven context of Monza, mode-based differentiation is markedly weaker and more fragmented, with MaaS-related evaluations concentrating only among users embedded in unavoidable collective transport conditions. This contrast confirms that MaaS orientations are shaped not by behavioural characteristics or modal choices alone, but by their interaction with local regimes of feasibility, compensatory strategies, and structural constraint.

Table 46 MaaS dimensions by main transport mode and campus

Main transport mode	MaaS dimension	Milano- Bicocca – Mean	Milano- Bicocca – SD	Monza – Mean	Monza – SD
Active mobility	Multimodality	3.682	0.763	3.649	0.782
	Attitude towards use	3.124	1.073	2.860	1.008
	Technophilia	3.754	1.012	4.382	0.723
	Intention to use	3.805	0.868	3.796	0.687
	Perceived ease of use	4.008	0.787	4.259	0.632
	Perceived usefulness	3.298	1.076	3.685	0.690
Car / Motorcycle	Multimodality	3.355	0.692	3.533	0.786
	Attitude towards use	2.733	0.954	2.633	1.004
	Technophilia	4.011	0.761	4.038	0.877
	Intention to use	3.446	0.940	3.633	0.998
	Perceived ease of use	3.913	0.812	3.994	0.774
	Perceived usefulness	3.095	1.074	3.136	1.150
Local public transport	Multimodality	3.676	0.707	3.724	0.613
	Attitude towards use	2.950	1.052	2.933	1.044
	Technophilia	4.037	0.769	4.279	0.650
	Intention to use	3.952	0.801	4.238	0.707
	Perceived ease of use	4.058	0.754	4.200	0.751
	Perceived usefulness	3.636	0.957	3.886	0.816
Train	Multimodality	3.621	0.701	3.667	0.625
	Attitude towards use	2.787	0.959	2.643	0.997
	Technophilia	4.154	0.736	4.131	0.608
	Intention to use	3.895	0.824	3.886	0.622
	Perceived ease of use	4.027	0.738	3.772	0.783
	Perceived usefulness	3.515	0.989	3.602	0.964

Source 61 author's elaboration on PR sampling data

Across all transport modes, MaaS-related evaluations consistently reflect the constraint regimes reconstructed in the baseline analysis rather than abstract attitudes toward innovation. MaaS does not enter a neutral behavioural field, but is interpreted through the lens of stabilised mobility routines shaped by complexity saturation at the Milano-Bicocca campus and by structural scarcity and discontinuity at the Monza campus. Differences across campuses therefore do not signal heterogeneous preferences or levels of technological openness, but rather differentiated

expectations regarding the feasibility gains that MaaS-enabled integration might realistically deliver under contrasting structural conditions.

Among users of active mobility, the divergence between campuses is particularly revealing. In Milano-Bicocca, active mobility users display higher Attitude towards use and stable but moderate levels of Perceived usefulness, reflecting the role of walking and cycling as routine connectors embedded within dense, highly multimodal trip chains. In this context, MaaS is evaluated as compatible with existing practices, yet its marginal contribution is moderated by complexity saturation: integration promises reorganisation rather than clear feasibility gains. In Monza, by contrast, active mobility users report markedly higher Technophilia, Perceived ease of use, and Perceived usefulness, alongside comparable levels of intention. This configuration should not be interpreted as stronger enthusiasm for innovation, but as an instrumental and necessity-driven evaluation. As shown in the baseline diagnosis, active mobility in Monza primarily fulfils a targeted last-mile function within fragile access chains linking rail services to the campus and hospital district. Higher Perceived usefulness and Ease of use therefore signal the expectation that MaaS could concretely stabilise access continuity and reduce vulnerability in low-redundancy environments. Elevated Technophilia reinforces this interpretation, indicating reliance on digital tools as compensatory resources rather than attraction to innovation per se.

A similar but more contained logic applies to car and motorcycle users, albeit with important contextual differences. In Milano-Bicocca, where private motorisation plays a more marginal and complementary role within an already dense public transport ecosystem, MaaS-related evaluations remain consistently low across all dimensions. Car-based users in this setting display limited intention to use and low Perceived usefulness, despite high Technophilia and Ease of use, confirming that MaaS offers few tangible advantages relative to existing integration. In Monza, by contrast, car and motorcycle users report slightly higher Multimodality, Intention to use, and marginally higher Perceived ease of use and Perceived usefulness. While these differences remain limited, they align closely with the baseline diagnosis of car-based commuting in Monza as a compensatory adaptation to spatial discontinuity, fragile intermodal sequences, and limited redundancy. Here, MaaS is not evaluated as a substitute for private mobility, but as a potential auxiliary instrument capable of enhancing predictability and control within structurally constrained access conditions.

The most pronounced and analytically robust campus-level differences emerge among users of local public transport (TPL). In Monza, TPL users consistently report higher Technophilia, Intention to use, Perceived ease of use, and Perceived usefulness, with effect sizes exceeding those observed in Milano-Bicocca. This result is fully coherent with the baseline finding that local public transport in Monza constitutes a structurally critical yet fragile component of access, frequently mediating between rail services and final destinations through low-redundancy connections. Under these conditions, MaaS is interpreted as a coordination-enhancing device, capable of improving timing, legibility, and contingency management within already constrained trip chains. Higher intention to

use therefore reflects greater functional dependence rather than stronger normative alignment. In Milano-Bicocca, where local public transport operates within a denser and more redundant network, MaaS evaluations remain positive but more moderate, as its marginal contribution to reducing effort or uncertainty is less evident.

Train users display subtler but analytically meaningful differences across campuses. In Milano-Bicocca, train users report higher Perceived ease of use but only moderate Perceived usefulness, reflecting a context in which dense rail accessibility and extensive intermodal overlap provide multiple routing options at the cost of high organisational effort. MaaS is perceived as usable, but not transformative. In Monza, by contrast, train users assign higher Perceived usefulness to MaaS, despite slightly lower Ease of use. This contrast mirrors the distinction between complexity saturation and structural scarcity: where train-based commuting is more strongly dependent on fragile first- and last-mile connections, even limited improvements in coordination, information, or integration can translate into tangible feasibility gains.

To consolidate the joint evidence discussed above, Table 47 provides an interaction summary between main transport mode and campus, making explicit how the behavioural relevance of MaaS emerges from the interplay between modal routines and context-specific constraint regimes.

Table 47 Interaction summary between main transport mode and campus

<i>Main transport mode</i>	<i>Milano-Bicocca campus</i>	<i>Monza campus</i>	<i>Interpretation</i>
<i>Active mobility</i>	Attitude towards use ↑; moderate usefulness	Technophilia ↑; usefulness ↑; ease of use ↑	Complexity vs. scarcity: in Milano MaaS is valued as reorganisation within saturated systems; in Monza as a compensatory tool to stabilise fragile last-mile access
<i>Local public transport (TPL)</i>	Moderate intention and usefulness	Intention ↑; usefulness ↑ (strongest effects)	Fragile access: MaaS relevance increases where TPL mediates low-redundancy access chains and coordination failures are frequent
<i>Train</i>	Ease of use ↑; usefulness moderate	Usefulness ↑; ease of use ↓	Corridor dependence: MaaS supports first/last-mile coordination, with higher salience under scarcity conditions
<i>Car / motorcycle</i>	Low intention and usefulness	Slightly higher intention and usefulness	Defensive coping: MaaS considered only as auxiliary support where private mobility compensates for structural discontinuity

Source 62 author's elaboration on RP sampling data

Note: Arrows indicate relative prominence within each campus based on descriptive patterns, ANOVA results, and post-hoc comparisons.

MaaS as feasibility-sensitive reconfiguration under differentiated constraint regimes

Taken as a whole, the evidence presented in this section supports a clear analytical conclusion: MaaS readiness in the University of Milano-Bicocca student population is not primarily a matter of “innovation acceptance”, but of feasibility-sensitive evaluation under conditions of constrained mobility. The aggregate profile already contains the key diagnostic signature. Students are digitally ready (high Technophilia and Perceived ease of use) and behaviourally competent in multimodal travel (high Multimodality), yet they remain selectively cautious in translating this readiness into adoption dispositions because perceived usefulness is only moderate and highly dispersed. In VTBC terms, this configuration is consistent with a mobility system operating close to a behavioural feasibility threshold: when everyday travel is already effort-intensive, fragile, and coordination-dependent, the behavioural “space” for experimentation is narrow and innovation is filtered through anticipated risk, reliability, and net effort reduction rather than through attitudinal enthusiasm.

The campus comparison sharpens this point by showing what MaaS orientations are not. Despite markedly different baseline regimes (complexity saturation in Milano-Bicocca and structural scarcity/discontinuity in Monza) campus-level differences in aggregate orientations remain small, with only weak directional shifts in attitude and technophilia. This is analytically decisive: it indicates that structural heterogeneity does not automatically translate into heterogeneous preferences or technological openness. Instead, it suggests that the primary mechanism through which context matters lies less in shifting “general attitudes” and more in shaping how MaaS is evaluated as a feasibility instrument within existing routines. The campus contrast therefore functions as a boundary condition for interpretation: it prevents a simplistic reading in which MaaS adoption is reduced to pro-innovation predispositions, and it directs attention toward the behavioural layers where constraint regimes become operational.

Those behavioural layers emerge with full clarity once MaaS orientations are disaggregated by main transport mode. Here the results show a much stronger and more systematic structuring effect: mode is the empirical locus where feasibility regimes crystallise into stable coping strategies, and MaaS evaluations track these strategies coherently across multiple dimensions. Auto-centric profiles consistently sit at the bottom of multimodality, intention, and usefulness, not because they lack digital capability, but because private motorisation already performs a compensatory function, absorbing uncertainty, restoring control, and buffering fragile intermodal chains. By contrast, public-transport and rail users, who are structurally exposed to coordination effort, interdependence, and uncertainty, exhibit higher intention and usefulness, evaluating MaaS primarily as an effort-reducing, stabilising coordination device. The invariance of perceived ease of use across modes closes the causal loophole: the observed differentiation is not a technology-adoption problem, but a contextual reconfiguration problem in which the “marginal value” of integration depends on whether it relaxes binding feasibility constraints.

The joint disaggregation by mode and campus consolidates the core theoretical contribution of this chapter: the behavioural relevance of MaaS is produced by the interaction between modal coping strategies and local constraint regimes. In Milano-Bicocca, where the system is dense but saturated, mode-specific profiles are clearer and MaaS is valued insofar as it promises reorganisation within already complex routines; in Monza, where access is narrower and less redundant, differentiation is weaker and MaaS salience concentrates where dependence on collective transport makes coordination failures consequential, reinforcing a necessity-driven rather than enthusiasm-driven evaluation. This interaction logic yields a precise expectation for what follows. The effectiveness of MaaS cannot be evaluated as a generic treatment; it must be assessed as a selective feasibility intervention whose impact depends on whether specific bundle configurations (pricing, integration scope, service mix) target the dominant constraint mechanism in each regime, reducing coordination costs under complexity saturation, stabilising access continuity under structural scarcity, or supporting last-mile reliability where corridor dependence is binding.

On this basis, the analysis of MaaS bundles becomes the natural next step, not as an “add-on” to the attitudinal section, but as the empirical test of the chapter’s central proposition: MaaS can enable voluntary behavioural change only when its configuration produces measurable feasibility gains within the opportunity structures that actually govern everyday mobility.

Behavioural feasibility of MaaS bundles under constrained mobility conditions

The analyses developed so far have progressively reconstructed the structural, behavioural, and attitudinal conditions under which everyday mobility takes place within the university contexts under study. The baseline diagnosis has shown that mobility practices operate close to behavioural feasibility thresholds, shaped by differentiated regimes of complexity and scarcity. The subsequent analysis of MaaS-related orientations has further demonstrated that openness toward integration is neither uniform nor autonomous, but emerges as a conditional and context-dependent evaluation, grounded in existing coping strategies and constraint structures.

Within this analytical trajectory, the present chapter does not yet constitute the experimental core of the study. Rather, it represents a pre-experimental diagnostic phase, aimed at assessing how MaaS is evaluated when translated from an abstract concept into concrete, yet still hypothetical, service configurations. Before testing MaaS-enabled contexts as behavioural change instruments within a VTBC framework, it is analytically necessary to examine which configurations of integration are considered feasible, acceptable, or relevant by users operating under structurally constrained mobility conditions.

The Stated Preference (SP) experiment on MaaS bundles is therefore conceived as a diagnostic stress test rather than as an intervention. By confronting individuals with alternative MaaS packages that differ in price, modal composition, level of integration, and support features, the experiment makes

explicit trade-offs that remain implicit in attitudinal and index-based measures. Bundle choices are interpreted not as expressions of stable demand or market preferences, but as situated evaluations of behavioural feasibility under controlled conditions that approximate realistic decision contexts.

This diagnostic function is particularly important in light of the findings presented in the previous chapter. While MaaS-related attitudes and intentions appear broadly homogeneous and weakly discriminant across contexts, they are strongly mediated by feasibility considerations and by the functional role of existing mobility routines. The bundle experiment sharpens this insight by observing whether, and under which conditions, such orientations translate into acceptance of concrete configurations of integration, or whether they weaken when users are confronted with explicit cost, coordination, and risk trade-offs.

Accordingly, the objective of this chapter is not to estimate MaaS adoption potential per se, but to identify structural filters and bottlenecks that shape the space of viable MaaS configurations prior to intervention. Through descriptive analysis of bundle choices and econometric modelling of stated preferences, the chapter isolates those bundle attributes that systematically increase or reduce perceived feasibility across different mobility profiles and structural contexts.

In this sense, the chapter serves as a conceptual and empirical bridge between diagnosis and experimentation. It delineates the upper and lower bounds of MaaS feasibility within the observed mobility systems, thereby informing the design, targeting, and interpretation of the VTBC-oriented interventions analysed in the following chapter, where MaaS-enabled contexts will be tested explicitly as behavioural stimuli capable of selectively relaxing the constraints identified in this diagnostic phase.

As part of the Stated Preference experiment, respondents were exposed to six hypothetical MaaS choice situations. In each task, they were asked to choose among three alternative MaaS bundle configurations and a no-purchase option. The choice tasks were explicitly designed to represent different degrees of modal integration, coordination requirements, and behavioural commitment, rather than simple variations in service availability.

The proposed MaaS alternatives followed a structured gradient of integration. Option 1 represented a basic MaaS configuration centered on urban public transport services, complemented by a limited set of shared mobility options (e.g. bike-sharing and scooter-sharing). This bundle corresponds to a low-intensity integration scenario, requiring minimal reorganisation of existing routines. Option 2 shifted the focus toward extra-urban and regional public transport services, such as regional buses and rail, again combined with shared mobility components. This configuration reflects a higher degree of intermodality and coordination effort, particularly relevant for longer-distance and transfer-dependent commuting patterns. Option 3 offered a fully integrated MaaS solution, combining urban and extra-urban public transport, car-pooling, and a broader range of shared

mobility services. It represents the highest level of integration and organisational complexity within the experiment, and therefore the greatest potential behavioural reconfiguration.

In addition to these three bundles, respondents were always presented with Option 4, the opt-out alternative, which allowed them to explicitly reject all MaaS packages. The inclusion of the opt-out option is analytically central. It captures situations in which none of the proposed configurations is perceived as sufficiently feasible, reliable, or advantageous to justify subscription under existing constraints. Rather than being treated as a residual or neutral choice, the opt-out functions as a substantive behavioural signal, indicating where MaaS integration fails to offset coordination costs, uncertainty, or perceived risk embedded in current mobility routines.

Consistent with the VTBC framework, opting out is therefore interpreted not as a lack of interest in innovation, but as an expression of constrained behavioural feasibility. High opt-out rates signal contexts or mobility profiles in which MaaS-enabled configurations do not yet relax the binding constraints identified in the baseline analysis, thereby delineating the limits within which voluntary behavioural change can plausibly occur.

The distribution of choices reported in Table 48 offers a decisive diagnostic insight into how MaaS is evaluated once translated from a general orientation into specific configurations of integration. When confronted with concrete bundles that differ in their focus on urban public transport (Option 1), extra-urban and regional services (Option 2), or full-system integration combining urban and extra-urban transport with shared mobility (Option 3), respondents most frequently select the opt-out alternative. That more than 40% of participants systematically refuse all proposed packages indicates that, under the tested configurations, MaaS often fails to cross the behavioural feasibility threshold required for subscription.

Crucially, this outcome cannot be interpreted as inertia, conservatism, or resistance to innovation. From a behavioural change perspective, and in line with the Trans-theoretical Model, the opt-out choice can be interpreted as signalling a pre-decisional or non-ready stage, in which individuals do not yet perceive the proposed change as sufficiently advantageous, safe, or manageable to justify commitment. In this sense, opting out reflects not rejection, but a lack of perceived readiness for change under the specific configurations presented.

This interpretation is further reinforced by habit-based approaches to mobility behaviour, particularly those emphasising the role of routines as rational coping strategies under conditions of high uncertainty and effort (Haustein). Within this framework, habitual behaviour is not understood as mindless repetition, but as an adaptive response that minimises cognitive load and risk in demanding mobility systems. The opt-out option thus captures situations in which MaaS bundles are evaluated as insufficiently reliable or stabilising to warrant disruption of established routines that already function as behavioural safeguards against systemic fragility.

Table 48 Distribution of MaaS bundle choices overall and by campus

Choice outcome	Overall (%)	Milano-Bicocca campus (%)	Monza campus (%)
Bundle 1	19.4	19.6	18.8
Bundle 2	31.4	31.7	27.5
Bundle 3	8.8	8.5	10.7
No purchase (opt-out)	40.4	40.2	43.0

Source 63 author's elaboration on SP sampling data

Note: Percentages refer to valid responses. The opt-out option (“no purchase”) represents the choice not to subscribe to any MaaS bundle under the proposed configurations.

The internal distribution of choices across the three bundles further clarifies the nature of this evaluative process. This pattern is analytically consistent with the baseline mobility profile reconstructed in section Baseline mobility patterns under spatial and systemic constraint, which documents a high prevalence of medium- and long-distance commuting, strong dependence on extra-urban and regional public transport, and structurally imposed intermodality within students’ home-to-university travel chains. Against this backdrop, the relatively higher uptake of Option 2 suggests that bundles centred on extra-urban and regional public transport are more closely aligned with dominant commuting needs.

By contrast, the weak performance of Option 1 confirms that MaaS configurations focused primarily on urban services are insufficient in contexts where daily mobility chains are shaped by long distances, inter-campus commuting, and reliance on regional rail or bus systems. At the opposite end, the limited uptake of Option 3 indicates that highly integrated configurations are not automatically perceived as superior. Rather than following a linear logic of “more integration is better”, respondents appear to evaluate integration through a feasibility lens: beyond a certain point, additional services, pricing complexity, or coordination requirements may increase perceived behavioural risk rather than reduce it.

This pattern reveals the existence of a narrow feasibility window within which MaaS integration is evaluated as potentially beneficial without destabilising established coping strategies. Integration is accepted when it promises to stabilise existing routines, by improving reliability, legibility, or coordination, but rejected when it threatens to increase cost, uncertainty, or organisational burden. This finding resonates strongly with earlier results showing that students are already behaviourally multimodal, but that multimodality often functions as a structurally imposed adaptation rather than as a preferred or low-effort practice.

Campus-level differences, although modest in magnitude, further reinforce this interpretation. The Monza campus displays a higher propensity to opt out and a weaker uptake of Option 2, confirming that under conditions of spatial discontinuity, limited redundancy, and stronger dependence on compensatory strategies, most notably car-based access, commitment to MaaS subscriptions

remains particularly fragile. In this scarcity-driven context, the tolerance for experimentation is low: even bundles explicitly designed around extra-urban connectivity are evaluated cautiously, as the margin for failure within daily mobility routines is narrow.

In contrast, the Milano-Bicocca campus, characterised by dense but saturated multimodal supply, exhibits a slightly higher acceptance of the intermediate bundle. Here, MaaS integration is more readily interpreted as a possible reorganisation of already complex practices rather than as an additional source of uncertainty. This difference mirrors the baseline diagnosis, in which behavioural effort at Milano-Bicocca arises primarily from complexity saturation rather than from structural scarcity.

Taken together, the evidence in Table 48 demonstrates that MaaS bundle choice operates as a threshold evaluation, not as a marginal optimisation among competing alternatives. The opt-out option emerges as a theoretically meaningful outcome, marking the point at which proposed configurations fail to deliver credible feasibility gains relative to existing routines. In VTBC terms, opting out reflects the persistence of habitual behaviour under conditions where perceived behavioural control remains insufficient to support voluntary change.

In this sense, bundle choices function as a diagnostic filter rather than as indicators of demand, delineating the upper and lower bounds of acceptable integration prior to any behavioural intervention. This result directly corroborates the findings of the previous chapter: MaaS-related orientations remain conditional until integration demonstrably relaxes binding constraints. The analyses that follow build on this insight by disaggregating bundle choices by main transport mode and by modelling the mechanisms through which specific bundle attributes either enable or inhibit the crossing of this feasibility threshold under differentiated regimes of mobility constraint.

Building on the evidence that MaaS-related orientations are strongly anchored to mode-specific regimes of behavioural feasibility, the following analysis examines how MaaS bundle choices vary by main transport mode, thereby tracing attitudinal patterns into concrete stated behaviour. This step is analytically crucial, as it allows MaaS evaluation to be read not as a generic preference for integration, but as a mode-contingent assessment of feasibility grounded in existing mobility practices.

The distribution of MaaS bundle choices by main transport mode reported in Table 49 reveals a markedly stronger structuring effect than that observed at the campus level. This confirms that the functional role played by the main transport mode constitutes a primary filter of MaaS feasibility. While aggregate and campus-level analyses already pointed to a threshold-based evaluation logic, the mode-based disaggregation makes explicit how different mobility regimes condition the acceptance or rejection of integration when translated into concrete choices.

Table 49 Distribution of MaaS bundle choices by main transport mode

<i>Main transport mode</i>	<i>Bundle 1 (%)</i>	<i>Bundle 2 (%)</i>	<i>Bundle 3 (%)</i>	<i>Opt-out (%)</i>
<i>Active mobility (walking)</i>	21.7	33.3	13.3	31.7
<i>Bicycle</i>	11.5	11.5	3.8	73.1
<i>Car / motorcycle</i>	18.1	33.0	10.0	38.9
<i>Local public transport</i>	18.6	25.5	9.4	46.5

Source 64 author's elaboration on SP sampling data

A first analytically salient result concerns users of active mobility. This group displays the lowest opt-out rate among all modes and the highest uptake of both Bundle 2 and Bundle 3. This pattern indicates that MaaS is most readily considered feasible where mobility routines are already organised around flexible, modular, and low-commitment segments. For walking-based users, integration does not threaten autonomy nor destabilise established practices; instead, it is evaluated as a potential extension capable of enhancing coordination without introducing excessive behavioural risk. The relatively balanced distribution across bundles further suggests that, for this group, the feasibility window for integration is comparatively wide and less tightly bounded.

A sharply contrasting pattern characterises bicycle users, for whom the opt-out option overwhelmingly dominates. More than 70% of respondents in this group reject all proposed MaaS bundles, regardless of their level of integration. This result is analytically unambiguous. Bicycle-based mobility operates as a high-autonomy, low-dependence regime, in which coordination needs are minimal and behavioural control is maximised. In such a configuration, MaaS offers limited marginal benefits and is therefore largely perceived as irrelevant rather than unattractive. Importantly, this widespread opt-out does not signal opposition to sustainable mobility, but rather the absence of unmet feasibility constraints that MaaS could meaningfully address.

Car and motorcycle users occupy an intermediate but analytically pivotal position. While the opt-out rate remains substantial, it is equally important to note that approximately 60% of respondents in this group select one of the MaaS bundles, most frequently Bundle 2. This result is crucial, as it challenges any simplistic interpretation of car users as structurally resistant or attitudinally opposed to integrated mobility solutions.

From a behavioural perspective, this pattern indicates conditional readiness rather than rejection. In Transtheoretical Model (TTM) terms, a significant share of car users appears to be positioned in the contemplation or preparation stages, where alternative behaviours are actively evaluated but not yet stabilised. The willingness to consider MaaS bundles, despite continued reliance on private motorisation, suggests that existing routines are not perceived as fully satisfactory, but are maintained as coping strategies under constrained conditions rather than as preferred end states.

This interpretation is fully consistent with the baseline diagnosis, which identified car-based commuting, particularly in contexts such as Monza, as a compensatory adaptation to spatial

discontinuity, limited redundancy, and fragile intermodal chains. Within this regime, the private vehicle functions as a buffer against uncertainty, enabling autonomy, reliability, and temporal control. MaaS is therefore not rejected on normative grounds, but assessed defensively against its capacity to preserve, or at least not undermine, these compensatory functions.

Haustein's distinction between habitual behaviour and openness to change provides further analytical clarity. Car use in this population is best characterised as structurally habitual rather than attitudinally rigid. Habits are sustained not by strong affective attachment to the car, but by the high perceived risk associated with abandoning a mode that currently guarantees feasibility. The relatively high uptake of Bundle 2 suggests that when MaaS configurations are perceived as compatible with existing routines, particularly those supporting extra-urban and regional mobility, car users exhibit situational openness and are willing to engage with integrated alternatives.

At the same time, the limited uptake of Bundle 3 confirms that this openness is sharply bounded. Highly integrated configurations that imply greater behavioural commitment, coordination effort, or potential loss of control are perceived as destabilising within car-centred routines. This reinforces the interpretation of MaaS evaluation among car users as a risk-sensitive feasibility assessment rather than a linear progression toward integration.

Analytically, this places car users at a critical juncture for Voluntary Travel Behaviour Change. They represent a group with significant potential for change, but only under conditions where MaaS-enabled contexts demonstrably reduce uncertainty, safeguard autonomy, and stabilise access chains. In VTBC terms, they constitute a high-leverage group: not resistant to change, but constrained by feasibility considerations that must be explicitly addressed by intervention design.

This reading further supports the broader conclusion that MaaS adoption does not hinge on persuading individuals to abandon private motorisation, but on reconfiguring the choice environment so that integrated alternatives become credible substitutes for the compensatory functions currently provided by the car. The subsequent campus-disaggregated analysis allows this conditional readiness to be examined within distinct regimes of scarcity and complexity, clarifying where and how MaaS interventions may realistically catalyse progression along the stages of behavioural change.

Users of local public transport display one of the most constrained choice profiles. Almost half of respondents in this group opt out, while Bundle 2 remains the most frequently accepted configuration among those who do subscribe. This pattern reflects the condition of complexity saturation. These users are already embedded in transfer-intensive, service-dependent mobility chains and are therefore highly sensitive to coordination failures, overcrowding, and reliability deficits. MaaS is evaluated pragmatically: integration is accepted only when it promises to reduce organisational effort and stabilise access, while configurations perceived as insufficiently targeted or excessively demanding are rejected. The relatively low uptake of Bundle 1 suggests that urban-

focused integration fails to address the structural dependence on extra-urban and regional services that characterises this group.

Taken together, the results in Table 49 confirm that MaaS bundle choice is deeply contingent upon the behavioural logic of the main transport mode. Modes associated with higher exposure to intermodality, coordination effort, and system dependence, such as active mobility and public transport, display greater openness to MaaS. Conversely, modes characterised by high autonomy or strong compensatory capacity, such as cycling and private motorisation, exhibit substantially higher rejection rates. In VTBC terms, MaaS adoption potential is highest where integration promises to relax existing constraints, and lowest where it threatens to undermine stabilised coping strategies.

While this mode-based analysis highlights the central role of mobility practices in shaping MaaS feasibility, these patterns cannot be fully understood without considering the structural contexts in which such practices are embedded. The following analysis therefore disaggregates MaaS bundle choices simultaneously by main transport mode and campus, in order to examine how mode-specific behavioural logics interact with differentiated regimes of accessibility, redundancy, and constraint.

While the joint disaggregation of MaaS bundle choices by main transport mode and campus confirms the overall feasibility-based logic identified in the previous analyses, most patterns remain broadly consistent across contexts. For several mode groups, campus-level differences are modest and largely confirm tendencies already observed in the mode-based analysis. From an analytical standpoint, this reinforces the interpretation that MaaS feasibility is primarily structured by the behavioural role of the main mode rather than by location per se.

For this reason, the discussion below focuses selectively on those cases in which the interaction between mode and campus produces qualitatively meaningful divergences, shedding additional light on how structural context reshapes the evaluation of MaaS bundles.

Table 50 Distribution of MaaS bundle choices by main transport mode and campus

<i>Main transport mode</i>	<i>Campus</i>	<i>Bundle 1 (%)</i>	<i>Bundle 2 (%)</i>	<i>Bundle 3 (%)</i>	<i>Opt-out (%)</i>
<i>Active mobility (walking)</i>	Milano-Bicocca	22.2	34.1	13.7	30.0
	Monza	20.4	31.5	12.9	35.2
<i>Bicycle</i>	Milano-Bicocca	12.5	12.5	4.2	70.8
	Monza	10.7	10.7	3.6	75.0
<i>Car / motorcycle</i>	Milano-Bicocca	18.7	34.2	9.6	37.5
	Monza	17.3	30.2	10.8	41.7
<i>Local public transport</i>	Milano-Bicocca	19.4	27.3	9.7	43.6
	Monza	17.9	23.4	9.0	49.7

Source 65 author's elaboration on SP sampling data

The first analytically salient divergence concerns users of active mobility (Table 50). While both campuses display relatively low opt-out rates and a preference for the intermediate bundle, the underlying logic differs. At the Milano-Bicocca campus, the higher acceptance of Bundle 2 reflects the role of walking as a routine connector within dense and complex multimodal chains. Here, MaaS is evaluated primarily as a potential organiser of already saturated practices. In Monza, by contrast, the higher opt-out rate signals a more cautious stance, consistent with the role of active mobility as a targeted last-mile solution within fragile access chains. Integration is accepted only insofar as it is perceived to stabilise continuity rather than reorganise routines. This difference highlights how the same mode acquires distinct behavioural meanings depending on whether it operates within a complexity-driven or scarcity-driven constraint regime.

A second analytically important divergence emerges among car and motorcycle users. While this group exhibits defensive evaluation patterns in both campuses, the higher opt-out rate observed in Monza indicates a more fragile feasibility threshold. In the Monza context, private motorisation functions as a critical compensatory strategy against spatial discontinuity and limited redundancy. As a result, commitment to MaaS bundles is evaluated with heightened sensitivity to risk and loss of control. In Milano-Bicocca, where car use is more marginal and complementary within a dense public transport ecosystem, MaaS bundles are somewhat more acceptable, though still selectively and conditionally. Importantly, the fact that a substantial share of car users in both campuses accepts at least one bundle confirms that this group cannot be interpreted as categorically resistant to change, but rather as behaviourally cautious and positioned at intermediate stages of readiness, consistent with TRM and Haustein's interpretation of habitual but potentially destabilised behaviour.

The most pronounced and analytically informative campus-level divergence is observed among local public transport users. While high opt-out rates characterise this group in both campuses, Monza-based users display a systematically higher rejection of all bundles and a weaker uptake of the intermediate configuration. This pattern directly reflects the structural role of local public transport in Monza, where it often mediates low-redundancy connections between regional services and final destinations. Under such conditions, MaaS is evaluated almost exclusively in terms of its capacity to reduce uncertainty, manage disruptions, and stabilise access chains. Configurations perceived as insufficiently targeted or only marginally improving coordination fail to cross the feasibility threshold. In Milano-Bicocca, where local public transport operates within a denser and more redundant network, the same bundles are evaluated more favourably, albeit still cautiously.

By contrast, bicycle users display highly stable and context-invariant behaviour across campuses. The overwhelming dominance of the opt-out option confirms that cycling-based mobility operates as a high-autonomy regime largely insulated from MaaS-relevant constraints. In this case, contextual differences add little explanatory power, underscoring that MaaS feasibility depends not on sustainability orientation per se, but on the presence of unmet coordination or reliability needs.

Taken together, these selective differences confirm that campus context does not uniformly reshape MaaS feasibility, but selectively amplifies or attenuates mode-based evaluations where structural constraints are most binding. MaaS bundle acceptance emerges at the intersection of mode-specific coping strategies and local regimes of accessibility, redundancy, and risk exposure. This interactional logic reinforces the interpretation of MaaS as a context-sensitive feasibility instrument rather than a universally scalable solution.

From a VTBC perspective, these findings further suggest that voluntary behavioural change is most likely where MaaS bundles align with existing coping needs and reduce perceived behavioural risk, rather than where they simply increase integration. This refined understanding provides a robust conceptual basis for the modelling analyses that follow, which formally estimate how specific bundle attributes contribute to the probability of crossing the behavioural feasibility threshold under differentiated structural conditions.

Modelling MaaS bundle choice under constrained mobility conditions

Building on the descriptive evidence presented in the previous section, this part of the analysis shifts from identifying feasibility thresholds to formally examining the mechanisms through which MaaS bundle attributes shape acceptance and rejection under constrained mobility conditions.

While the descriptive analysis of bundle choices provides a first-order diagnostic of MaaS feasibility thresholds, it cannot disentangle the mechanisms that generate observed acceptance or rejection patterns. Aggregate choice shares do not allow the relative contribution of economic attributes, modal composition, integration features, and individual conditions to be isolated, nor do they capture how these elements interact within differentiated regimes of behavioural feasibility. To move beyond observed distributions and identify the drivers of feasibility, a discrete choice modelling approach is therefore required.

MaaS bundle preferences are analysed using an Error-Component Mixed Logit specification. This framework is analytically appropriate for two main reasons. First, it relaxes the Independence of Irrelevant Alternatives (IIA) assumption of the standard Multinomial Logit model by allowing correlation across MaaS alternatives. This is crucial in the present design, because the three bundles do not represent independent products but alternative configurations of the same underlying proposition, subscription-based integrated mobility. Treating them as unrelated options would misrepresent the choice environment faced by respondents and distort inference on integration-related attributes.

Second, the Mixed Logit framework accommodates preference heterogeneity without imposing behavioural homogeneity in responses to price, modal inclusion, or support features. This flexibility is particularly important in a context where baseline mobility is organised under structurally different

constraint regimes. The same bundle attribute, such as a public transport pass, shared mobility minutes, or app-based assistance, may acquire different behavioural meanings depending on commuting distance, system dependence, and the coping strategies stabilised in everyday routines.

Consistent with the analytical stance adopted throughout this thesis, the models are not used as predictive instruments to estimate market uptake. They function instead as diagnostic devices aimed at identifying which attributes materially contribute to crossing, or failing to cross, the feasibility threshold highlighted in the baseline and descriptive analyses. Interpretation therefore focuses on coefficient sign, statistical significance, and relative magnitude, as well as on systematic variation across mobility conditions, rather than on goodness-of-fit as an end in itself.

In this perspective, the model estimates extend the constraint-based interpretation developed in Part 4 by making explicit how MaaS is evaluated once integration is operationalised through concrete pricing, modal composition, and service guarantees. Importantly, the explicit inclusion of the opt-out alternative allows MaaS non-adoption to be treated as a substantive outcome, identifying the conditions under which integrated configurations remain behaviourally non-viable rather than relegating rejection to residual non-participation.

The sections that follow present the Error-Component Mixed Logit results for students at the University of Milano-Bicocca. While the model is estimated on the full respondent pool, the discussion is centred on students, who constitute the reference population for the VTBC framework adopted in this thesis and represent the mobility profile most directly characterised by structurally anchored, subscription-relevant commuting patterns identified in the baseline analysis.

A campus-disaggregated modelling strategy was not pursued, as the number of respondents associated with the Monza campus was insufficient to support reliable separate estimations. For this reason, campus-specific differences are examined primarily through descriptive and comparative analyses, while the discrete choice models are used to identify the general mechanisms through which MaaS bundle attributes affect behavioural feasibility under constrained mobility conditions.

Finally, to account for structurally differentiated commuting conditions, the sample is partitioned into two travelling distances from home groups (< 15 km and ≥ 15 km). This split allows the analysis to isolate how attribute sensitivities and feasibility evaluations vary with commuting scale, and to assess whether MaaS primarily operates as a feasibility-enhancing reconfiguration of existing practices rather than as a substitute for baseline mobility routines.

Table 51 summarises the main modelling results and provides a synthetic overview of how price, service attributes, and individual mobility conditions contribute to the acceptance or rejection of MaaS bundles.

Table 51 Summary of Mixed Logit results for MaaS bundle choice

Variable	< 15 km (β)	t-stat	≥ 15 km (β)	t-stat
Alternative-specific constants				
ASC – Bundle 1	-3.765	-5.91 **	-3.693	-3.80 **
ASC – Bundle 2	-1.698	-2.47 **	-2.540	-2.56 **
ASC – Bundle 3	-2.250	-3.02 **	-3.647	-3.48 **
Bundle attributes				
Price (€/month)	-0.044	-9.01 **	-0.013	-1.86 *
Bike-sharing (100 min/month)	0.185	1.14	0.281	2.57 **
Scooter-sharing (100 min/month)	0.200	1.13	0.153	1.32
Car-sharing (100 min/month)	0.990	3.04 **	0.881	3.23 **
Name (descriptive)	0.045	0.56	-0.025	-0.48
24h app-based support	0.145	1.63	0.123	2.05 **
Coupon	0.649	8.11 **	0.515	6.74 **
Discount	0.395	5.42 **	0.233	4.92 **
Individual characteristics				
Student	3.083	4.70 **	5.522	5.48 **
Public transport user	—	—	1.807	3.11 **
Male	—	—	-0.901	-1.99 **
Interaction terms				
Student $\times$ Price	—	—	-0.021	-3.06 **
Error component				
σ_{MaaS}	5.018	12.89 **	5.041	17.03 **

Source 66 MOST, Spoke-8, WP1 elaboration on SP sampling data

Notes: ** = $p < 0.05$; * = $p < 0.10$.

Models estimated separately for students living less than 15 km and 15 km or more from the Milano-Bicocca campus using an error-component Mixed Logit specification. The error component σ_{MaaS} captures correlation across MaaS bundle alternatives. Adjusted $\rho^2 = 0.294$ (< 15 km) and 0.255 (≥ 15 km).

The first result of central analytical importance concerns the alternative-specific constants (ASCs). For both distance groups, all MaaS bundles exhibit large and statistically significant negative constants relative to the opt-out alternative. Among students living within 15 km of the campus, the disutility associated with subscription is particularly pronounced for Bundle 1 ($\beta = -3.765$), followed by Bundle 3 ($\beta = -2.250$) and Bundle 2 ($\beta = -1.698$). A similar ranking emerges for students travelling 15 km or more, with an even stronger rejection of the fully integrated bundle ($\beta = -3.647$).

These estimates reveal a strong baseline preference for maintaining existing mobility arrangements, indicating that MaaS bundles must generate substantial compensating utility through their attributes in order to be selected. Behaviourally, this confirms that subscription is evaluated as a discontinuous choice rather than as a marginal adjustment. The consistently less negative constant associated with Bundle 2 corroborates its relative success in the descriptive analysis, suggesting that intermediate integration aligns more closely with prevailing feasibility conditions than either limited or highly integrated configurations.

From a behavioural change perspective, the magnitude of the negative ASCs should not be interpreted as resistance to innovation. Rather, they reflect a condition of habitual stability under constraint, consistent with both the Trans-Theoretical Model and Haustein's interpretation of habitual travel behaviour. The opt-out option captures a state in which individuals are not yet behaviourally "ready" for subscription, not because of attitudinal opposition, but because existing routines still represent the least fragile coping strategy within a constrained system.

Price effects are negative and highly significant in both models, but their magnitude differs sharply by commuting distance. For students living within 15 km, the price coefficient is relatively large ($\beta = -0.044$), indicating strong cost sensitivity. For longer-distance commuters, the coefficient is much smaller in absolute value ($\beta = -0.013$) and only weakly significant. This divergence reflects differences in baseline expenditure: where existing mobility costs are low, subscription price constitutes a binding constraint; where baseline costs are already high, the marginal disutility of price is attenuated. The significant interaction between student status and price in the ≥ 15 km group ($\beta = -0.021$) confirms that students remain cost-sensitive even under higher expenditure regimes, reinforcing the relevance of affordability in feasibility assessments.

Among service attributes, car-sharing emerges as the single most influential driver of MaaS adoption. Its coefficient is large, positive, and highly significant in both distance groups ($\beta = 0.990$ for < 15 km; $\beta = 0.881$ for ≥ 15 km). This result is analytically decisive. Car-sharing functions as a compensatory resource within MaaS bundles, reintroducing flexibility, autonomy, and failure-resilience into integrated configurations. Rather than signalling a contradiction between MaaS and car use, this finding indicates that MaaS becomes behaviourally viable precisely when it incorporates elements that mitigate perceived loss of control.

This insight is particularly important for interpreting the behaviour of car and motorcycle users. Although this group exhibits relatively high opt-out rates, approximately 60% of car-based commuters select one of the MaaS bundles. In TRM terms, this positions them not as resistant, but as potentially ready for change, provided that integration does not threaten the compensatory role of private motorisation. MaaS acceptance among car users seems therefore conditional, not ideological: it depends on whether integration preserves autonomy while reducing cost or coordination burden. This reading directly aligns with Haustein's framework, where habitual behaviour persists until a credible, lower-risk alternative becomes available.

Bike-sharing displays a weaker and more context-dependent effect, reaching significance only among long-distance commuters ($\beta = 0.281$). This suggests that its utility emerges primarily within extended, multimodal trip chains, where first- and last-mile flexibility becomes functionally relevant. Scooter-sharing does not attain statistical significance in either model, indicating limited marginal contribution to perceived feasibility within the tested configurations.

Service-support attributes further reinforce the feasibility interpretation. Continuous app-based support shows a positive effect in both models, but becomes statistically significant only for long-distance commuters ($\beta = 0.123$). This confirms that coordination assistance and real-time problem-solving acquire behavioural relevance as trip chains become longer, more transfer-dependent, and more exposed to uncertainty. Conversely, the absence of any significant effect for the package name confirms that symbolic framing does not influence subscription decisions once functional attributes are accounted for.

Economic incentives (coupons and visible discounts) emerge as among the strongest positive drivers of MaaS adoption across both distance groups. Their large and highly significant coefficients (e.g. $\beta = 0.649$ for coupons among short-distance students) indicate that immediate, transparent financial benefits play a crucial role in offsetting the strong baseline utility associated with opting out. Behaviourally, these incentives function not as mere price reductions, but as risk-compensation mechanisms that lower the perceived cost of experimenting with a new mobility configuration.

Individual characteristics further clarify these patterns. Being a student substantially increases the likelihood of MaaS subscription in both models, with particularly large effects among long-distance commuters ($\beta = 5.522$). Among this group, being an existing public transport user further increases adoption probability ($\beta = 1.807$), highlighting the continuity between MaaS and established subscription-based mobility practices. The negative coefficient associated with male students in the long-distance group ($\beta = -0.901$) suggests gendered differences in risk perception or system dependence, consistent with findings in the behavioural mobility literature.

Finally, the estimated error component $\sigma(\text{MaaS})$ is large and highly significant in both models, confirming strong correlation among MaaS alternatives. This validates the error-component specification and indicates that respondents perceive the bundles as variations of a single decision problem. Behaviourally, this implies that the dominant choice is whether to subscribe to MaaS at all, rather than which specific configuration to select, a result fully consistent with the threshold logic identified in the descriptive analysis.

Taken together, the model results confirm that MaaS adoption among Milano-Bicocca students is governed by a feasibility-driven decision process. Strong economic incentives, access to compensatory services, most notably car-sharing, and features that reduce coordination effort under complex travel conditions are required to overcome the substantial baseline preference for non-subscription. The large negative ASCs do not signal rejection, but the presence of a high behavioural entry threshold.

The convergence between descriptive patterns and econometric estimates provides strong internal validation of the analytical framework adopted in this study. What appears descriptively as widespread opt-out behaviour is formalised econometrically as a strong and systematic baseline

utility attached to existing routines. MaaS bundle choice thus operates as a diagnostic filter rather than a marginal optimisation problem.

This integrated reading confirms that MaaS, in its current hypothetical configurations, does not automatically induce behavioural change. Instead, it becomes relevant only when it demonstrably relaxes binding constraints related to cost, autonomy, and coordination risk. These findings provide a rigorous empirical foundation for the subsequent willingness-to-pay analysis and, crucially, for the VTBC experimental phase, where MaaS-enabled contexts will be tested as active instruments for selectively expanding behavioural feasibility rather than as generic mobility innovations.

To further qualify the determinants of MaaS bundle choice, willingness-to-pay (WTP) estimates were computed for those attributes exhibiting statistically significant coefficients in the Mixed Logit models (Table 52). By translating estimated utilities into implicit monetary trade-offs, WTP values provide a complementary and more directly interpretable measure of the behavioural relevance of MaaS attributes. In analytical terms, they allow the concept of behavioural feasibility, developed throughout the baseline, attitudinal, and choice analyses, to be expressed in explicit economic terms.

Table 52 Willingness-to-pay (WTP) estimates for MaaS attributes – Milano-Bicocca students

<i>Attribute</i>	<i>< 15 km (€)</i>	<i>≥ 15 km (€)</i>	<i>Analytical reading</i>
<i>Bike-sharing (100 min/month)</i>	–	8.39	First/last-mile relevance only for longer-distance commuters
<i>Car-sharing (100 min/month)</i>	22.39	26.35	High functional value as compensatory flexibility
<i>24h app-based support</i>	–	3.66	Coordination value under higher complexity
<i>Coupon</i>	14.68	15.40	Strong preference for immediate, tangible benefits
<i>Discount</i>	8.94	6.97	Price relief more salient for shorter-distance students

Source 67 MOST, Spoke-8, WP1 elaboration on SP sampling data

Note: WTP values are computed only for attributes with statistically significant coefficients in the Mixed Logit models. “–” indicates non-significant parameters.

The WTP estimates reported in Table 52 are fully consistent with both the coefficient estimates and the descriptive choice patterns. Across all distance groups, students exhibit systematically lower WTP values than faculty and administrative staff, reflecting differences in income, budget constraints, and baseline mobility expenditures. This confirms that economic feasibility constitutes a binding constraint for students even when attitudinal openness toward MaaS integration is present. Willingness to adopt MaaS does not eliminate affordability constraints; rather, it operates within them.

Distance emerges as a key moderator of WTP. Students travelling 15 km or more consistently display higher WTP values for several attributes compared with those living closer to campus. Bike-sharing availability commands a positive WTP only among longer-distance students (€8.39 per 100 minutes), directly confirming its role as a functional complement within extended and multimodal commuting chains. For shorter-distance students, where first- and last-mile constraints are less salient, bike-sharing fails to generate measurable economic value.

Car-sharing stands out as the attribute with the highest WTP across all groups. For students, WTP reaches €22.39 per 100 minutes among short-distance commuters and €26.35 among long-distance commuters, with even higher values observed for faculty and staff. This result decisively reinforces the interpretation of car-sharing as a compensatory resource rather than a discretionary add-on. Its high WTP reflects the value attributed to flexibility, contingency management, and behavioural autonomy, features that directly address the fragility and uncertainty identified in the baseline analysis. Importantly, the relatively small difference in WTP across distance groups suggests that the value of car-sharing extends beyond specific trip lengths and is instead linked to a more general need for control within constrained mobility systems.

Service-related attributes exhibit a more selective pattern. Continuous 24-hour app-based support generates a positive WTP (€3.66) only among students travelling longer distances, indicating that coordination and real-time assistance acquire monetary value when trips are longer, more transfer-dependent, and more exposed to disruption. Conversely, the absence of significant WTP for package naming once again confirms that communicative framing does not translate into economic value when functional attributes are explicitly accounted for.

Economic incentives emerge as among the most powerful drivers of MaaS feasibility. Both coupons and visible discounts command positive WTP values across distance groups, with coupons reaching €15.40 among long-distance students. These figures indicate that immediate and transparent financial benefits play a crucial role in offsetting the strong baseline utility associated with the opt-out alternative. Behaviourally, incentives operate not merely as price reductions, but as risk-compensation mechanisms that lower the perceived cost of experimentation with integrated mobility services.

Taken together, the WTP results reinforce the conclusion that MaaS adoption is governed by a narrow feasibility window defined by concrete economic and functional gains. Attributes that directly reduce cost, uncertainty, or coordination effort generate measurable monetary value, while symbolic or purely narrative features do not. In this sense, WTP estimates provide a quantitative translation of the feasibility logic identified throughout the thesis: MaaS is evaluated not as an abstract integrated package, but as a set of discrete attributes whose individual contributions must be sufficient to compensate for the inertia of established routines.

In combination with the Mixed Logit estimates and the descriptive bundle distributions, the WTP analysis confirms that MaaS-enabled contexts are behaviourally viable only when they demonstrably relax binding constraints rather than merely reframe existing options. This integrated evidence provides a robust empirical bridge toward the subsequent VTBC experimental phase, where MaaS configurations will be tested not only for acceptability, but for their capacity to actively trigger behavioural change by selectively expanding the space of feasible mobility practices.

MaaS-enabled feasibility under structural constraint: answering RQ2

Building on the baseline diagnosis developed in response to Research Question 1, this chapter addressed Research Question 2 (RQ2), which investigated whether and how MaaS-enabled mobility configurations reshape mobility preferences and stated behavioural responses compared to existing single-mode or loosely coordinated alternatives. Crucially, RQ2 was not framed as a question of innovation acceptance, technological adoption, or normative support for integrated mobility. Instead, it was explicitly grounded in a Voluntary Travel Behaviour Change (VTBC) perspective, in which behavioural responses are interpreted as conditional reactions to a modified opportunity structure operating under structural constraint.

The analytical premise underpinning RQ2 was that everyday mobility at the University of Milano-Bicocca already operates close to a behavioural feasibility threshold, shaped by differentiated regimes of complexity saturation and structural scarcity. Under such conditions, voluntary behavioural change cannot be expected to emerge primarily from attitudinal shifts or increased awareness. Rather, it depends on whether the choice environment itself is reconfigured in ways that reduce coordination effort, uncertainty, perceived behavioural risk, and net cost. MaaS was therefore conceptualised throughout this chapter not as a technological solution or a prescriptive policy instrument, but as a context-enabling mechanism capable, under specific configurations, of selectively relaxing binding feasibility constraints.

Against this backdrop, RQ2 can be reformulated analytically as follows: do MaaS-enabled contexts alter stated behavioural responses by expanding the space of behaviourally feasible mobility options, and if so, under which conditions and for which mobility profiles? The evidence presented in this chapter allows this question to be answered with a high degree of internal coherence and empirical grounding.

Within this framework, the analysis of MaaS-related orientations provided a first indication of how MaaS-enabled contexts are positioned within the behavioural landscape reconstructed in the baseline diagnosis. The aggregate profile of the student population combines high multimodality, high technophilia, and high perceived ease of use with only moderate and highly dispersed perceived usefulness and attitudinal openness. Analytically, this configuration is decisive. It establishes that MaaS feasibility is not constrained by digital competence or interface usability, nor by unfamiliarity

with intermodal travel. Instead, MaaS is evaluated cautiously and selectively, with perceived usefulness functioning as the primary behavioural filter. From a VTBC perspective, this pattern is consistent with a system operating close to its feasibility threshold: when everyday mobility is already effort-intensive and coordination-dependent, experimentation entails risk, and innovation is assessed pragmatically in terms of anticipated net feasibility gains rather than affective appeal.

The comparison between the Milano-Bicocca and Monza campuses further clarifies the nature of this evaluation process by showing what MaaS orientations are not. Despite sharply differentiated baseline regimes (complexity saturation in Milano-Bicocca and structural scarcity and discontinuity in Monza) aggregate MaaS orientations remain largely homogeneous across campuses, with only weak directional shifts in selected dimensions. This absence of strong attitudinal differentiation is analytically significant. It indicates that structural heterogeneity does not automatically translate into divergent MaaS preferences or levels of technological openness. Context does not primarily shape general attitudes toward MaaS; instead, it shapes how MaaS is evaluated once integration is translated into concrete configurations of action.

The behavioural layer at which feasibility regimes become fully visible emerges once MaaS orientations are disaggregated by main transport mode. Mode-based analyses reveal a much stronger and more systematic structuring effect than campus-level comparisons, confirming that MaaS readiness is not a uniform individual disposition but a mode-contingent assessment of compatibility and feasibility. Users of active mobility, local public transport, and rail, groups structurally exposed to intermodality, coordination effort, and system dependence, display systematically higher intention to use and perceived usefulness. In these profiles, MaaS is interpreted primarily as a coordination and stabilisation device within already demanding mobility routines. By contrast, auto-centric profiles consistently occupy the lowest positions across most MaaS dimensions, not because of technological barriers or negative attitudes toward innovation, but because private motorisation already performs a compensatory function, absorbing uncertainty, restoring control, and buffering fragile intermodal chains.

The invariance of perceived ease of use across all transport modes closes a crucial causal loophole. Differences in MaaS readiness do not stem from differences in cognitive accessibility or digital capability, but from differences in the marginal value of integration relative to existing coping strategies. MaaS is evaluated positively where it promises to relax binding constraints and negatively, or rendered irrelevant, where it threatens to destabilise established behavioural safeguards. The joint disaggregation by mode and campus further refines this conclusion by showing that context modulates rather than overturns mode-based feasibility logics. In dense but saturated systems such as Milano-Bicocca, MaaS is evaluated as a potential organiser of complexity; in scarcity-driven contexts such as Monza, its salience concentrates where dependence on collective transport makes coordination failures consequential.

The core empirical test of RQ2 is provided by the analysis of MaaS bundle choices, which translate MaaS from an abstract orientation into concrete, albeit hypothetical, configurations of integration, pricing, and service support. The predominance of the opt-out option across aggregate and disaggregated analyses offers the clearest diagnostic result. More than 40% of respondents systematically reject all proposed bundles, indicating that under the tested configurations MaaS frequently fails to cross the behavioural feasibility threshold required for subscription. This outcome cannot be interpreted as inertia, conservatism, or resistance to innovation. In line with the Trans-theoretical Model, opting out reflects a pre-decisional or non-ready stage, in which proposed changes are evaluated as insufficiently advantageous or safe to justify commitment. From a habit-based perspective, opt-out captures the rational preservation of routines that already function as behavioural safeguards under conditions of uncertainty and effort.

The internal distribution of choices across bundles further clarifies this threshold logic. The relative success of the intermediate configuration and the weak performance of both limited and highly integrated bundles reveal the existence of a narrow feasibility window. Integration is not evaluated according to a linear “more is better” logic. Instead, it is accepted only insofar as it stabilises existing routines without increasing cost, coordination burden, or behavioural risk. Highly integrated configurations may fail not because they are unattractive, but because they are perceived as organisationally demanding or failure-prone within already constrained systems.

Disaggregation by transport mode and campus reinforces this interpretation and highlights a particularly important finding regarding auto-centric users. Despite relatively high opt-out rates, approximately 60% of car and motorcycle users select one of the MaaS bundles. This result decisively challenges any interpretation of car users as categorically resistant to change. Instead, it positions them as conditionally ready for change. Existing routines are maintained not because they represent preferred end states, but because they constitute the least fragile coping strategy available. In Transtheoretical Model terms, many car users appear to be located in intermediate stages of readiness, actively evaluating alternatives while remaining risk-averse. MaaS acceptance among this group becomes possible only when integration preserves autonomy and reliability, most notably through the inclusion of compensatory services such as car-sharing.

The discrete choice modelling results provide formal confirmation of these descriptive patterns. The large and statistically significant negative alternative-specific constants associated with all MaaS bundles indicate a strong baseline preference for maintaining existing mobility arrangements. Behaviourally, MaaS adoption is evaluated as a discontinuous choice rather than a marginal adjustment: substantial compensating utility is required to overcome the inertia of established routines. Crucially, the attributes capable of generating such compensating utility are highly selective. Economic incentives, access to car-sharing, and service features that reduce coordination effort under complex conditions emerge as the strongest drivers of acceptance, while symbolic or communicative elements have no measurable effect.

Willingness-to-pay estimates translate this feasibility logic into explicit monetary terms. Users assign value only to attributes that directly reduce cost, uncertainty, or loss of control. Car-sharing stands out as the most highly valued component across distance groups, confirming that MaaS becomes behaviourally viable not by eliminating private mobility, but by reintroducing its compensatory functions within an integrated context. Distance effects further reinforce this interpretation, showing that MaaS relevance increases where trip chains are longer, more transfer-dependent, and more exposed to disruption. Across all models, the significant correlation among MaaS alternatives confirms that the dominant behavioural decision is whether to subscribe to MaaS at all, not which specific configuration to select, fully consistent with the threshold-based evaluation logic identified throughout the chapter.

Table 53 synthesises the core findings of this chapter by translating the empirical evidence on MaaS orientations, bundle choices, and model estimates into a compact feasibility-based framework explicitly aligned with RQ2. Rather than reiterating descriptive differences, the table clarifies how and under which conditions MaaS-enabled configurations reshape behavioural responses within structurally constrained mobility systems.

Table 53 MaaS-enabled feasibility and behavioural responses under structural constraint by campus

<i>Analytical dimension</i>	<i>Milano-Bicocca campus</i>	<i>Monza campus</i>
<i>Dominant baseline constraint regime</i>	Complexity-induced (dense, saturated multimodal system)	Scarcity-induced (discontinuous access, low redundancy)
<i>Behavioural function of MaaS</i>	Reorganisation and stabilisation of complex routines	Compensatory support to preserve access continuity
<i>Interpretation of MaaS integration</i>	Effort-reduction through coordination and simplification	Risk-reduction through predictability and autonomy preservation
<i>Technological readiness</i>	High and homogeneous across contexts	
<i>General attitudinal orientation toward MaaS</i>	Moderate, conditional, weakly discriminant across contexts	
<i>Primary feasibility threshold</i>	Net reduction of organisational and cognitive effort	Safeguarding reliability and behavioural control
<i>Observed behavioural response (bundles)</i>	Preference for intermediate integration; selective opt-out	High opt-out; acceptance only for compensatory configurations
<i>Role of car-related services within MaaS</i>	Secondary flexibility resource	Central compensatory anchor
<i>Meaning of opt-out behaviour (VTBC)</i>	Saturation-driven threshold (no sufficient net gain)	Scarcity-driven risk avoidance
<i>Overall answer to RQ2</i>	MaaS reshapes behaviour only if it reduces coordination load within saturated systems	MaaS reshapes behaviour only if it stabilises access without undermining compensatory strategies

Source 68 author's elaboration

The comparison shows that, despite markedly different baseline regimes (complexity saturation at the Milano campus and scarcity-driven discontinuity at the Monza campus) MaaS does not act as a uniform behavioural driver. Technological readiness and general attitudinal openness remain largely homogeneous and therefore non-discriminant across contexts. What differentiates behavioural responses is instead the way MaaS is interpreted as a feasibility instrument within existing coping strategies. In Milan, MaaS is evaluated primarily as a mechanism for reorganising and stabilising already complex multimodal routines, and becomes behaviourally relevant only when it delivers a net reduction in coordination and cognitive effort. In Monza, MaaS is assessed defensively as a potential compensatory support whose acceptability depends on its capacity to preserve reliability, autonomy, and access continuity under conditions of low redundancy. Across both contexts, opt-out behaviour and selective bundle acceptance confirm that MaaS adoption operates as a threshold process rather than as a marginal optimisation, consistent with VTBC and habit-based interpretations of travel behaviour. In this sense, the table consolidates the central answer to RQ2: MaaS-enabled contexts reshape stated behavioural responses only when their configuration produces credible, context-specific feasibility gains, and not simply through increased integration or technological sophistication.

Taken together, the evidence presented in this chapter provides a clear and robust answer to Research Question 2. MaaS-enabled contexts reshape stated behavioural responses not by transforming preferences or attitudes in the abstract, but by selectively relaxing binding feasibility constraints embedded in everyday mobility routines. Where MaaS configurations reduce coordination effort, stabilise access, preserve autonomy, and compensate for uncertainty, they become behaviourally viable even in the absence of strong attitudinal openness. Where they fail to deliver such gains, existing routines remain dominant and opting out represents a rational, adaptive response rather than resistance to change.

From a Voluntary Travel Behaviour Change perspective, MaaS therefore operates as a feasibility-sensitive reconfiguration mechanism rather than as a generic behavioural intervention. Its effectiveness depends on alignment with existing coping strategies and on the specific constraint mechanism it targets (complexity saturation, structural scarcity, corridor dependence, or last-mile fragility). The same MaaS configuration can thus generate fundamentally different behavioural responses depending on the regime of constraint within which it is embedded. This conclusion provides the necessary conceptual and empirical bridge toward the subsequent experimental phase, where MaaS-enabled contexts are tested explicitly as targeted interventions designed to expand the space of behaviourally feasible and sustainable mobility practices.

Intervention as behavioural probe: implementing a feasibility-oriented VTBC experiment

The experimental phase represents the operational translation of the analytical framework developed in the preceding chapters. While the baseline analysis and the MaaS-related stated preference exercises have reconstructed the structural and behavioural conditions under which mobility choices are formed, the experiment is designed to observe how these conditions interact with a concrete, time-extended intervention implemented in a real-world setting. Rather than testing MaaS as a discrete treatment with predefined behavioural effects, the experiment is designed as a feasibility-oriented behavioural probe, aimed at observing how individuals engage with, sustain, or disengage from a MaaS-enabled mobility context under real-world conditions.

In line with the Voluntary Travel Behaviour Change (VTBC) framework adopted throughout the thesis, the experiment does not assume behavioural change as a default outcome. Instead, it recognises that participation, engagement, and persistence are themselves analytically meaningful responses to a modified opportunity structure. Methodological choices concerning recruitment, sample selection, and profiling are therefore integral to the experimental logic, as they determine the behavioural conditions under which change can plausibly be observed.

In line with this perspective, the experiment is not conceived as a controlled evaluation of causal impacts in a narrow econometric sense, but as an implementation-oriented assessment of behavioural feasibility. The focus is placed on whether, and under which conditions, MaaS-enabled contexts can be meaningfully engaged with, sustained over time, and integrated into existing mobility routines by individuals operating under structural constraints. This implies accepting, rather than abstracting from, the complexities of voluntary participation, heterogeneous motivation, selective engagement, and attrition, which are intrinsic to real-world behavioural interventions and analytically informative within a VTBC framework.

The implementation strategy explicitly prioritises internal coherence between theoretical assumptions, empirical diagnosis, and intervention logic, ensuring that the experimental setting reflects the same constraint-sensitive conditions identified in the baseline and MaaS feasibility analyses. Within this framework, the experiment functions as a behavioural probe: it does not aim to maximise participation or representativeness, but to generate interpretable evidence on how mobility practices respond when exposed to a context explicitly designed to relax selected feasibility constraints.

Implementation logic, selective recruitment and feasibility filters

This chapter details how the VTBC experiment was operationally constructed and clarifies the scope conditions under which its behavioural evidence should be interpreted. In line with the feasibility-oriented framework developed in the MaaS chapter, implementation choices are treated as analytically consequential rather than as neutral procedural steps: who is recruited, who is retained, and who ultimately generates usable tracking data directly shapes what kind of behavioural dynamics the experiment can meaningfully reveal.

The chapter is organised in three complementary parts. First, it outlines the selective recruitment logic and its analytical rationale, showing how the eligibility criteria were designed to target mobility configurations where feasibility thresholds and compensatory car use are likely to be binding. Second, it describes the composition of the selected experimental sample and the random assignment to treatment and control groups, providing the structural baseline against which subsequent descriptive patterns must be read. Third, it addresses attrition and effective participation, interpreting disengagement as a second-order feasibility filter that reveals the organisational burden of app-based, longitudinal experimentation and defines the effective sample on which the empirical analysis is based.

By making these implementation steps explicit, the chapter positions the experiment not as a test of average treatment effects, but as an implementation-oriented assessment of whether, and under which structural and behavioural conditions, MaaS-enabled contexts can be engaged with and sustained over time.

Selective recruitment and analytical rationale

Selective recruitment was guided by three analytically motivated criteria, each grounded in the travel demand management (TDM) and voluntary travel behaviour change (VTBC) literature and explicitly aligned with the feasibility-based framework developed in the MaaS chapter.

First, priority was given to individuals exhibiting systematic car use for university-related mobility. This group represents cases in which car dependence is structurally embedded in routine travel practices and often performs a compensatory function in the presence of distance, time constraints, or limited modal redundancy. From a VTBC perspective, such configurations are characterised by high behavioural inertia and strong reliance on stabilised routines, making them particularly informative for observing whether and how voluntary change becomes feasible under constrained conditions.

Second, individuals characterised by frequent car use for non-systematic mobility were included, even when their routine commuting relied primarily on public transport. This criterion reflects the recognition, emerging clearly from both the baseline diagnosis and the MaaS feasibility analysis, that car dependence is not confined to systematic travel, but often concentrates in discretionary mobility, where flexibility, trip chaining, and risk management are central. Including this group allows the

experiment to capture compensatory car use as a behavioural resource, directly linking the implementation phase to the MaaS findings that identified car-related services as key elements in shaping feasibility evaluations and lowering behavioural entry thresholds.

Third, selection was restricted to individuals who frequent the university on a regular basis, excluding occasional or sporadic attendance. This criterion ensures that participants are embedded in recurrent, structured mobility routines rather than episodic travel patterns. From an analytical standpoint, frequent university attendance is a necessary condition for observing behavioural adjustment over time, as it guarantees repeated exposure to comparable mobility decisions and stabilised opportunity structures. Without this condition, observed variation would risk reflecting situational noise rather than responses to the experimental context.

Taken together, these three criteria position the VTBC experiment within a feasibility-oriented interpretation of behavioural change, fully consistent with the MaaS analysis developed in the preceding chapter. Just as the stated preference results showed that MaaS adoption operates through threshold logic, where opt-out behaviour signals insufficient feasibility gains rather than attitudinal resistance, the experimental design targets participants for whom behavioural thresholds are salient and potentially binding. The recruitment strategy therefore ensures continuity between the diagnostic role of MaaS bundle choice and the implementation phase of the experiment, allowing engagement, disengagement, and behavioural adjustment to be interpreted as context-dependent responses to feasibility conditions rather than as expressions of abstract preference or innovation acceptance.

Importantly, this selection strategy does not assume that all recruited participants will be equally able to engage with the experimental setting. On the contrary, it explicitly anticipates that differential engagement and attrition will emerge as further indicators of behavioural feasibility under implementation, a dimension examined in detail in the following section.

Composition of the selected experimental sample

Table 58 illustrates the distribution of mobility profiles within the initial pool of respondents and provides the empirical basis for the selection strategy adopted in the experiment. The data show that frequent car use for non-systematic mobility represents the largest group, accounting for more than half of the initial sample. This highlights the relevance of car use not only in routine university-related travel, but especially in discretionary and non-routine trips, where flexibility, trip chaining, and time constraints tend to play a central role.

A smaller but analytically significant share of respondents relies on private cars for systematic university-related mobility, indicating the presence of more structurally embedded forms of car dependence. At the same time, the inclusion of individuals with occasional or no car use confirms the heterogeneity of mobility practices within the broader population reached during recruitment. On this basis, the experimental sample was deliberately drawn from those groups exhibiting systematic

or frequent car use, for whom voluntary travel behaviour change is both most challenging and most policy-relevant.

Table 54 Mobility groups within the initial pool of participants

Mobility group	N
<i>Systematic car use for university-related mobility</i>	23
<i>Frequent car use for non-systematic mobility</i>	86
<i>Occasional car use for non-systematic mobility</i>	16
<i>No car use</i>	33
Total	158

Source 69 author's elaboration based on preliminary screening data

Following the selection process, participants were randomly assigned to either a treatment group or a control group. Random assignment ensures that exposure to the intervention is exogenous to individual mobility characteristics, reinforcing the internal validity of subsequent behavioural comparisons. Table 55 reports the main characteristics of the selected sample (N = 109) and their distribution across experimental groups. The two groups display a broadly comparable composition in terms of predominant commuting mode, home–university distance, attendance frequency, and frequency of car use for non-systematic mobility.

Table 55 Characteristics of the sample selected for the VTBC experiment, by experimental group

Characteristic	Total n (%)	Treatment n (%)	Control n (%)
<i>Predominant mode for travelling to university</i>			
<i>Private car</i>	23 (21.1)	15 (25.0)	8 (16.3)
<i>Public transport (bus, metro, train)</i>	78 (71.6)	42 (70.0)	36 (73.5)
<i>Personal bicycle</i>	3 (2.8)	1 (1.7)	2 (4.1)
<i>Walking</i>	2 (1.8)	2 (3.3)	0 (0.0)
<i>Home–university distance</i>			
<i>≤ 15 km</i>	24 (22.0)	12 (20.0)	12 (24.5)
<i>15–30 km</i>	33 (30.3)	20 (33.3)	13 (26.5)
<i>30–60 km</i>	37 (33.9)	23 (38.3)	14 (28.6)
<i>≥ 60 km</i>	12 (11.0)	5 (8.3)	7 (14.3)
<i>Frequency of university attendance</i>			
<i>Every day</i>	34 (31.2)	24 (40.0)	10 (20.4)
<i>3–4 times per week</i>	52 (47.7)	28 (46.7)	24 (49.0)
<i>Twice a week</i>	8 (7.3)	3 (5.0)	5 (10.2)
<i>Once a week</i>	4 (3.7)	2 (3.3)	2 (4.1)
<i>Twice a month</i>	8 (7.3)	3 (5.0)	5 (10.2)
<i>Frequency of car use for non-systematic mobility</i>			
<i>One or more times per day</i>	39 (35.8)	22 (36.7)	17 (34.7)
<i>Several times per week</i>	52 (47.7)	26 (43.3)	26 (53.1)
<i>Once per week</i>	18 (16.5)	12 (20.0)	6 (12.2)

Source 70 author's elaboration based on preliminary screening data.

Minor differences across groups reflect the constraints of real-world randomisation in a relatively small experimental sample and do not indicate systematic selection bias. Importantly, the treatment group is characterised by slightly higher commuting intensity and a marginally higher prevalence of car-based mobility, suggesting that any behavioural change observed among treated participants cannot be attributed to more favourable baseline conditions.

Attrition, effective participation, and scope conditions

At the conclusion of the recruitment and implementation process, 30 out of the 109 selected participants completed the VTBC experiment and generated usable tracking data. While this level of attrition is non-negligible, it should not be interpreted as a methodological failure. Rather, it should be read in direct continuity with the selective recruitment strategy adopted, as attrition constitutes a second-order feasibility filter operating at the level of sustained engagement rather than initial eligibility (Eysenbach, 2005; Pawson and Tilley, 1997; Fujii and Taniguchi, 2006).

Consistent with the literature on voluntary, digital and longitudinal behavioural interventions, attrition reflects differentiated capacities to sustain cognitive, organisational and temporal demands over time rather than random loss (Eysenbach, 2005; Fujii and Taniguchi, 2006; Stopher et al., 2007). Participation and continued engagement are therefore analytically meaningful outcomes, intrinsic to the logic of real-world VTBC interventions, and indicative of the scope conditions under which behavioural change can plausibly occur (Pawson and Tilley, 1997; Shadish, Cook and Campbell, 2002).

Participation in the experimental phases required sustained engagement over time, regular interaction with a digital tool, and willingness to share detailed mobility data across multiple weeks. These requirements impose non-trivial cognitive, organisational, and motivational demands on participants. As such, continued participation cannot be assumed to be neutral with respect to individual mobility constraints, daily routines, or perceived behavioural effort. Attrition therefore operates as an endogenous filter, selectively retaining those individuals for whom the experimental setting itself remains behaviourally feasible, and excluding those for whom the additional cognitive, organisational, or temporal demands exceed their existing capacity to adapt.

From a Voluntary Travel Behaviour Change perspective, this process is analytically consequential. VTBC theory emphasises that behavioural change unfolds through stages of readiness and that engagement with an intervention is itself a form of behavioural response. In this sense, non-participation or early disengagement should not be interpreted simply as lack of compliance, but as an indication that the intervention, independently of its substantive content, fails to fit within the participant's existing opportunity structure. Attrition thus signals the boundaries of feasibility within which voluntary change can realistically be observed.

This interpretation is consistent with habit-based and constraint-oriented accounts of travel behaviour, which conceptualise routines not as inertial residues, but as adaptive responses that

minimise cognitive load and risk under demanding conditions. For individuals operating close to their behavioural feasibility threshold, the additional effort required to engage with an experimental MaaS-enabled context may itself represent a destabilising factor, leading to rational withdrawal rather than sustained participation. In this light, attrition becomes a diagnostic indicator of intervention burden rather than a purely technical limitation.

Recognising attrition as a substantive outcome has direct implications for the interpretation of experimental results. Rather than assuming that behavioural change should be observable across the entire selected sample, the analysis explicitly acknowledges that observed changes pertain to a sub-sample for whom both participation and experimentation were behaviourally viable. This does not weaken the analytical value of the findings; instead, it clarifies the scope conditions under which MaaS-enabled contexts can be implemented and sustained.

To make these scope conditions explicit, the socio-mobility profile of effective participants is examined separately. This step serves three complementary purposes. First, it allows assessment of whether attrition has altered the composition of the sample in systematic ways, potentially amplifying self-selection effects related to commuting distance, attendance intensity, or mode dependence. Second, it provides the empirical baseline against which behavioural changes observed during the tracking phases must be interpreted, ensuring that change and non-change are read in relation to the structural conditions of those who remained engaged. Third, it allows the experiment to be repositioned analytically as a test of behavioural feasibility under implementation, rather than as a test of average treatment effects.

Table 56 reports on the socio-mobility characteristics of the 30 participants who effectively took part in the VTBC experiment and generated usable tracking data, distinguishing between treatment and control groups. Compared to the initially selected sample, effective participants are characterised by a strong predominance of public transport use for systematic university-related mobility, combined with persistent reliance on private cars for non-systematic activities. This configuration suggests that attrition has not eliminated car dependence from the experimental context, but has reshaped its expression, shifting it away from routine commuting and toward discretionary mobility.

Table 56 Characteristics of the effective participants in the VTBC experiment, by experimental group

<i>Characteristic</i>	<i>Total n (%)</i>	<i>Treatment n (%)</i>	<i>Control n (%)</i>
<i>Predominant mode for travelling to university</i>			
<i>Private car</i>	4 (13.3)	2 (11.8)	2 (15.4)
<i>Public transport (bus, metro, train)</i>	26 (86.7)	15 (88.2)	11 (84.6)
<i>Personal bicycle</i>	0 (0.0)	0 (0.0)	0 (0.0)
<i>Walking</i>	0 (0.0)	0 (0.0)	0 (0.0)
<i>Home–university distance</i>			
<i>≤ 15 km</i>	6 (20.0)	3 (17.6)	3 (23.1)
<i>15–30 km</i>	9 (30.0)	7 (41.2)	2 (15.4)
<i>30–60 km</i>	12 (40.0)	7 (41.2)	5 (38.5)
<i>≥ 60 km</i>	3 (10.0)	0 (0.0)	3 (23.1)
<i>Frequency of university attendance</i>			
<i>Every day</i>	9 (30.0)	7 (41.2)	2 (15.4)
<i>3–4 times per week</i>	13 (43.3)	8 (47.1)	5 (38.5)
<i>Twice a week</i>	3 (10.0)	1 (5.9)	2 (15.4)
<i>Once a week</i>	0 (0.0)	0 (0.0)	0 (0.0)
<i>Twice a month</i>	5 (16.7)	1 (5.9)	4 (30.8)
<i>Frequency of car use for non-systematic mobility</i>			
<i>One or more times per day</i>	10 (33.3)	5 (29.4)	5 (38.5)
<i>Several times per week</i>	15 (50.0)	9 (52.9)	6 (46.2)
<i>Once per week</i>	5 (16.7)	3 (17.6)	2 (15.4)

Source 71 author's elaboration based on preliminary screening data.

Importantly, the effective sample remains structurally constrained in key dimensions: medium- and long-distance commuting remains prevalent, attendance intensity is relatively high, particularly among treated participants, and non-systematic car use continues to play a central role in daily mobility. These features indicate that the intervention was not observed in the context of low constraint or high behavioural flexibility, but rather within a sub-sample still operating under significant organisational and structural pressures.

Taken together, these patterns define the concrete scope conditions of the VTBC experiment. The results presented in the following sections do not represent average behavioural responses among all selected participants, nor generalisable estimates of MaaS effectiveness. Instead, they capture behavioural dynamics observed among a group for whom participation itself was feasible, and for whom MaaS-enabled contexts could be meaningfully tested as potential facilitators, or inhibitors, of voluntary behavioural change. Within the logic of this thesis, such a reflexive and bounded interpretation constitutes a substantive analytical contribution, as it makes explicit the conditions under which behavioural change interventions can be implemented, sustained, and meaningfully evaluated under real-world constraints.

Descriptive foundations: mobility intensity and spatial organisation

Before assessing behavioural change, it is necessary to clarify the empirical context in which the VTBC experiment is observed. This chapter provides a descriptive baseline of recorded mobility, treating observed patterns not as intervention outcomes but as scope conditions that shape behavioural feasibility, exposure to decision points, and the interpretability of subsequent results.

The analysis proceeds in two complementary steps. First, it examines mobility intensity and exposure, using trip counts to characterise how frequently participants are engaged in everyday travel and how participation dynamics affect observed activity across phases. Second, it shifts attention from frequency to spatial organisation, documenting the territorial extent and administrative fragmentation of activity spaces and linking these spatial conditions to the coordination burden within which mobility routines are enacted.

Read together, these descriptive dimensions delineate the constraint-sensitive setting in which MaaS-enabled experimentation takes place. They provide the reference frame required to interpret later evidence on modal portfolios, intermodality and travel chains, and anchoring behavioural interpretations to the concrete mobility contexts experienced by participants.

Mobility intensity and exposure

This section provides a descriptive overview of mobility intensity among participants in the VTBC experiment, measured through the number of trips recorded by the app-based tracking system. The analysis covers both tracking phases and distinguishes between treatment and control groups, with the aim of characterising participants' exposure to everyday mobility practices prior to any assessment of behavioural change. Mobility intensity is treated here not as an outcome of the intervention, but as a structural condition shaping both opportunities for change and the effort required to engage with the experimental setting.

In a VTBC perspective, mobility intensity constitutes a critical conditioning variable rather than a background characteristic. Higher trip frequencies imply repeated exposure to decision points, coordination demands, and situational constraints, thereby increasing both the potential leverage of behavioural interventions and the cumulative effort required to engage with them. Conversely, lower mobility intensity limits opportunities for experimentation and renders short-term behavioural adjustments less observable. For this reason, differences in mobility intensity are analytically relevant not only for interpreting behavioural change, but also for understanding differential engagement with the experimental context itself.

The number of observed trips is adopted as the primary indicator of mobility intensity. This choice reflects both methodological and analytical considerations. From a measurement perspective, trip counts provide a robust and comparable indicator across individuals and phases, avoiding potential

distortions associated with distance or travel-time calibration in GPS-based data. From an analytical perspective, trip frequency captures the degree of daily engagement with mobility practices and therefore the extent to which individuals are exposed to the behavioural conditions targeted by the VTBC intervention.

Table 57 reports the number of trips recorded for each individual across the two tracking phases, offering a first micro-level insight into observed mobility intensity. Even before aggregation, substantial heterogeneity emerges both within and between experimental groups. In phase 1, treated participants tend to display higher levels of observed mobility, with several individuals recording a large number of trips, while the control group is more concentrated in lower and intermediate ranges. This pattern indicates that, already at baseline, treated participants are characterised by greater exposure to daily travel activities and more demanding mobility routines. From an analytical standpoint, this higher baseline exposure implies that treated participants operate within more saturated mobility schedules, where coordination costs, time pressure and routine consolidation are likely to be more salient. Within such contexts, voluntary behavioural change, if observed, cannot be attributed to spare capacity or low behavioural commitment, but must be interpreted as occurring under relatively demanding feasibility conditions. This reinforces the relevance of mobility intensity as a contextual precondition for interpreting subsequent behavioural dynamics.

Table 57 Number of trips per individual and phase

<i>ID</i>	<i>Group</i>	<i>Phase 1 – n. trips</i>	<i>Phase 2 – n. trips</i>
1	Treated	6	13
2		20	40
3		44	42
4		5	0
5		9	23
6		14	19
7		3	0
8		6	0
9		5	0
10		5	1
11		7	6
12		8	8
13		6	4
14		12	11
15		7	8
16		15	0
17		4	0
	Total	176	175
18	Control	1	0
19		3	2
20		13	0
21		5	4
22		4	0
23		18	7
24		15	21
25		1	3
26		4	1
27		5	14
28		1	0
29		20	17
30		1	0
	Total	91	69
		267	244

Source 72 author's elaboration based on app-based tracking data.

Across phases, individual trajectories reveal differentiated patterns of mobility intensity rather than uniform changes. A subset of participants in both groups maintains consistently high numbers of trips across the two phases, suggesting stable and intensive mobility routines. At the same time, other individuals exhibit lower or more sporadic levels of observed movement, contributing to a wide dispersion in the distribution of trips. These differences underline that mobility intensity is unevenly distributed within the experimental sample and reflect diverse daily activity patterns and degrees of spatial engagement.

Treated participants account for a substantially larger share of total trips in both tracking phases. While the overall number of observed trips decreases from phase 1 to phase 2, the treated group continues to generate a markedly higher volume of recorded movements than the control group (Table 58). This aggregate pattern reinforces the indication that treated participants are, on average, more intensely mobile and therefore more exposed to the behavioural and organisational conditions under which the VTBC intervention operates. Importantly, this differential exposure does not imply that treated participants are more predisposed to change. On the contrary, higher mobility intensity is often associated with stronger routine consolidation and reduced behavioural flexibility. In this sense, greater exposure simultaneously increases the number of potential leverage points for intervention while raising the behavioural costs of experimentation. This dual role of mobility intensity, as both opportunity and constraint, is central to the feasibility-oriented interpretation adopted in this thesis.

Table 58 Number of trips per group and phase

Group	Phase 1 – total trips	Phase 2 – total trips
<i>Treated</i>	176	175
<i>Control</i>	91	69
<i>Total</i>	267	244

Source 73 author's elaboration based on app-based tracking data.

Taken together, the individual- and group-level evidence highlights mobility intensity as a key dimension structuring the experimental sample. Differences in the number of trips do not simply reflect variation in travel behaviour, but also differential exposure to coordination demands, time pressure, and organisational effort, factors that are central to the feasibility of voluntary behavioural change.

Table 59 summarises the distribution of the number of trips by group and tracking phase, providing a consolidated view of mobility intensity, dispersion, and participation dynamics. To distinguish mobility intensity from tracking continuity, Table 59 reports phase 2 statistics both including zero-trip observations and conditional on effective participation.

Table 59 Number of trips by group and tracking phase

<i>Phase</i>	<i>Group</i>	<i>N participants</i>	<i>Mean trips</i>	<i>Std. dev.</i>	<i>Min</i>	<i>Max</i>
<i>Phase 1</i>	Treated	17	10.35	9.78	3	44
	Control	13	7.00	6.93	1	20
	Total	30	8.90	8.73	1	44
<i>Phase 2 (incl. 0 trips)</i>	Treated	17	10.29	13.52	0	42
	Control	13	5.31	7.30	0	21
	Total	30	8.13	11.37	0	42
<i>Phase 2 (participants only)</i>	Treated	11	15.91	13.93	1	42
	Control	8	8.63	7.65	1	21
	Total	19	12.84	11.69	1	42

Source 74 author's elaboration based on app-based tracking data.

Notes:

"Phase 2 (incl. 0 trips)" includes individuals with no valid tracking data in Phase 2, reflecting attrition.

"Phase 2 (participants only)" is conditional on effective participation (n. trips > 0).

Zero-trip observations indicate absence of valid tracking data, not absence of mobility.

In tracking phase 1, treated participants exhibit a higher average number of trips than the control group, confirming the individual-level patterns observed in Table 57. This difference is accompanied by substantial dispersion in both groups, as indicated by large standard deviations and wide ranges between minimum and maximum values. Mobility intensity within the sample is therefore highly heterogeneous, with participants characterised by markedly different levels of daily travel exposure.

In tracking phase 2, the inclusion of zero-trip observations leads to a general reduction in average mobility intensity, particularly within the control group. This decline should not be interpreted as a straightforward reduction in mobility behaviour. In app-based and longitudinal experiments, decreases in observed activity over time frequently reflect challenges related to sustained engagement with tracking technologies, such as managing permissions, maintaining app usage, or coping with participation burden, rather than actual reductions in daily mobility (Eysenbach, 2005; Stopher et al., 2007; Cottrill et al., 2013). Zero-trip observations thus primarily capture disengagement from tracking rather than the absence of travel (Stopher and Greaves, 2007; Bricka et al., 2012).

From a feasibility perspective, disengagement from tracking should be interpreted as part of the behavioural response to the intervention context rather than as missing data alone (Pawson and Tilley, 1997; Shadish, Cook and Campbell, 2002). Sustained participation in app-based tracking requires additional organisational and cognitive effort layered on top of existing mobility routines (Stopher et al., 2007; Wolf et al., 2004). For participants already operating under high mobility intensity, this added burden may exceed behavioural feasibility thresholds, leading to selective disengagement even in the absence of any reduction in actual travel activity (Eysenbach, 2005; Fujii and Taniguchi, 2006).

When the analysis is restricted to participants who generated at least one recorded trip in tracking phase 2, average mobility intensity increases substantially in both groups. Treated participants continue to display higher mean values, while variability remains pronounced. The persistence of high maximum values across phases indicates that a subset of participants maintains very intensive mobility routines throughout the experiment, reinforcing the interpretation that aggregate declines are driven by participation dynamics rather than behavioural contraction.

Overall, the descriptive evidence presented in this section highlights two analytically relevant features. First, systematic differences in mobility intensity between treatment and control groups suggest differentiated exposure to the conditions under which the VTBC intervention operates. Second, strong inter-individual variability and participation dynamics confirm that mobility intensity and engagement are unevenly distributed across the sample. These features define the empirical context in which subsequent analyses of modal composition, multimodality, and behavioural change must be interpreted, providing a transparent and coherent descriptive foundation for the sections that follow. In particular, recognising mobility intensity as a conditioning factor rather than a neutral descriptor is essential for interpreting subsequent analyses of modal composition and multimodality. Patterns of mode choice and intermodality observed in the following sections must be read against differentiated levels of exposure, routine saturation, and participation burden, which shape both the space of feasible behavioural adjustments and the likelihood that such adjustments can be empirically observed within a limited experimental timeframe.

Spatial extent, territorial fragmentation and mobility organisation

Having characterised mobility intensity as a conditioning dimension of behavioural feasibility, this section shifts attention to the spatial organisation of observed mobility, examining the territorial extent and administrative fragmentation of participants' activity spaces. The analysis shifts attention from how often participants move to where mobility unfolds, treating spatial organisation not as a background descriptor but as a conditioning dimension of behavioural feasibility.

Within a Voluntary Travel Behaviour Change (VTBC) framework, space is not conceived as a neutral backdrop to travel decisions. The spatial scale at which activities are distributed, ranging from intramunicipal movements to regional and national travel, shapes the coordination demands, temporal constraints and exposure to uncertainty that characterise everyday mobility practices.

The section builds directly on the preceding analysis of mobility intensity. While mobility intensity captures the frequency of exposure to travel decisions, spatial distribution qualifies the nature of that exposure by distinguishing between compact, territorially bounded mobility patterns and more extended or fragmented activity spaces. As a result, individuals with comparable numbers of observed trips may nevertheless operate under markedly different behavioural constraints, depending on the spatial reach and administrative complexity of their movements.

To make these differences explicit, trips are first classified according to their spatial typology, distinguishing movements within the City of Milan, the Metropolitan City of Milan, the wider Lombardy region, and the national territory. The analysis then examines whether trips cross municipal boundaries, as an indicator of territorial fragmentation and coordination burden. Finally, spatial patterns are related to modal deployment and intermodality, allowing the functional interplay between spatial scale, mode use and trip organisation to be explored.

By clarifying the spatial context of observed mobility practices, the section provides a structural reference for interpreting subsequent analyses of behavioural routines, intermodality and the functional role of the private car within everyday travel.

Table 60 describes the spatial distribution of observed trips by administrative scope, providing a first empirical characterisation of the activity spaces within which participants' everyday mobility unfolds. The table documents the territorial scales at which mobility is organised, thereby clarifying the spatial constraints that condition behavioural feasibility across experimental groups and tracking phases.

Table 60 Distribution of trips by spatial typology, group and tracking phase

<i>Trip spatial typology</i>	<i>Control – Phase 1</i>	<i>Control – Phase 2</i>	<i>Treated – Phase 1</i>	<i>Treated – Phase 2</i>
<i>City of Milan</i>	18	13	14	13
<i>Metropolitan City of Milan</i>	21	19	33	32
<i>Lombardy region</i>	35	14	118	66
<i>National territory</i>	17	23	11	64

Source 75 author's elaboration based on geolocalised origin–destination app-based tracking data.

Notes:

City of Milan includes trips with both origin and destination within the Municipality of Milan.

Metropolitan City of Milan includes trips with at least one end outside the Municipality of Milan but within the Metropolitan City of Milan.

Lombardy Region includes trips with at least one end outside the Metropolitan City of Milan but within Lombardy.

National territory includes trips with at least one end outside Lombardy.

Among control participants, trips are relatively evenly distributed across spatial typologies in tracking phase 1. A substantial share of observed mobility extends beyond the City of Milan into the wider Lombardy region and the national territory, indicating activity spaces that are spatially extended and territorially fragmented. This configuration suggests that everyday mobility for control participants frequently involves crossing administrative and geographic boundaries, with associated coordination and timing demands. In tracking phase 2, although the overall number of recorded trips declines, the relative presence of extra-regional and national trips remains significant.

The treated group displays a more concentrated spatial profile in tracking phase 1. The majority of observed trips extend beyond the Metropolitan City of Milan into the Lombardy region, indicating a strong orientation toward regional-scale mobility. This pattern is consistent with intensive and spatially extended activity spaces, plausibly associated with medium- and long-distance commuting,

dispersed activity locations, or tightly scheduled daily routines. At the same time, trips confined to the City of Milan account for a comparatively small share of observed mobility.

In tracking phase 2, treated participants continue to exhibit a pronounced regional component, alongside a marked increase in trips classified at the national scale. This redistribution should not be interpreted as spatial expansion induced by the experimental context. Rather, it reflects participation dynamics and the continued presence of individuals whose mobility is structurally anchored in long-distance and territorially fragmented patterns. From a behavioural feasibility perspective, such configurations imply elevated coordination demands, higher exposure to uncertainty, and limited tolerance for disruption.

Read comparatively, Table 60 shows that both experimental groups operate within non-local mobility regimes, but with important differences in scale and concentration. While control participants display a more balanced distribution across spatial levels, treated participants are characterised by a pronounced concentration of trips at the regional and supra-regional scale, particularly in tracking phase 1. This distinction suggests that treated participants enter the experimental setting with more spatially demanding mobility contexts, in which behavioural adjustments must be negotiated across larger distances and multiple administrative jurisdictions.

Overall, the spatial typologies documented in Table 60 confirm that the VTBC experiment unfolds within structurally constrained and territorially extended activity spaces rather than compact, locally bounded mobility environments. These spatial conditions are central to understanding subsequent patterns of modal integration, intermodality and routine consolidation. Extended and fragmented activity spaces tend to amplify coordination costs and shape the functional role of stabilising mobility resources, most notably the private car, within everyday travel portfolios. As such, spatial distribution constitutes a key conditioning dimension for interpreting the behavioural feasibility of MaaS-enabled mobility contexts.

Having established the territorial extent and administrative fragmentation of participants' activity spaces, the analysis now turns to how these spatial conditions translate into differentiated patterns of modal deployment and combination across space.

Table 61 complements spatial typology analysis by distinguishing trips according to their administrative scope, separating intramunicipal from intermunicipal mobility. While spatial typologies capture the territorial reach of trips, this distinction provides a more direct measure of administrative discontinuity in everyday travel and serves as a proxy for the level of organisational and coordination effort required to perform trips under existing institutional and infrastructural constraints.

Table 61 Trip administrative scope (intramunicipal vs intermunicipal) by group and tracking phase

Trip administrative typology	Control – Phase	Control – Phase	Treated – Phase	Treated – Phase
	1	2	1	2
Intermunicipal trips	59	35	102	81
Intramunicipal trips	32	34	74	94
Total trips	91	69	176	175

Source 76 author's elaboration based on geolocalised origin–destination app-based tracking data.

Notes:

Intramunicipal trips start and end within the same municipality.

Intermunicipal trips start and end in different municipalities.

Across both tracking phases, intermunicipal trips constitute a substantial share of observed mobility for both experimental groups. This confirms that participants' activity spaces frequently extend beyond municipal boundaries, reinforcing the interpretation emerging from Table 60: the VTBC experiment unfolds within mobility contexts characterised by structurally extended and administratively fragmented spatial configurations, rather than within locally bounded urban environments.

Marked differences nevertheless emerge between the two groups in the relative composition of trips. In tracking phase 1, while treated participants record a higher absolute number of intermunicipal trips, control participants exhibit a markedly higher *ratio* of intermunicipal to intramunicipal trips, with intermunicipal movements accounting for approximately twice the number of intramunicipal ones. This suggests that extended administrative scope characterises both groups, albeit through partially different mobility configurations.

For treated participants, the larger absolute volume of intermunicipal trips indicates that a substantial share of their mobility is organised across multiple municipalities, implying elevated coordination demands in terms of travel planning, timing alignment and modal integration. Intermunicipal mobility typically entails greater exposure to uncertainty, related to network interfaces, transfer reliability and institutional boundaries, which increases the behavioural effort required to sustain stable daily routines.

In tracking phase 2, intermunicipal trips decrease in absolute terms for both groups, reflecting participation dynamics, reduced observed activity, and potentially, period-specific factors related to the observation window rather than a substantive reorganisation of activity spaces. Importantly, intermunicipal mobility remains structurally relevant for both groups and continues to represent a large share of recorded trips among treated participants, suggesting that extended administrative scope is not incidental but a stable feature of their mobility organisation.

Intramunicipal trips, by contrast, represent a smaller but non-negligible component of observed mobility across both groups. Among treated participants, the increase in intramunicipal trips observed in tracking phase 2 should not be interpreted as a spatial contraction induced by the

experimental context. Rather, it reflects selective participation and the continued engagement of individuals whose mobility portfolios combine local and intermunicipal activities. The coexistence of intramunicipal and intermunicipal trips within the same individuals underscores the internal heterogeneity of activity spaces.

From a behavioural feasibility perspective, the prevalence of intermunicipal mobility, whether expressed in absolute terms or through high inter/intra ratios, is analytically significant. Crossing municipal boundaries typically amplifies coordination effort, reduces tolerance for disruption and increases reliance on predictable and controllable mobility resources. These conditions tend to reinforce the functional role of stabilising modes while simultaneously shaping the scope for modal integration and the necessity of intermodality.

Overall, Table 61 confirms that both experimental groups operate under conditions of high spatial and administrative complexity, albeit with different configurations. Treated participants exhibit particularly demanding mobility contexts in terms of absolute intermunicipal exposure, while control participants display a strong relative orientation toward intermunicipal travel in phase 1. Administrative fragmentation thus emerges as a key conditioning dimension for interpreting subsequent analyses of modal composition, intermodality and the role of the car. Understanding whether mobility unfolds within or across municipal boundaries is therefore essential not only for assessing how modes are combined, but for explaining why certain modes come to function as behavioural anchors within everyday travel practices.

While administrative scope captures the degree of territorial fragmentation characterising everyday mobility, it does not in itself explain how individuals operationally cope with these spatial constraints. The following analysis therefore examines how different transport modes are mobilised across spatial contexts, shedding light on the functional strategies through which mobility is organised under varying conditions of distance and coordination effort.

By adopting a presence-based modal intensity approach, Table 62 captures how modes coexist within trips under varying spatial conditions, rather than assuming exclusive substitution between alternatives. This perspective is particularly suited to contexts characterised by intermodality and articulated travel chains, where multiple modes may be functionally complementary within the same trip.

Table 62 Presence-based modal intensity by trip spatial typology, group and phase

<i>Trip spatial typology</i>	<i>Mode category</i>	<i>Control – Phase 1</i>	<i>Control – Phase 2</i>	<i>Treated – Phase 1</i>	<i>Treated – Phase 2</i>
<i>City of Milan</i>	Active mobility	17	6	6	3
	Car	1	5	0	3
	Public transport	9	8	13	11
<i>Metropolitan City of Milan</i>	Active mobility	12	14	16	25
	Car	15	17	21	17
	Public transport	5	2	29	25
<i>Lombardy region</i>	Active mobility	4	3	78	39
	Car	31	13	44	19
	Public transport	1	1	38	25
<i>National territory</i>	Active mobility	4	9	6	37
	Car	12	13	3	29
	Public transport	3	3	4	4

Source 77 author's elaboration based on geolocalised origin–destination app-based tracking data.

Notes:

Modal counts are calculated using a *mode-intensity presence-based approach*.

Each transport mode used within a trip contributes one count.

Trips involving multiple public transport services (e.g. train–bus–metro) contribute multiple public transport counts.

Figures do not sum to the total number of trips, as multiple modes may be used within the same trip.

Across both experimental groups, modal intensity varies systematically with spatial scope, confirming that the functional role of transport modes is strongly conditioned by the territorial extension of trips.

Within the City of Milan, mobility is primarily structured around public transport and active modes. This pattern is particularly evident among control participants in tracking phase 1 and among treated participants across both tracking phases. The very limited presence of the car in this spatial typology, especially within the treated group, suggests that, in dense and highly accessible urban contexts, motorised private mobility is not required as a stabilising resource. Here, spatial proximity, network density and service redundancy reduce coordination effort and allow mobility to be organised through modes characterised by lower individual control but higher collective availability.

As spatial scope expands to the Metropolitan City of Milan, modal intensity patterns become more differentiated. Active mobility remains present, particularly among treated participants, but the intensity of car use increases substantially for both groups. At the same time, public transport usage becomes markedly more prominent among treated participants than among controls. This configuration points to a transitional spatial regime in which multiple modes coexist to manage intermediate levels of distance, institutional fragmentation and coordination complexity. For treated participants, the combination of active mobility and public transport suggests the use of articulated modal configurations to navigate metropolitan-scale trips, whereas for control participants the car increasingly assumes a stabilising and simplifying role.

The most pronounced contrasts emerge for trips extending beyond the metropolitan boundary, within the Lombardy region and across the national territory. In these spatial typologies, car presence intensifies sharply among control participants, confirming the role of the private car as the primary coping mechanism for long-distance and institutionally fragmented mobility. In such contexts, public transport and active mobility play only marginal roles, indicating a strong reliance on a single, high-control mode to manage uncertainty, timing constraints and coordination effort.

Treated participants, by contrast, display a markedly different modal configuration in extended spatial contexts. Even for regional- and national-scale trips, public transport and active mobility maintain substantial presence alongside the car. This pattern indicates that spatial extension is managed not through exclusive reliance on private motorised mobility, but through modal integration, whereby different categories are combined to address specific functional requirements within the same trip. Importantly, the presence of active mobility in long-distance contexts reflects its role as an access, egress or connective component within articulated travel chains, rather than as a substitute for motorised modes.

From a behavioural feasibility perspective, these patterns reveal two distinct strategies for coping with spatial complexity. Among control participants, increasing spatial scope is associated with progressive modal concentration, as the car becomes the dominant organising resource used to minimise coordination effort and perceived behavioural risk. Among treated participants, spatial extension is instead associated with modal diversification, where complexity is managed through the combination of multiple modes rather than through consolidation around a single behavioural default.

Overall, Table 62 demonstrates that spatial scale is a key determinant of the functional role played by transport modes within everyday mobility practices. Differences between the experimental groups do not reflect simple preferences or differences in modal availability, but distinct organisational logic through which individuals respond to increasing spatial and institutional constraints. These findings provide a crucial analytical bridge toward the examination of intermodality by spatial typology, where the internal structure of trips and the necessity, or avoidance, of modal combination can be examined more directly.

Table 63 examines how intermodality is distributed across different spatial typologies. Read in conjunction with Table 62, the table clarifies not only where different modes are mobilised, but under which spatial conditions modal combination becomes structurally necessary or, conversely, behaviourally avoided.

Table 63 Intermodality by trip spatial typology, group and phase

<i>Trip spatial typology</i>	<i>Intermodality</i>	<i>Control – Phase 1</i>	<i>Control – Phase 2</i>	<i>Treated – Phase 1</i>	<i>Treated – Phase 2</i>
<i>City of Milan</i>	Monomodal	12	10	10	10
	Intermodal	6	3	4	3
<i>Metropolitan City of Milan</i>	Monomodal	11	6	19	16
	Intermodal	10	13	14	16
<i>Lombardy region</i>	Monomodal	34	11	87	52
	Intermodal	1	3	31	14
<i>National territory</i>	Monomodal	15	21	10	62
	Intermodal	2	2	1	2

Source 78 author's elaboration based on geolocalised origin–destination app-based tracking data.

Within the City of Milan, trips are predominantly monomodal for both experimental groups and across both tracking phases. The limited incidence of intermodal trips in this spatial context reflects the high density and functional redundancy of the urban transport system, where single-mode solutions, particularly public transport or walking, are generally sufficient to satisfy everyday mobility needs. In this setting, intermodality appears as optional rather than structurally required, and its limited presence does not differentiate the two groups in a substantive way.

Clearer contrasts emerge on the metropolitan scale. Within the Metropolitan City of Milan, the share of intermodal trips increases for both groups, but particularly among treated participants. At this spatial level, dispersion of activities and administrative fragmentation introduce coordination challenges that are not easily resolved through single-mode travel. For treated participants, intermodality functions as an adaptive organisational response, allowing different modes to be combined to manage access, distance and timing constraints. Among control participants, intermodal trips also increase, but remain more unevenly distributed across phases, suggesting a less systematic reliance on modal integration.

The divergence between the two groups becomes most pronounced for trips extending beyond the metropolitan boundary, within the Lombardy region. In this spatial typology, treated participants exhibit a substantial incidence of intermodal trips, whereas intermodality among control participants remains marginal. This contrast points to fundamentally different coping strategies under conditions of regional-scale mobility. For treated participants, extended spatial reach is managed through the integration of multiple modes, often combining active mobility with public transport, reflecting a capacity to assemble articulated travel chains under constraint. For control participants, by contrast, regional trips are overwhelmingly monomodal, consistent with the dominant reliance on the private car observed in previous analyses.

Trips on the national scale are almost entirely monomodal for both groups. This convergence suggests that, beyond a certain spatial threshold, intermodality loses its functional advantage and mobility is reorganised around single long-distance modes, whether private car or long-haul public

transport services. In such contexts, coordination costs, transfer penalties and institutional boundaries are likely to outweigh the benefits of modal integration, leading to behavioural simplification rather than further articulation.

Read together, the spatial distribution of trips, the modal intensity patterns, and the incidence of intermodality delineate a coherent picture of how spatial scale structures the organisation and feasibility of everyday mobility practices. Rather than acting as an independent backdrop, space operates as a conditioning framework within which different behavioural coping strategies are activated, shaping whether mobility is managed through modal concentration or modal integration.

At shorter spatial scales, particularly within the City of Milan, mobility is predominantly monomodal for both experimental groups, reflecting a context of high accessibility and modal redundancy where single-mode solutions are generally sufficient. In this setting, differences between groups are attenuated and intermodality remains optional rather than structurally required. As spatial extension increases to the metropolitan and regional levels, however, mobility practices become progressively more articulated, and it is at these intermediate scales that differences between groups become analytically salient.

For treated participants, increasing spatial reach is systematically associated with higher modal diversity and a greater reliance on intermodal configurations. Spatial complexity is addressed through the functional integration of active modes and public transport, allowing trips to be assembled as segmented chains tailored to access constraints, distance and institutional boundaries. For control participants, by contrast, extended spatial mobility is more often managed through modal concentration, with the private car functioning as a stabilising resource that reduces coordination effort and perceived behavioural risk. In this group, intermodality remains limited and largely auxiliary, even when spatial conditions would technically allow for integration.

At the largest spatial scale, the national territory, both groups converge toward predominantly monomodal mobility, suggesting the existence of an upper spatial threshold beyond which behavioural simplification becomes the dominant coping strategy. This convergence confirms that intermodality is not a linear function of distance, but emerges within a specific spatial window where complexity is high enough to require integration, yet not so high as to make single long-distance modes behaviourally dominant.

Overall, the spatial analysis demonstrates that intermodality is a context-dependent organisational response rather than a generalised behavioural trait. It emerges selectively under particular spatial and institutional conditions and interacts strongly with the broader mobility regimes characterising each group. By showing how spatial extension conditions modal integration, this chapter provides a crucial interpretative bridge to the subsequent analysis of travel chains and the functional role of the private car. The following section therefore shifts the focus from spatial differentiation to the internal

structure of trips, examining how modes are combined and positioned within travel chains under different regimes of behavioural feasibility.

Behavioural organisation of mobility: routine dominance and variability

Building on the evidence on mobility intensity, spatial extension and modal organisation, this section characterises the behavioural substrate within which the VTBC intervention unfolds, focusing on the degree of routine consolidation and behavioural variability. The focus shifts from how much and where participants travel to how their mobility is structured: the stability of modal routines, the breadth of modal-chain repertoires, and the degree to which behaviour is anchored to a dominant configuration versus distributed across multiple alternatives. This provides the behavioural baseline required to interpret subsequent evidence on modal portfolios and trip structure within a VTBC feasibility perspective.

Within this interpretative framework, stability and variability are treated as conditioning properties rather than outcomes. Highly stable routines typically reduce cognitive effort and coordination burden by stabilising expectations and decision-making, but may also delimit the behavioural space within which voluntary change can plausibly occur. Conversely, higher variability may reflect adaptive capacity and situational responsiveness, yet it can equally indicate structurally fragmented mobility with elevated organisational effort. The analytical goal is therefore not to rank behaviours, but to identify the behavioural regimes (routinised, flexible, or fragmented) within which exposure to the experimental context takes place.

Accordingly, the indicators introduced below are used to map routine dominance and modal repertoire at the individual level. By distinguishing between the breadth of modal chain configurations and the extent to which one configuration prevails, the analysis specifies the initial behavioural conditions of participants' mobility organisation and clarifies how feasibility, effort, and flexibility are distributed across the observed sample.

The individual-level indicators reported in Table 64 provide a detailed picture of how mobility practices are organised in terms of routine dominance and behavioural variability across participants and tracking phases. Rather than revealing uniform patterns, the table highlights pronounced heterogeneity in the internal structure of observed mobility, both within and between experimental groups.

Behavioural variability is operationalised through the combination of two indicators: the number of distinct modal chains observed over the tracking period and the modal variability ratio, defined as the ratio between distinct modal chains and total recorded trips. Higher values indicate more diversified mobility repertoires, while lower values signal stronger routine dominance. Complementarily, routine dominance is captured by the identification of the dominant modal chain

and its relative share of total trips, indicating the extent to which everyday mobility is anchored to a single recurrent configuration.

Because variability indicators are sensitive to the number of observed trips, interpretation is conditional on tracking exposure; configurations based on very low trip counts are therefore retained but treated cautiously in the profiling step that follows.

Table 64 Individual-level indicators of behavioural variability and routine dominance by tracking phase

<i>ID</i>	<i>Group</i>	<i>Phase</i>	<i>N trips</i>	<i>N distinct modal chains</i>	<i>Modal variability ratio</i>	<i>Dominant modal chain</i>	<i>Dominant chain share (%)</i>
1	Treated	Phase 1	6	3	0.50	car	50.0
1	Treated	Phase 2	13	2	0.15	foot	61.5
2	Treated	Phase 1	20	10	0.50	car	35.0
2	Treated	Phase 2	40	17	0.42	foot	35.0
3	Treated	Phase 1	44	4	0.09	bike	65.9
3	Treated	Phase 2	42	5	0.12	car	50.0
4	Treated	Phase 1	5	3	0.60	car	60.0
5	Treated	Phase 1	9	5	0.56	bike	33.3
5	Treated	Phase 2	23	4	0.17	bike	69.6
6	Treated	Phase 1	14	6	0.43	car	28.6
6	Treated	Phase 2	19	10	0.53	bike → train	15.8
7	Treated	Phase 1	3	2	0.67	foot	66.7
8	Treated	Phase 1	6	4	0.67	car	50.0
9	Treated	Phase 1	5	3	0.60	train → foot	40.0
10	Treated	Phase 1	5	1	0.20	car	100.0
10	Treated	Phase 2	1	1	1.00	foot	100.0
11	Treated	Phase 1	7	4	0.57	train	28.6
11	Treated	Phase 2	6	3	0.50	train	50.0
12	Treated	Phase 1	8	6	0.75	foot	25.0
12	Treated	Phase 2	8	5	0.62	car → foot	37.5
13	Treated	Phase 1	6	5	0.83	foot → metro	33.3
13	Treated	Phase 2	4	2	0.50	car	75.0
14	Treated	Phase 1	12	7	0.58	foot	25.0
14	Treated	Phase 2	11	5	0.45	train	63.6
15	Treated	Phase 1	7	2	0.29	foot	71.4
15	Treated	Phase 2	8	2	0.25	car	75.0
16	Treated	Phase 1	15	4	0.27	bike → train	33.3
17	Treated	Phase 1	4	1	0.25	car	100.0
18	Control	Phase 1	1	1	1.00	car	100.0
19	Control	Phase 1	3	2	0.67	train	66.7
19	Control	Phase 2	2	1	0.50	train	100.0
20	Control	Phase 1	13	3	0.23	car	76.9
21	Control	Phase 1	5	5	1.00	metro	20.0
21	Control	Phase 2	4	3	0.75	car	50.0
22	Control	Phase 1	4	2	0.50	car	75.0
23	Control	Phase 1	18	2	0.11	car	94.4

23	Control	Phase 2	7	1	0.14	car	100.0
24	Control	Phase 1	15	3	0.20	foot	80.0
24	Control	Phase 2	21	5	0.24	foot	52.4
25	Control	Phase 1	1	1	1.00	car	100.0
25	Control	Phase 2	3	1	0.33	car	100.0
26	Control	Phase 1	4	2	0.50	car	75.0
26	Control	Phase 2	1	1	1.00	car	100.0
27	Control	Phase 1	5	5	1.00	foot → train	20.0
27	Control	Phase 2	14	6	0.43	car	64.3
28	Control	Phase 1	1	1	1.00	bus	100.0
29	Control	Phase 1	20	4	0.20	car	40.0
29	Control	Phase 2	17	4	0.24	car → foot	47.1
30	Control	Phase 1	1	1	1.00	train → foot	100.0

Source 79 author's elaboration based on app-based tracking data.

Notes:

The table includes only individuals with at least one recorded trip in the corresponding phase.

Modal chains are defined as the ordered sequence of transport modes used within each trip (activityID).

The modal variability ratio is calculated as the number of distinct modal chains divided by the number of trips per individual and phase.

The dominant modal chain is the most frequently observed chain for each individual and phase.

The dominant chain share expresses the percentage of trips accounted for by the dominant chain.

Table 64 shows that markedly different behavioural organisations can coexist even among participants with comparable levels of mobility intensity. Some individuals display strongly routinised mobility, characterised by a limited number of modal chains and a dominant chain accounting for the large majority of observed trips. In these cases, mobility is structured around a clear behavioural default that stabilises expectations and reduces coordination effort by narrowing repeated decisions into a predictable configuration. Analytically, such patterns indicate high routine dominance and strong behavioural consolidation: variability is limited, and any voluntary adjustment would plausibly require a disruption, or a reconfiguration, of the prevailing chain rather than marginal variation at the margin.

At the opposite end of the spectrum, several participants exhibit a broad set of distinct modal chains combined with low dominant-chain shares. These profiles indicate mobility organised around multiple weakly prevailing configurations, where no single routine clearly structures daily travel. Within a VTBC perspective, this pattern is compatible with higher behavioural plasticity in the sense of greater scope for recombination and contingent decision-making. At the same time, it may also reflect structurally fragmented mobility, characterised by higher organisational effort and greater exposure to situational constraints. For this reason, high variability is not treated as inherently desirable; it is interpreted as an indicator of a mobility organisation that may be adaptive, but also potentially costlier in terms of coordination and cognitive load.

Between these extremes lies a wide range of intermediate configurations, in which a moderate repertoire of modal chains coexists with partial routine dominance. These cases point to mobility

practices that are structured but not monopolised by a single default: individuals rely on a limited set of recurrent configurations while retaining the capacity to switch between them in response to contextual cues. Importantly, flexibility here does not imply the absence of routines, but the presence of more than one stabilised option that can be activated under different conditions.

Comparing tracking phase 1 and phase 2 further supports the interpretation of variability as an organisational property rather than a direct reflection of experimental exposure. For several individuals, both repertoire and dominance indicators remain relatively stable across phases, suggesting persistent ways of managing mobility. For others, shifts occur either in the number of configurations used or in the dominance of the prevailing chain, indicating rebalancing rather than linear transitions from stability to variability (or vice versa). These dynamics underline that behavioural organisation is not fixed, but evolves within bounded ranges shaped by routines, situational demands, and the conditions of observation.

Crucially, Table 64 also shows that routine dominance and behavioural variability are not mechanically tied to specific modes. Highly routinised profiles can be centred on private car use, active mobility, or public transport, while highly variable profiles often involve intermodal chains combining walking, cycling, and rail-based services. This reinforces the analytical distinction between modal choice and behavioural structure: within a VTBC framework, what matters is not only which modes are used, but how consistently and flexibly they are combined over time, and whether mobility is governed by a single prevailing configuration or by a broader and weaker set of defaults.

Overall, the individual-level indicators in Table 64 establish a behavioural reference frame for the experiment. They show that participants enter the experimental setting with markedly different combinations of routine dominance and modal repertoire, implying differentiated degrees of behavioural consolidation, coordination burden, and scope for reconfiguration. Mapping variability and dominance at the individual level therefore shifts the focus from outcomes to conditioning structure, providing the basis for the composite profiles developed in the next section and for interpreting subsequent analyses of multimodality, intermodality, and the role of the car.

To synthesise the individual-level indicators of behavioural variability and routine dominance discussed above, a two-dimensional classification framework is introduced. The framework combines the breadth of the modal repertoire with the degree of dominance of the prevailing modal chain, allowing mobility practices to be positioned along a continuum ranging from highly routinised to highly variable organisational configurations. Rather than identifying behavioural outcomes, this classification serves to structure observed mobility practices in terms of routine consolidation and flexibility, thereby clarifying the behavioural starting conditions of participants.

Modal repertoire class (based on the number of distinct modal chains observed per individual and phase):

- *Low repertoire*: 1–2 modal chains
- *Medium repertoire*: 3–5 modal chains
- *High repertoire*: ≥ 6 modal chains

The repertoire class captures the breadth of behavioural configurations activated within everyday mobility. A low repertoire indicates reliance on a very limited set of modal arrangements, suggesting narrow behavioural articulation, while a high repertoire reflects the activation of multiple modal combinations across trips. Importantly, a broader repertoire does not necessarily imply greater ease or lower constraint, but rather a wider range of organisational responses to situational demands consistent with interpretations of behavioural variability in complex activity–travel systems (Axhausen et al., 2002; Heinen & Chatterjee, 2015).

Routine dominance class (based on the share of trips accounted for by the dominant modal chain):

- *High dominance*: $\geq 70\%$
- *Medium dominance*: 40–69.9%
- *Low dominance*: $< 40\%$

The dominance class reflects the extent to which observed mobility is structured around a prevailing routine. High dominance indicates strong routine consolidation, where a single configuration functions as a behavioural default across most trips. Medium dominance captures partially stabilised routines combined with meaningful alternation, while low dominance signals the absence of a clearly prevailing configuration and a more distributed organisation of mobility practices. This interpretation is consistent with habit literature, which conceptualises routine strength in terms of behavioural repetition and concentration rather than attitudinal commitment (Verplanken & Wood, 2006; Bamberg et al., 2011).

The thresholds adopted to define repertoire and dominance classes are not intended to identify behavioural “types” in a strict or psychological sense, but to support a transparent and analytically meaningful structuring of observed mobility practices. In line with the feasibility-oriented perspective adopted throughout the thesis, these thresholds are designed to capture qualitatively different regimes of behavioural organisation, rather than fine-grained individual differences, following an approach commonly adopted in exploratory and diagnostic mobility research (Stopher et al., 2007; Shove, Pantzar & Watson, 2012).

Given the limited sample size and the exploratory–diagnostic purpose of the analysis, threshold selection prioritises interpretability and robustness over statistical optimization (Shadish, Cook & Campbell, 2002). The objective is to distinguish between mobility practices that are structurally anchored by a dominant routine, those that are flexible but organised, and those that are highly variable or weakly stabilised, in a way that is consistent with the constraint-based interpretation developed in the baseline and MaaS chapters.

For the modal repertoire, the cut-offs between low (1–2 chains), medium (3–5 chains), and high (≥ 6 chains) are grounded in both the empirical distribution of observed chains and their behavioural meaning. One or two modal chains typically correspond to clearly routinised or narrowly articulated mobility practices, where behavioural effort is minimised through repetition (Verplanken et al., 2008). A repertoire of three to five chains indicates the presence of multiple stabilised alternatives, suggesting a form of structured flexibility in which adaptation occurs within bounded limits (Heinen & Chatterjee, 2015). Values equal to or above six identify mobility practices characterised by a level of articulation that goes beyond occasional variation and reflects either systematic multimodality or behavioural fragmentation, as discussed in the activity-based mobility literature (Axhausen et al., 2002).

For routine dominance, the thresholds of 70% and 40% are chosen to distinguish between clearly prevailing routines, partially stabilised configurations, and the absence of a dominant behavioural default. A dominant chain share of 70% or more indicates that a single configuration structures the large majority of observed trips, justifying its interpretation as a behavioural anchor (Verplanken & Wood, 2006). Shares between 40% and 69.9% reflect intermediate situations in which a routine exists but does not monopolise behaviour, while values below 40% signal weak dominance and high dispersion across configurations. These cut-offs allow routine consolidation to be assessed in relative terms, avoiding the overinterpretation of dominance in contexts where mobility practices are already segmented or situationally contingent.

Overall, the thresholds are deliberately conservative and descriptive. Their function is not to infer latent preferences or predict behavioural change, but to locate observed mobility practices within a structured space of routine strength and behavioural flexibility. This positioning is essential for interpreting how individuals operating under different baseline feasibility conditions may engage with, sustain, or disengage from MaaS-enabled mobility contexts.

By mapping mobility practices along the two dimensions of repertoire breadth and routine dominance, the classification framework makes explicit the behavioural feasibility conditions under which the experimental intervention unfolds. In particular, it clarifies whether MaaS-enabled configurations are encountered by participants whose mobility is anchored in strong routines, organised through flexible but stabilised alternatives, or already characterised by high variability and coordination effort. This distinction is central to the subsequent analysis, as the behavioural relevance of MaaS does not depend on abstract openness to innovation, but on whether integrated mobility contexts interact with existing routines by reinforcing, reconfiguring, or exceeding their feasibility thresholds.

By crossing repertoire and dominance classes, nine composite behavioural profiles are defined, as summarised in Table 65. These profiles represent analytically distinct configurations of mobility organisation, positioned along two fundamental dimensions: the breadth of modal configurations

activated in everyday travel and the degree to which a single configuration structures observed behaviour.

Table 65 Composite profiles of mobility routines and behavioural variability

<i>Repertoire \ Dominance</i>	<i>High dominance (≥70%)</i>	<i>Medium dominance (40–69.9%)</i>	<i>Low dominance (<40%)</i>
<i>Low repertoire (1–2)</i>	A – Routinised stable	B – Mostly stable	C – Rare but unstable
<i>Medium repertoire (3–5)</i>	D – Structured flexibility	E – Flexible routine	F – Adaptive variability
<i>High repertoire (≥6)</i>	G – Complex but anchored	H – High variability	I – Explorative / fragmented

Source: 80 author's elaboration

Each profile corresponds to a specific combination of stability, flexibility and organisational effort, reflecting different ways in which mobility practices are structured under constraint.

- *Profile A – Routinised stable*: mobility organised around a very limited set of configurations, dominated by a single routine. Behaviour is highly stabilised and habit-driven, with low variability and reduced cognitive effort.
- *Profile B – Mostly stable*: a small number of configurations are used with meaningful alternation. A dominant routine exists, but does not fully monopolise behaviour.
- *Profile C – Rare but unstable*: low repertoire combined with weak dominance, typically associated with intermittent mobility patterns or limited exposure rather than consolidated routines.
- *Profile D – Structured flexibility*: a relatively broad repertoire coexists with a clearly dominant routine, indicating flexibility anchored to a stable behavioural default.
- *Profile E – Flexible routine*: medium repertoire and medium dominance. Mobility is organised around a balanced combination of stability and adaptability, with multiple recurrent configurations. This profile is particularly relevant for MaaS-enabled contexts, where integration builds on existing flexibility without requiring full routine disruption.
- *Profile F – Adaptive variability*: a moderate number of configurations with no clearly prevailing routine, suggesting context-dependent or opportunistic decision-making under variable constraints.
- *Profile G – Complex but anchored*: high behavioural complexity combined with a dominant routine, where variability is managed around a stable core configuration.
- *Profile H – High variability*: a broad repertoire with medium dominance, indicating frequent variation across trips while maintaining some recurring preferences.
- *Profile I – Explorative / fragmented*: high repertoire and low dominance, with no behavioural default. This profile may reflect high flexibility, but also potential instability, fragmentation or elevated cognitive burden.

Importantly, these profiles are analytical categories rather than normative judgements. Higher variability does not necessarily imply more sustainable, desirable or “progressive” behaviour, just as stability does not imply resistance to change. Instead, the profiles identify different behavioural starting conditions in terms of habit’s strength, flexibility and organisational burden. As such, they provide a structured lens through which subsequent analyses of intermodality, car use and behavioural dynamics can be interpreted within a VTBC framework.

To ensure transparency in the interpretation of individual-level variability indicators, a data sufficiency flag is introduced. Individuals with fewer than three recorded trips within a given phase are retained in the analysis but flagged as having low data sufficiency. In these cases, the identification of dominant modal chains and composite profiles is necessarily sensitive to limited observation and should be interpreted with caution. This procedure avoids conflating behavioural variability with low observational exposure, while preserving the descriptive integrity of the panel structure.

- *Sufficient data*: N trips ≥ 3
- *Low data sufficiency*: N trips < 3

Table 65 reports the composite behavioural variability profiles assigned to each participant by tracking phase, integrating information on modal repertoire and routine dominance. Read at the individual level, the table makes visible the diversity of behavioural configurations within the experimental sample and highlights how mobility practices are structured prior to any assessment of behavioural change.

Table 66 Composite behavioural variability profile by individual and phase

ID	Group	Phase	Repertoire class	Dominance class	Composite profile
1	Treated	Phase 1	Medium	Medium	E – Flexible routine
1	Treated	Phase 2	Low	Medium	B – Mostly stable
2	Treated	Phase 1	High	Low	I – Explorative / fragmented
2	Treated	Phase 2	High	Low	I – Explorative / fragmented
3	Treated	Phase 1	Medium	Medium	E – Flexible routine
3	Treated	Phase 2	Medium	Medium	E – Flexible routine
4	Treated	Phase 1	Medium	Medium	E – Flexible routine
5	Treated	Phase 1	Medium	Low	F – Adaptive variability
5	Treated	Phase 2	Medium	Medium	E – Flexible routine
6	Treated	Phase 1	High	Low	I – Explorative / fragmented
6	Treated	Phase 2	High	Low	I – Explorative / fragmented
7	Treated	Phase 1	Low	Medium	B – Mostly stable
8	Treated	Phase 1	Medium	Medium	E – Flexible routine
9	Treated	Phase 1	Medium	Medium	E – Flexible routine
10	Treated	Phase 1	Low	High	A – Routinised stable
10	Treated	Phase 2	Low	High	A – Routinised stable (<i>low data suff.</i>)
11	Treated	Phase 1	Medium	Low	F – Adaptive variability
11	Treated	Phase 2	Medium	Medium	E – Flexible routine

12	Treated	Phase 1	High	Low	I – Explorative / fragmented
12	Treated	Phase 2	Medium	Low	F – Adaptive variability
13	Treated	Phase 1	Medium	Low	F – Adaptive variability
13	Treated	Phase 2	Low	High	A – Routinised stable
14	Treated	Phase 1	High	Low	I – Explorative / fragmented
14	Treated	Phase 2	Medium	Medium	E – Flexible routine
15	Treated	Phase 1	Low	High	A – Routinised stable
15	Treated	Phase 2	Low	High	A – Routinised stable
16	Treated	Phase 1	Medium	Low	F – Adaptive variability
17	Treated	Phase 1	Low	High	A – Routinised stable
18	Control	Phase 1	Low	High	A – Routinised stable (<i>low data suff.</i>)
19	Control	Phase 1	Low	Medium	B – Mostly stable
19	Control	Phase 2	Low	High	A – Routinised stable (<i>low data suff.</i>)
20	Control	Phase 1	Medium	High	D – Structured flexibility
21	Control	Phase 1	Medium	Low	F – Adaptive variability
21	Control	Phase 2	Medium	Medium	E – Flexible routine
22	Control	Phase 1	Low	High	A – Routinised stable
23	Control	Phase 1	Low	High	A – Routinised stable
23	Control	Phase 2	Low	High	A – Routinised stable
24	Control	Phase 1	Medium	High	D – Structured flexibility
24	Control	Phase 2	Medium	Medium	E – Flexible routine
25	Control	Phase 1	Low	High	A – Routinised stable (<i>low data suff.</i>)
25	Control	Phase 2	Low	High	A – Routinised stable
26	Control	Phase 1	Low	High	A – Routinised stable
26	Control	Phase 2	Low	High	A – Routinised stable (<i>low data suff.</i>)
27	Control	Phase 1	Medium	Low	F – Adaptive variability
27	Control	Phase 2	High	Medium	H – High variability
28	Control	Phase 1	Low	High	A – Routinised stable (<i>low data suff.</i>)
29	Control	Phase 1	Medium	Medium	E – Flexible routine
29	Control	Phase 2	Medium	Medium	E – Flexible routine
30	Control	Phase 1	Low	High	A – Routinised stable (<i>low data suff.</i>)

Source 81 author's elaboration based on app-based tracking data.

The first salient result is the marked heterogeneity of behavioural profiles, particularly within the treated group. This dispersion indicates that treated participants do not enter the experimental setting with a homogeneous behavioural baseline. Instead, exposure to the intervention intersects with markedly different combinations of habit strength, flexibility and organisational complexity. From a VTBC perspective, this heterogeneity is analytically relevant because it implies that the same experimental context is experienced under very different behavioural feasibility conditions.

By contrast, the mobility among control participants is more frequently organised around consolidated behavioural defaults, with fewer cases of extensive exploration or fragmentation.

Looking across phases, the table also shows that stability and variability are not fixed attributes, but properties that may evolve over time within bounded ranges. Some individuals maintain the same

composite profile across both phases, indicating stable behavioural organisation despite continued observation. Others exhibit transitions between profiles, often driven by changes in dominance rather than by radical expansions or contractions of the modal repertoire. These shifts point to rebalancing processes, routines may be reinforced, weakened or reorganised in response to contextual and organisational conditions, rather than to linear trajectories from stability to variability or vice versa. Importantly, such movements should not be interpreted as directional change or improvement.

The presence of profiles flagged with low data sufficiency further underlines the importance of cautious interpretation. In cases with very limited observed trips, high dominance and low repertoire may reflect restricted observational exposure rather than genuinely consolidated routines. By explicitly flagging these cases, the analysis avoids conflating behavioural stability with data scarcity and preserves the descriptive and diagnostic nature of the profiling exercise.

Overall, the distribution of composite behavioural profiles confirms that routine consolidation and behavioural variability coexist within the experimental sample, often within the same group and, in some cases, within the same individual across phases. Within a VTBC framework, this finding is central: behavioural change cannot be meaningfully interpreted without first understanding the structure and strength of existing routines. They delineate the behavioural landscape within which the intervention unfolds, clarifying where habits are strong, where flexibility is already present, and where mobility practices are fragmented or exploratory.

Table 67 provides a synthetic overview of the distribution of composite behavioural variability profiles by experimental group and tracking phase, allowing the behavioural landscape of the VTBC experiment to be read at a glance.

Table 67 Composite behavioural variability profiles by group and phase

<i>Repertoire \ Dominance</i>	<i>High dominance (≥70%)</i>	<i>Medium dominance (40–69.9%)</i>	<i>Low dominance (<40%)</i>
<i>Low repertoire (1–2)</i>	<i>A – Routinised stable</i> Treated – Phase 1: 4 Treated – Phase 2: 3 Control – Phase 1: 6 Control – Phase 2: 4	<i>B – Mostly stable</i> Treated – Phase 1: 2 Treated – Phase 2: 1 Control – Phase 1: 1 Control – Phase 2: 0	<i>C – Rare but unstable</i> Treated – Phase 1: 0 Treated – Phase 2: 0 Control – Phase 1: 0 Control – Phase 2: 0
<i>Medium repertoire (3–5)</i>	<i>D – Structured flexibility</i> Treated – Phase 1: 0 Treated – Phase 2: 0 Control – Phase 1: 2 Control – Phase 2: 0	<i>E – Flexible routine</i> Treated – Phase 1: 5 Treated – Phase 2: 4 Control – Phase 1: 1 Control – Phase 2: 3	<i>F – Adaptive variability</i> Treated – Phase 1: 4 Treated – Phase 2: 2 Control – Phase 1: 2 Control – Phase 2: 0
<i>High repertoire (≥6)</i>	<i>G – Complex but anchored</i> Treated – Phase 1: 0 Treated – Phase 2: 0 Control – Phase 1: 0 Control – Phase 2: 0	<i>H – High variability</i> Treated – Phase 1: 0 Treated – Phase 2: 0 Control – Phase 1: 0 Control – Phase 2: 1	<i>I – Explorative / fragmented</i> Treated – Phase 1: 2 Treated – Phase 2: 1 Control – Phase 1: 0 Control – Phase 2: 0

Source 82 author's elaboration based on app-based tracking data.

The first salient result concerns the strong concentration of control participants in highly routinised profiles. In both tracking phases, the control group is predominantly anchored in Profile A (Routinised stable), which represents the most consolidated behavioural configuration: a low modal repertoire combined with a highly dominant routine. This concentration indicates that mobility among control participants is largely organised around stable behavioural defaults, characterised by limited internal differentiation and low behavioural flexibility. Even in tracking phase 2, when some redistribution across profiles occurs, routinised configurations continue to dominate, underscoring the persistence of consolidated routines over time.

By contrast, the treated group occupies a much wider portion of the profile space. Already in phase 1, treated participants are distributed across multiple profiles, including Flexible routine (E), Adaptive variability (F) and Explorative/fragmented (I), alongside routinised configurations. This dispersion signals that treated participants enter the experimental setting with heterogeneous behavioural structures, characterised by varying degrees of routine strength, flexibility and organisational complexity. Importantly, this heterogeneity is not an effect of the intervention, but a property of the behavioural baseline shaped by selective recruitment and self-selection processes.

The comparison across phases further highlights that exposure to the experimental context unfolds within different behavioural regimes. In the treated group, phase 2 does not produce convergence toward a single dominant configuration, nor a uniform shift toward greater variability. Instead, profiles remain distributed across the central area of the matrix, with a continued presence of Flexible routine (E) and Adaptive variability (F), and a smaller but persistent share of Explorative/fragmented

profiles (I). This pattern suggests that treated participants continue to manage mobility through a combination of routines and adaptive strategies, rather than through systematic consolidation or destabilisation of behaviour.

Two additional structural features of the distribution are analytically relevant. First, the near absence of Profile G (Complex but anchored) across both groups and phases indicates that highly complex mobility configurations anchored to a strong routine are rare within the sample. Where behavioural complexity emerges, it is more often associated with weakened dominance rather than with the consolidation of a complex behavioural default, reinforcing the interpretation that higher complexity tends to entail greater organisational effort and reduced routine strength. Second, the virtual absence of Profile C (Rare but unstable) suggests that configurations combining low repertoire and low dominance, often linked to sporadic mobility or limited exposure, are not prevalent among effective participants, supporting the relevance of the data sufficiency threshold adopted in the analysis.

Overall, Table 67 shows that the two experimental groups differ not only in mobility intensity or spatial extension, but in the structural organisation of their mobility practices. The control group is characterised by a narrow behavioural corridor dominated by routinised stability, whereas the treated group operates within a broader and more differentiated behavioural space. Within a VTBC framework, this distinction is critical: voluntary behavioural change does not occur in a vacuum, but is conditioned by the degree of routine consolidation and behavioural flexibility that characterises individuals at baseline.

Against this behavioural baseline, the next section turns to the composition of mobility portfolios, examining which modes are present and how they combine into functional categories, before moving to the internal structure of trips and the role played by the car within travel chains.

Modal architecture of mobility: portfolios, chains and the role of the car

This chapter moves from the spatial context described above to the internal organisation of mobility, examining how participants assemble and stabilise their travel practices under real-world constraints. Rather than approaching modes as isolated alternatives, the analysis treats mobility as an organisational system made of portfolios (the set of modes mobilised over time) and travel chains (the way modes are combined within trips). In a VTBC feasibility perspective, these structures are analytically prior to behavioural change: they define the resources, coordination effort and behavioural risk within which any voluntary adjustment could plausibly occur.

The chapter is organised in two complementary steps. The first focuses on mobility portfolios and modal organisation, documenting which modes are present in observed practices and how the balance between private car, active mobility and public transport structures everyday mobility

regimes. The second examines trip structure, shifting from mode presence to the internal composition of journeys, monomodal versus intermodal trips, recurrent chain typologies, and the functional position of the car within chains (organising backbone, access/egress component, or absence).

Together, these analyses clarify not only what modes are used, but how they operate as behavioural resources under constraint. This provides the necessary foundation for interpreting subsequent evidence on intermodality, routine consolidation and the potential scope, if any, for behavioural reconfiguration within the experimental setting.

Mobility portfolios and modal organisation under constraint

This section shifts the analytical focus from the spatial and behavioural structure of mobility to its modal architecture, examining how participants assemble and stabilise their mobility portfolios under real-world constraints. Rather than treating modes as isolated alternatives the analysis approaches modal composition as a structural property of everyday mobility practices. Phase-to-phase differences are therefore interpreted descriptively and in light of tracking continuity and participation dynamics.

Building on the behavioural regimes identified in the previous section (routinised, flexible and fragmented), the analysis concentrates on two closely related questions: which modes are structurally present in participants' mobility portfolios, and how the functional balance between private car, active mobility and public transport organises everyday travel. In this perspective, modal composition is not a secondary descriptor but a key element of behavioural organisation, shaping coordination effort, perceived behavioural risk and the range of feasible adjustments available to individuals.

Modal composition is examined prior to any assessment of change because it defines the opportunity structure within which voluntary behavioural reconfiguration may, or may not, occur. As shown in the previous section, participants differ substantially in terms of mobility intensity, spatial extension and routine consolidation. These differences imply heterogeneous degrees of exposure to daily travel decisions and differentiated feasibility conditions for integrating alternative modes. Understanding how mobility portfolios are structured is therefore a necessary analytical prerequisite for interpreting subsequent patterns of multimodality, intermodality, car use and behavioural adaptation within a VTBC framework.

Table 68 reports the presence-based modal share for treatment and control groups across the two tracking phases. A presence-based approach is adopted to reflect the fact that trips may involve multiple transport modes, and that modes often coexist within the same travel chain rather than replacing one another on a one-to-one basis.

Interpreted in this way, the table reveals how mobility practices are functionally organised under existing constraints. The relative prominence of different modes indicates whether mobility portfolios are structured around a dominant organising resource, such as the private car, or around more articulated combinations of active and collective transport. This distinction is analytically central within a VTBC framework, as it conditions both the perceived effort associated with mobility and the behavioural space available for voluntary change.

Across both tracking phases, Table 68 reveals clear and persistent differences in the structural organisation of mobility between the two experimental groups. These differences do not concern marginal variations in the use of specific modes, but rather reflect distinct modal logics underpinning everyday travel practices.

Table 68 Presence-based modal share by group and tracking phase

Group	Mode	Phase 1 – trips with mode	Phase 1 – share (%)	Phase 2 – trips with mode	Phase 2 – share (%)
<i>Control</i>	Car	59	64.8	48	69.6
	Foot	35	38.5	32	46.4
	Bus	7	7.7	4	5.8
	Metro	6	6.6	6	8.7
	Train	5	5.5	4	5.8
	Bike	2	2.2	0	0.0
	Total trips	91		69	
<i>Treated</i>	Car	68	38.6	66	37.7
	Foot	55	31.3	62	35.4
	Bike	51	29.0	42	24.0
	Train	48	27.3	36	20.6
	Metro	22	12.5	18	10.3
	Bus	12	6.8	9	5.1
	Tram	2	1.1	2	1.1
	Motorbike	0	0.0	2	1.1
	Total trips	176		175	

Source 83 author's elaboration based on app-based tracking data.

Notes:

Modal shares are calculated at the trip level (activityID) following a presence-based approach.

A trip contributes to a given mode if that mode is used in at least one segment of the trip.

Percentages do not sum to 100%, as trips may include multiple modes.

Among control participants, mobility is strongly centred on private car use. The car is present in nearly two thirds of trips in tracking phase 1 and increases further in tracking phase 2, confirming its role as the dominant organising resource within this group's mobility portfolio. This configuration suggests a strategy in which the car functions as a stabilising backbone, relied upon to manage time constraints, coordination demands and variability across daily activities.

Walking, however, plays a distinct and non-marginal role within this configuration. Its substantial and increasing presence across both phases indicates that walking operates as a complementary mode closely integrated with car-based mobility, rather than as an independent alternative. Walking appears primarily to support short-distance access, last-mile connections, and activity chaining within car-centered travel patterns, reinforcing rather than challenging the dominant role of the car.

By contrast, other modes, such as bus, metro, train and cycling, remain weakly represented and display limited temporal stability. Their low presence and lack of growth across phases suggest that they do not function as autonomous organising resources within the control group's mobility system, but rather as occasional or situational supplements with minimal capacity to restructure everyday travel practices.

By contrast, treated participants exhibit a markedly more diversified modal composition across both phases. While the car remains a relevant component of their mobility practices, it is present in a substantially smaller share of trips and does not dominate the portfolio. Active modes and public transport feature prominently and persistently, often coexisting within the same trips. This pattern indicates that mobility among treated participants is organised around articulated and segmented travel chains, where different modes are mobilised to fulfil specific functional roles rather than substituted wholesale for one another.

From a feasibility perspective, these configurations imply fundamentally different ways of coping with everyday mobility constraints. The treated group's modal portfolios are characterised by higher redundancy and functional flexibility, which may expand the space of feasible options but also entail greater organisational effort, coordination demands and cognitive load. In contrast, the control group's strong reliance on the car reflects a strategy oriented towards minimising complexity and uncertainty by anchoring mobility practices around a single, high-control mode.

These patterns delineate distinct mobility regimes within which subsequent analyses of intermodality, car use and behavioural dynamics must be situated. By clarifying the structural role of different modes prior to and after intervention effects, Table 68 establishes the necessary analytical context for examining how mobility practices are internally organised and how the private car is positioned within broader travel chains.

Aggregating modal shares into three functional categories, private car, active mobility and public transport, allows the structural differences between the two experimental groups to be interpreted more clearly, by abstracting from individual modes and focusing instead on the dominant organising logics of mobility practices (Table 69).

Table 69 Presence-based modal share by group and tracking phase, aggregated by main mode

Group	Mode category	Phase 1 – trips with mode	Phase 1 – share (%)	Phase 2 – trips with mode	Phase 2 – share (%)
Control	Car	59	64.8	48	69.6
	Active mobility	37	40.7	32	46.4
	Public transport	18	19.8	14	20.3
	Total trips	91		69	
Treated	Car	68	38.6	68	38.8
	Active mobility	106	60.2	104	59.4
	Public transport	84	47.7	65	37.1
	Total trips	176		175	

Source 84 author's elaboration based on app-based tracking data.

Notes:

Modal categories are defined as follows: *Car* includes car and motorbike, *Active mobility* includes walking and cycling, *Public transport* includes bus, metro, train and tram.

Modal shares are calculated using a presence-based approach: a trip is counted under a given category if that mode is used in at least one segment of the trip.

Percentages do not sum to 100%, as trips may involve multiple mode categories.

Among control participants, private car use clearly constitutes the central pillar of mobility across both phases. The car is present in nearly 70% of trips and consistently outweighs both active mobility and public transport. This configuration points to a mobility regime in which access, timing and coordination are primarily secured through reliance on a single, high-control mode. Active mobility and public transport play secondary and supportive roles, complementing car-based travel rather than structuring mobility independently.

By contrast, the treated group exhibits a fundamentally different balance across categories. Active mobility emerges as the most prevalent component of observed trips, followed closely by public transport, while the car plays a clearly less dominant role. Importantly, the relatively high presence of all three categories indicates that mobility among treated participants is not organised around a single backbone mode, but around a diversified portfolio in which different categories coexist and are mobilised according to trip-specific functional needs.

From a behavioural feasibility perspective, these differences reflect contrasting strategies for managing everyday mobility constraints. The control group's configuration prioritises predictability and effort minimisation through modal concentration, even at the expense of reduced redundancy. Conversely, the treated group's configuration suggests a higher degree of functional flexibility and adaptive capacity, achieved through the parallel use of multiple mode categories, but at the cost of increased organisational and cognitive effort.

Crucially, this categorical reading confirms that the two groups differ not only in mobility intensity, spatial extension, stability and variability but also in the structural architecture of their mobility

practices. These architectures define distinct behavioural contexts within which intermodality, car dependence and potential behavioural change must be interpreted.

Trip structure: intermodality, travel chains, and the role of the car

Moving from modal presence to the internal organisation of trips, the distribution of monomodal and intermodal trips provides a more direct measure of structural complexity in observed mobility practices (Table 70). Intermodality is therefore read here not as a proxy for behavioural openness per se, but as a trip-structural expression of different routine and repertoire regimes highlighted in the previous section.

Across both tracking phases, monomodal trips remain predominant for both treated and control participants, indicating that a substantial share of daily mobility continues to be organised around relatively simple, single-mode journeys. At the same time, a non-negligible proportion of trips involves the combination of multiple modes, confirming that intermodality constitutes a recurrent, rather than exceptional, feature of everyday travel.

Table 70 Monomodal and intermodal trips by group and tracking phase

<i>Group</i>	<i>Phase</i>	<i>Chain type</i>	<i>N trips</i>	<i>Share (%)</i>
<i>Control</i>	Phase 1	Monomodal	71	78.0
		Intermodal	20	22.0
	Phase 2	Monomodal	47	68.1
		Intermodal	22	31.9
<i>Treated</i>	Phase 1	Monomodal	126	71.6
		Intermodal	50	28.4
	Phase 2	Monomodal	136	77.7
		Intermodal	39	22.3

Source 85 author's elaboration based on app-based tracking data.

Notes:

Trips are classified as monomodal when only one mode is used within the same activityID, and as intermodal when two or more modes are combined.

Shares are calculated with respect to the total number of trips per group and phase.

Clear differences emerge between the two groups, particularly in tracking phase 1. Treated participants exhibit a higher share of intermodal trips compared to the control group, suggesting that their mobility practices are, on average, more articulated and more frequently rely on the combination of different transport modes within the same trip. Such configurations point to a greater use of modal integration strategies, where different modes are mobilised to address specific segments of the trip rather than substituted on a one-to-one basis.

In contrast, mobility among control participants is more strongly oriented toward monomodal trips, in line with the dominant role of the private car highlighted in the modal share analysis. Even when intermodal trips occur, they account for a smaller share of overall mobility, indicating a preference

for simpler and less fragmented travel configurations. From a behavioural feasibility perspective, this pattern is consistent with mobility strategies aimed at minimising coordination effort, cognitive load, and exposure to uncertainty.

Across tracking phases, the persistence of both monomodal and intermodal trips indicates that intermodality is not a transient or incidental phenomenon, but a stable component of mobility practices for a subset of participants. Importantly, the presence of intermodal trips should not be interpreted as an indicator of greater behavioural flexibility or openness to change per se. Rather, it reflects differentiated ways of coping with spatial, temporal, and organisational constraints: combining modes may represent either an adaptive strategy actively maintained over time or a necessity imposed by contextual conditions.

Overall, the analysis of travel chains shows that the two experimental groups differ not only in the intensity and modal composition of their mobility, but also in the internal structure of their trips. These differences define distinct configurations of effort, coordination, and behavioural feasibility, which are central to interpreting the functional role played by specific modes within everyday mobility. On this basis, the following section examines more closely how modes are combined within trips and the specific positions they occupy within travel chains, in order to further clarify the role of the car as an organising or integrative element of mobility practices.

The analysis of travel chain typologies moves beyond modal presence to examine the internal logic through which trips are assembled, revealing marked differences in how mobility is organised across the two experimental groups (Table 71). Among control participants, mobility is structured around a limited number of dominant chains, most notably monomodal car trips. Across both tracking phases, car-only journeys account for a substantial share of observed trips, indicating a configuration characterised by low internal differentiation and limited reliance on modal integration. In this group, the private car functions as the primary organising backbone of everyday mobility.

When intermodal chains occur among control participants, they tend to be relatively simple and typically involve the car in a terminal position. Intermodality thus operates as an auxiliary adjustment to otherwise car-centred routines, mobilised selectively to address specific spatial or access constraints without challenging the central role of the car. Modal combination in this context does not represent an alternative organising principle, but rather an extension of car-based mobility.

Table 71 Travel chain typologies by group and tracking phase

Group	Chain typology	Phase 1 – n. trips	Phase 1 – share (%)	Phase 2 – n. trips	Phase 2 – share (%)
Control	car	46	50.5	29	42.0
	foot	17	18.7	16	23.2
	car → foot or foot → car	12	13.2	16	23.2
	Local public transport	4	4.4	2	2.8
	train	2	2.2	2	2.9
	foot → train	2	2.2	1	1.4
	foot → Local public transport	2	2.2	1	1.4
	bike	1	1.1	0	0.0
	Other chains	3	3.3	2	2.9
	Total trips	91	100	69	100
Treated	car	52	29.5	52	29.7
	foot	23	13.1	32	18.3
	bike	28	15.9	26	14.9
	train	19	10.8	17	9.7
	foot → train	11	6.3	12	6.9
	bike → train	5	2.8	6	3.4
	car → foot or foot → car	4	2.3	7	4.0
	foot → Local public transport	4	2.3	4	2.3
	foot → train → foot	3	1.7	0	0.0
	other chains	27	15.3	19	10.9
	Total trips	176	100	175	100

Source 86 author's elaboration based on app-based tracking data.

Notes:

"Local Public transport" includes trips performed exclusively by public transport modes (bus, metro, tram).

"Other chains" aggregates low-frequency combinations to preserve readability.

The treated group displays a considerably more diversified set of travel chains. No single configuration dominates the distribution, and a wide range of monomodal and intermodal chains coexist across both phases. Alongside car-only trips, a substantial share of journeys is performed entirely by active modes or public transport, while intermodal chains frequently combine walking, cycling, and rail-based services. This pattern points to a mobility portfolio organised around functional integration of modes rather than exclusive dependence on a single dominant option. By contrast, the control group's reliance on car-centered chains reflects a different coping logic: uncertainty and organisational burden are reduced by anchoring mobility practices around a single, flexible, and controllable mode. In VTBC terms, this configuration minimises perceived behavioural risk, even at the cost of reduced modal diversity.

The distribution of trips by the role played by the car within travel chains further clarifies these contrasting mobility configurations. Moving beyond simple measures of car presence, Table 72 distinguishes between trips performed exclusively by car, trips in which the car functions as an access or egress mode within intermodal chains, and trips that do not involve the car at all. This distinction

allows the behavioural function of the car to be examined in relation to broader mobility organisation strategies rather than mere frequency of use.

Table 72 Role of the car within travel chains by group and tracking phase

Group	Car role within trip	Phase 1 – n. trips	Phase 1 – share (%)	Phase 2 – n. trips	Phase 2 – share (%)
Control	Car only	46	50.5	29	42.0
	Car as access/egress	13	14.3	19	27.5
	No car	32	35.2	21	30.4
	Total trips	91	100	69	100
Treated	Car only	52	29.5	52	29.7
	Car as access/egress	15	8.5	14	8.0
	Car as intermediate	1	0.6	0	0.0
	No car	108	61.4	109	62.3
	Total trips	176	100	175	100

Source 87 author's elaboration based on app-based tracking data.

Among control participants, car use remains structurally central across both tracking phases. In tracking phase 1, more than half of all observed trips are performed exclusively by car, while an additional share involves the car as an access or egress mode within intermodal journeys. Taken together, these patterns indicate that the car constitutes the dominant organising element of mobility for the control group, shaping both monomodal and intermodal travel configurations. Importantly, intermodality in this group does not reduce car dependence; rather, it extends it by embedding the car within multi-stage trips, primarily in terminal positions.

In tracking phase 2, the share of car-only trips among control participants decreases, while the proportion of trips in which the car plays an access or egress role increases. This shift suggests a partial functional reallocation of car use, from exclusive reliance toward a more complementary role. However, even under this reconfiguration, the car continues to feature in a majority of observed trips, confirming its persistent role as the structural anchor of mobility. From a feasibility perspective, this pattern reflects a strategy in which uncertainty and coordination effort are managed by retaining the car as the primary stabilising resource, even when some degree of modal integration is introduced.

In contrast, the treated group exhibits a markedly different distribution. Across both phases, the majority of trips do not involve the car at all. Car-only trips represent less than one third of total trips and remain remarkably stable between phases. The use of the car as an access or egress mode is comparatively limited, and the presence of the car as an intermediate mode within travel chains is marginal. This configuration indicates that, for treated participants, the car does not function as the default organising backbone of mobility, but rather as one option within a broader and more diversified mobility portfolio.

Conversely, the control group's heavier reliance on both exclusive and terminal car use reflects a coping strategy oriented toward reducing organisational burden and perceived behavioural risk by anchoring mobility practices around the private car. In VTBC terms, the car functions as a compensatory device that stabilises routines under conditions of uncertainty, effort and time pressure, even when alternative modes are available.

Read together, the evidence on modal presence, intermodality, travel chain typologies and the functional role of the car points to two structurally distinct mobility configurations. Among control participants, mobility is organised around the private car as the primary organising element, with intermodality playing a secondary and largely auxiliary role. Modal combinations, when present, tend to extend rather than weaken car dependence by embedding the car within multi-stage journeys, typically in terminal positions.

Among treated participants, mobility is organised around more articulated and diversified chains, in which active modes and public transport play a central role, and the car occupies a more circumscribed and situational position. This configuration does not imply lower mobility needs or weaker structural constraints. On the contrary, as shown by higher mobility intensity and greater chain complexity, treated participants operate under demanding organisational conditions, where complexity is managed through modal integration rather than avoided through simplification.

From a behavioural feasibility perspective, these configurations reflect different coping logics under constraint. Car-centered mobility minimises coordination effort and perceived behavioural risk by concentrating control in a single mode, while integrated mobility distributes effort across modes, increasing functional flexibility at the cost of higher organisational and cognitive demands.

Behavioural feasibility regimes and mobility organisation: baseline profiles of treated and control participants

This concluding section synthesises the descriptive and analytical evidence developed in the preceding chapters in order to characterise the behavioural baselines within which the VTBC experiment is observed. Rather than assessing behavioural change or intervention effects, the objective here is to delineate the concrete mobility regimes enacted by treated and control participants in each tracking phase, and to position these regimes within a feasibility-oriented interpretation of everyday travel behaviour.

Bringing together mobility intensity and exposure, spatial organisation, routine dominance and behavioural variability, and the internal architecture of mobility portfolios and travel chains, the chapter reconstructs four analytically distinct behavioural profiles of two groups during two tracking phases. These profiles are conceived as diagnostic representations of how mobility is organised under constraint at different moments of observation.

In line with the Voluntary Travel Behaviour Change (VTBC) framework adopted throughout the thesis, these observed configurations are interpreted as expressions of behavioural feasibility, routine consolidation and organisational coping strategies, rather than as reflections of abstract preferences or latent openness to change. The analytical purpose is therefore to clarify what kind of mobility is being observed, under which spatial and organisational conditions, and with what baseline degree of routine strength and modal integration, before any attempt is made to interpret phase-to-phase differences as behavioural change attributable to the experimental context.

The analysis begins with treated participants in tracking phase 1, which constitutes the primary behavioural baseline against which subsequent configurations will be read. This first profile captures how mobility is organised under constraint at the initial moment of observation, before any consideration of phase-to-phase dynamics or experimental effects and provides a reference point for interpreting both internal reconfigurations and cross-group contrasts in later sections.

Treated participants:

In tracking phase 1, mobility among treated participants is characterised by *high intensity, spatial extension and pronounced organisational complexity*. The treated group generates the largest volume of observed trips and operates within territorially extended and administratively fragmented activity spaces, with a strong concentration of trips on the regional scale and a substantial prevalence of intermunicipal mobility. These features indicate that everyday mobility unfolds under demanding coordination conditions, involving long distances, multiple jurisdictions and limited tolerance for disruption.

Within this spatial and exposure context, treated participants exhibit a *heterogeneous behavioural organisation*. Individual-level indicators of routine dominance and modal variability show that highly routinised profiles coexist with flexible and fragmented configurations. At the synthetic level, a substantial share of treated participants is positioned in profiles such as Flexible routine, Adaptive variability and Explorative/fragmented, alongside routinised stability. This dispersion indicates that treated mobility is not anchored in a single dominant behavioural corridor, but organised through multiple coexisting regimes of routine strength and flexibility.

The modal architecture of treated mobility in tracking phase 1 further reinforces this interpretation. *Mobility portfolios are structurally diversified*, with active mobility and public transport featuring prominently alongside the private car. No single mode monopolises observed practices, and different categories coexist within articulated travel chains. Intermodality is recurrent, particularly at metropolitan and regional spatial scales, where modal integration functions as an organisational response to distance, access constraints and institutional fragmentation.

The functional role of the car is correspondingly circumscribed. Although present in a non-negligible share of trips, the car does not operate as the dominant organising backbone of mobility. A majority of trips do not involve the car at all, and car-only trips coexist with a wide range of non-car

monomodal and intermodal configurations. When the car is mobilised, it functions as one resource among others rather than as the default behavioural anchor.

Read within a VTBC perspective, tracking phase 1 treated mobility constitutes a *feasibility regime organised around modal integration and behavioural articulation*. Spatial complexity and high exposure are managed not through modal concentration, but through the combination of multiple modes within segmented chains. This configuration implies relatively high functional flexibility, but also elevated organisational and cognitive effort, as mobility stability is achieved through integration rather than simplification.

In tracking phase 2, treated participants continue to operate within *structurally extended and fragmented activity spaces*, with a persistent regional component and a marked presence of long-distance trips. Administrative discontinuity remains high, confirming that the spatial feasibility conditions observed in phase 1 are not transient features of the baseline, but stable properties of treated mobility contexts.

Behavioural organisation indicators show that *heterogeneity* remains a defining feature of treated mobility. Composite profiles continue to span *routinised, flexible and highly variable regimes*, with no convergence toward a single dominant configuration. For several individuals, repertoire breadth and routine dominance remain broadly stable across phases, while others exhibit bounded rebalancing of dominance and variability. These movements reflect internal reorganisation rather than linear transitions toward greater stability or fragmentation.

The modal architecture of treated mobility in tracking phase 2 remains diversified. Active mobility and public transport continue to feature prominently within portfolios, and intermodality persists as a recurrent structural property of trips, particularly at intermediate spatial scales. The distribution of travel chain typologies confirms that no single configuration dominates observed practices, and that articulated chains combining walking, cycling and rail-based services remain central components of everyday mobility.

The functional role of the car remains circumscribed and remarkably stable. Car-only trips account for less than one third of observed trips and do not increase between phases. A majority of trips continue to exclude the car altogether, while its use as an access or egress component within chains remains limited. This indicates that the car does not emerge as a compensatory stabilising device within treated mobility, even under continued exposure to demanding spatial and organisational conditions.

Analytically, *treated mobility in phase 2 can therefore be read as the continuation of an integration-based feasibility regime*. Mobility stability continues to be achieved through modal diversification and chain articulation rather than through routine consolidation around a single backbone mode. Within a VTBC framework, this regime corresponds to a context in which behavioural feasibility is maintained through organisational complexity and functional flexibility, at the cost of elevated coordination and cognitive demands.

Control participants:

Having reconstructed the behavioural feasibility regime characterising treated participants across the two tracking phases, the analysis now turns to the control group. This shift of focus makes it possible to delineate how mobility is organised under comparable structural constraints in the absence of experimental exposure, and to establish the descriptive baseline configuration against which subsequent interpretations of behavioural dynamics will later be anchored.

In tracking phase 1, mobility among control participants is characterised *by lower observed intensity* than among treated participants, but unfolds within similarly extended and administratively fragmented activity spaces. Trips are distributed across local, metropolitan, regional and national scales, and intermunicipal mobility is prevalent, indicating that control participants also operate under non-trivial spatial and institutional constraints.

In contrast to the treated group, *behavioural organisation among control participants is strongly concentrated in routinised configurations*. Individual-level variability indicators and composite profiles reveal a marked dominance of *highly routinised stability*, with a large share of participants positioned in Profile A. Modal repertoires are narrow, dominant chains account for large majorities of observed trips, and behavioural flexibility is limited. This configuration points to a mobility regime structured around strong behavioural defaults and low internal differentiation.

The modal architecture of control mobility in phase 1 reinforces this interpretation. Portfolios are *heavily centred on the private car*, which is present in a majority of observed trips. Travel chain typologies are dominated by car-only journeys, and intermodal configurations are relatively infrequent and structurally simple. When intermodality occurs, it typically involves the car in a terminal position, functioning as access or egress to otherwise monomodal trips.

The *car thus operates as the primary organising backbone of mobility*. It absorbs spatial uncertainty, reduces coordination burden and stabilises routines by concentrating control within a single high-reliability mode. Active mobility and public transport play secondary and supportive roles, complementing car-based travel rather than structuring mobility independently.

From a VTBC perspective, tracking phase 1 control mobility constitutes a *feasibility regime organised around modal concentration*. Stability is achieved through routine consolidation and reliance on a single behavioural default, minimising cognitive load and perceived behavioural risk even under extended and fragmented spatial conditions.

In tracking phase 2, observed mobility among control participants declines in volume, reflecting participation dynamics and engagement with tracking rather than substantive contraction of activity spaces. Extra-regional and national trips remain present, and intermunicipal mobility continues to account for a substantial share of observed trips, confirming the persistence of extended and administratively fragmented feasibility conditions.

Behavioural organisation remains strongly routinised. Composite profiles continue to be heavily concentrated in highly stable configurations, and no expansion of modal repertoires or systematic

weakening of routine dominance is observed. Mobility practices therefore remain anchored in narrow behavioural corridors structured by strong defaults.

The modal architecture of control mobility in phase 2 continues to be car-centered. While the share of car-only trips decreases slightly, the proportion of trips in which the *car functions as access or egress increases*. Taken together, these patterns indicate a partial functional reallocation of car use from exclusive reliance toward complementary integration, without any displacement of the car as the structural anchor of mobility.

Intermodality remains limited and largely auxiliary. At regional spatial scales, where treated participants display substantial modal integration, control participants continue to rely predominantly on monomodal configurations, consistent with a strategy of behavioural simplification under spatial and organisational complexity.

Analytically, control mobility in tracking phase 2 can therefore be read as the *continuation of a concentration-based feasibility regime*. Mobility stability continues to be secured through routine consolidation and modal concentration around the private car, with only marginal internal reconfiguration of its functional role within chains.

Taken together, the four behavioural profiles reconstructed in this chapter delineate the concrete mobility regimes within which the VTBC experiment is observed. *Treated and control participants do not simply differ in mode use or trip frequency; they operate within distinct organisational logics through which everyday mobility is rendered behaviourally feasible under spatial extension, administrative fragmentation and routine pressure.* At this stage, the analytical task is therefore not to compare groups in causal terms, but to stabilise what is meant by “mobility behaviour” in each group–phase configuration, so that subsequent phase-to-phase contrasts can be interpreted against a clearly specified baseline.

From a VTBC and stage-based travel behaviour change perspective; this step is not ancillary but necessary. VTBC interventions act through feasibility margins and threshold dynamics rather than through uniform average responses; and, within stage-based accounts such as the TTM, readiness and action depend on how routines, perceived effort, control and risk are distributed across everyday mobility practices. Similarly, the MaaS chapter has shown that uptake and opt-out reflect feasibility evaluations (i.e., whether integration yields sufficient gains relative to perceived organisational burden). The descriptive dimensions analysed so far (exposure, space, routines, portfolios and chains) are precisely the empirical correlates of these feasibility evaluations. Without integrating them into a coherent regime-level representation, any later attempt to identify behavioural change would risk conflating genuine behavioural reconfiguration with observational artefacts, participation dynamics, or bounded rebalancing within stable coping logics.

To consolidate this regime-level representation, Table 73 performs an explicit analytical function: it translates heterogeneous indicators into four VTBC-coded feasibility regimes, one for each group and

tracking phase, thereby specifying the baseline ‘conditions of possibility’ for behavioural adaptation. In other words, the table is not a summary of results; it is the conceptual device that makes subsequent interpretation of dynamics analytically defensible.

Table 73 Synthetic characterisation of observed mobility regimes by group and tracking phase

<i>Analytical dimension</i>	<i>Treated – Phase 1</i>	<i>Treated – Phase 2</i>	<i>Control – Phase 1</i>	<i>Control – Phase 2</i>
<i>Mobility intensity & exposure</i>				
<i>Trip volume</i>	High	High (stable)	Medium–low	Lower observed (tracking attrition)
<i>Exposure to daily mobility</i>	High	High	Medium	Medium–low
<i>Participation continuity</i>	High	Selective attrition (tracking drop-out)	Moderate	Selective attrition (tracking drop-out)
<i>Spatial organisation</i>				
<i>Dominant spatial scale</i>	Regional	Regional + national	Mixed local–regional	Mixed local–regional
<i>Territorial extension</i>	High	High	High	High
<i>Administrative fragmentation</i>	High (intermunicipal prevalent)	High (persistent)	High	High
<i>Behavioural organisation</i>				
<i>Routine dominance</i>	Medium–low (heterogeneous)	Medium–low (stable)	High	High
<i>Behavioural variability</i>	High	High (stable)	Low	Low–medium
<i>Modal repertoire breadth</i>	Medium–high	Medium–high	Low–medium	Low–medium
<i>Behavioural regime</i>	Flexible / fragmented	Flexible / fragmented	Routinised stable	Routinised stable
<i>Modal architecture</i>				
<i>Portfolio structure</i>	Diversified	Diversified	Car-centred	Car-centred
<i>Backbone mode</i>	None	None	Private car	Private car
<i>Active mobility role</i>	Structural (access + core)	Structural	Residual	Residual
<i>Public transport role</i>	Structural (core + integration)	Structural	Secondary	Secondary
<i>Trip structure & intermodality</i>				
<i>Share of intermodal trips</i>	High	Medium–high	Low–medium	Medium
<i>Chain articulation</i>	High	High	Low	Medium
<i>Car functional role</i>	Situational	Situational	Backbone + terminal	Backbone + terminal
<i>Intermodality logic</i>	Integrative	Integrative	Auxiliary	Auxiliary

Feasibility regime (VTBC)				
<i>Organisational coping strategy</i>	Modal integration	Modal integration	Modal concentration	Modal concentration
<i>Coordination burden</i>	High	High	Lower	Lower
<i>Cognitive effort</i>	High	High	Lower	Lower
<i>Behavioural feasibility anchored in</i>	Flexibility + redundancy	Flexibility + redundancy	Routine + control	Routine + control
<i>Dominant VTBC stage (interpretative)</i>	Preparation / Action	Action	Precontemplation	Precontemplation–Contemplation

Source 88 author's elaboration based on app-based tracking data.

Read through this integrated lens, Table 73 makes explicit that the two experimental groups are embedded, already at baseline and in both tracking phases, within qualitatively different feasibility regimes rather than along a simple continuum of flexibility or multimodality. Among treated participants, mobility is organised around an integration-based regime in which stability is achieved through modal diversification, articulated travel chains and functional redundancy. High mobility intensity and territorially extended, intermunicipal activity spaces define a demanding exposure environment; within this context, feasibility is maintained through organisational coping via integration rather than through simplification. In VTBC terms, treated mobility is anchored in a regime where behavioural feasibility derives from flexibility and redundancy, but requires sustained coordination and cognitive work. In TTM-consistent language, this configuration is compatible with later-stage positioning (Preparation/Action) not because it implies “pro-change attitudes”, but because it indicates an operational repertoire in which recombination and integration are already behaviourally viable under constraint. Here, “stage positioning” is used as an interpretative shorthand for observed routine strength and feasibility margins, not as a psychological classification of individuals.

Crucially, the treated feasibility regime is already fully formed in tracking phase 1 and remains structurally stable in phase 2. The persistence of high trip volume, continued territorial extension and fragmentation, diversified portfolios and recurrent chain articulation indicates that treated participants continue to stabilise mobility through integration rather than through concentration around backbone mode. This stability matters analytically: it suggests that any phase-to-phase differences later observed within the treated group must be interpreted as potential reconfiguration within an integration-based regime, not as a shift from concentration to integration.

By contrast, control participants display a routine-anchored, car-centered feasibility regime in both phases. Even under extended and fragmented spatial conditions, mobility is stabilised through modal concentration and routine consolidation. The private car functions as a backbone mode that absorbs uncertainty, reduces coordination burden and limits behavioural risk by concentrating control within a single high-reliability resource. Active mobility and public transport remain secondary and largely

supportive, and intermodality is predominantly auxiliary—often extending car-based mobility rather than constituting an alternative organising principle. In VTBC terms, feasibility here is anchored in routine + control, and the organisational logic is one of simplification under constraint. In TTM-consistent terms, this pattern aligns with earlier-stage positioning (Precontemplation / Contemplation), again not as a psychological claim but as an interpretative mapping between routine strength, perceived effort/risk, and the boundedness of feasible alternatives.

This regime is likewise already consolidated in phase 1 and remains stable in phase 2. Where internal reallocation occurs (e.g., a modest shift from car-only to car-as-access/egress), it does not alter the underlying coping logic: behavioural feasibility continues to be secured through backbone-mode reliance rather than through modal integration.

Overall, the table clarifies a core conceptual point that anchors the next chapter: the experiment is observed against two different baseline feasibility architectures. Treated participants cope with constraint through integration and redundancy, while control participants cope through concentration and routine consolidation. These regimes distribute effort, control, cognitive load and behavioural risk differently, and therefore delimit, *ex ante*, the kinds of behavioural adjustments that can plausibly emerge and be sustained.

This diagnostic positioning is analytically central within a VTBC–TTM–MaaS framework. Any later claim of behavioural change attributable to the VTBC experiment must be evaluated against (i) these regime-specific feasibility thresholds, (ii) the participation and tracking filters that shape what becomes observable, and (iii) the possibility of internal rebalancing within stable coping logics. The following chapter therefore builds directly on these reconstructed baselines to assess whether phase-to-phase differences, within the treated group and relative to the control group, constitute genuine behavioural reconfiguration consistent with VTBC mechanisms, rather than artefacts of observation, selective engagement, or routine-preserving adaptation.

Behavioural change under feasibility constraints: a VTBC interpretation of the experiment

This chapter examines behavioural change in the VTBC experiment as a problem of regime stability and threshold dynamics under binding feasibility constraints. Rather than treating behavioural variation as a direct response to experimental exposure, the analysis reconstructs how observed mobility dynamics are organised within pre-existing feasibility regimes and governed by the thresholds that separate bounded internal rebalancing from genuine regime-level reconfiguration. The central question is therefore not whether behaviour “changes”, but whether staged VTBC and MaaS exposure is capable of shifting the feasibility calculus that anchors routines, portfolios and compensatory strategies, thereby enabling transitions across regime boundaries rather than marginal redistribution within stable stabilisation logics.

To address this question, the chapter situates observed mobility dynamics within their empirical scope conditions and within the staged exposure logic through which the experiment was implemented. Behavioural change is analysed as a threshold phenomenon emerging, or failing to emerge, from the interaction between baseline feasibility architectures, selective engagement with the experimental setting, and differentiated exposure to cognitive, informational and operational components.

Behavioural change: analytical scope and staged exposure

Behavioural change is treated here not as an isolated outcome of participation, but as a process unfolding within constrained mobility contexts, structured by baseline feasibility regimes, filtered by selective engagement, and conditioned by staged intervention exposure.

The analytical starting point is therefore not tracking phase 1 as such, but the pre-tracking stage and the selection process through which participants entered, remained in, or disengaged from the experiment. As established in the chapter on attrition, effective participation and scope conditions, participation functions as a non-neutral feasibility filter: who is recruited, who persists, and who ultimately produces usable tracking data directly conditions which regimes, thresholds and reconfiguration dynamics can plausibly be observed.

This positioning has two immediate implications. First, phase-to-phase differences cannot be interpreted independently of baseline behavioural organisation and feasibility constraints, since observed mobility always results from routines interacting with opportunity structures under bounded organisational capacity. Second, attrition and early disengagement are treated not as technical disturbances to be “corrected away”, but as analytically meaningful outcomes that reveal

the organisational and cognitive burden of voluntary, longitudinal and digitally mediated experimentation under real-world constraint.

On this basis, the analysis is anchored to the pre-tracking baseline and to the mobility profiles characterising treated and control participants during selection, before turning to how observed mobility configurations evolve across the two tracking phases. The analytical task is not to infer effects mechanically from a baseline–treatment dichotomy, but to assess whether, and under which regime-specific conditions, phase-to-phase reconfigurations can be interpreted as behavioural change consistent with VTBC mechanisms, rather than as artefacts of selective engagement, tracking-induced reactivity, or internal rebalancing within stable coping logics. Read in this way, the experiment operates as a staged empirical setting in which everyday mobility practices are progressively exposed to modified cognitive, informational, and material conditions. Behavioural change, if observed, must therefore be interpreted against baseline feasibility architectures and threshold dynamics.

Pre-tracking baseline and scope conditions define what can be observed. The pre-tracking screening data constitute the only genuinely exogenous behavioural baseline available in this research design: at that stage, participants had not yet been exposed to app-based self-monitoring, VTBC framing, MaaS-related informational inputs, or personalised behavioural guidance. Reported mobility practices therefore reflect stabilised routines and compensatory strategies developed under ordinary structural constraints. As shown in the pre-tracking mobility profiles by experimental group (Table 56), both groups include substantial shares of individuals exhibiting frequent or systematic reliance on the private car, particularly for non-systematic and discretionary mobility, confirming that recruitment targeted mobility configurations characterised by compensatory car use and binding feasibility constraints, in line with the rationale developed in the MaaS chapter. At the same time, analytically relevant asymmetries between groups are already visible prior to tracking. Within a feasibility-oriented interpretation, these baseline differences are not treated as anomalous “noise”, but as part of the empirical reality of voluntary behavioural experimentation in a small sample, shaped by selective recruitment, self-selection into participation, and the practical limits of real-world randomisation. Crucially, these baseline asymmetries anticipate the regime-level architectures later reconstructed from tracking data, reinforcing a core interpretative caution: later group differences are not generated *ex nihilo* by experimental exposure, but filtered and bounded by pre-existing feasibility regimes.

A second scope condition concerns attrition and selective engagement with the experimental setting. Only a limited subset of the selected sample ultimately generated usable tracking data. Within a VTBC framework, this attrition is interpreted as a second-order feasibility filter rather than as a purely technical limitation. Sustained participation required continued interaction with an app-based tracking system over multiple weeks, tolerance of battery and permission burdens, responsiveness to notifications, and willingness to share detailed mobility data. These requirements add cognitive

and organisational demands to already constrained daily routines; participation continuity is therefore not behaviourally neutral. Attrition selectively retains those individuals for whom the experimental setting remains feasible, while excluding those for whom additional organisational burden exceeds available capacity or willingness to adapt. Within habit- and constraint-oriented accounts, routines operate as stabilisation strategies that minimise cognitive load and behavioural risk under demanding conditions; for individuals operating near their feasibility threshold, the experiment's additional burden may itself become destabilising, making withdrawal a rational coping response rather than a signal of disinterest or resistance.

The socio-mobility profile of effective participants further specifies the corridor within which behavioural change is observed. Relative to the initially selected sample, effective participants are characterised by a strong predominance of public transport use for systematic university-related mobility, coupled with persistent reliance on the private car for non-systematic and discretionary activities; medium- and long-distance commuting remains prevalent, and attendance intensity is relatively high, particularly among treated participants. Attrition therefore does not eliminate structural constraint from the experimental context; it reshapes its behavioural articulation by concentrating car dependence in discretionary mobility, where flexibility, trip chaining, and risk management are most salient. Taken together, pre-tracking baseline profiles and attrition-driven selection define a bounded empirical corridor: behavioural dynamics are observed within a context that is heterogeneous already at baseline, structurally constrained in key dimensions, selectively filtered by participation dynamics, and non-neutral with respect to routine strength and feasibility margins.

Tracking phase 1 must therefore be interpreted within a staged exposure trajectory rather than as a neutral baseline. Before interpreting phase-to-phase differences as behavioural change, it is necessary to clarify the analytical status of phase 1 within the experimental design. This non-neutrality is not a methodological flaw but a structural feature of the experiment as implemented: within feasibility-oriented and stage-based accounts, framing, information, and self-monitoring are themselves mechanisms through which VTBC interventions operate. Treating phase 1 as purely observational would therefore erase part of the intervention logic.

As summarised in the experimental component structure (Table 11), treated and control participants are embedded, prior to behavioural tracking, in asymmetric exposure contexts. Both groups attend a general training meeting on objectives and protocol; however, treated participants alone receive training on VTBC logic and behavioural objectives, and treated participants alone are trained on the MaaS app beyond its passive tracking functionality. These components do not alter the material opportunity structure of mobility, but they plausibly alter how constraints, trade-offs, and routines are cognitively framed and evaluated. In VTBC-consistent terms, treated participants enter phase 1 within an interpretative regime in which mobility behaviour is foregrounded as an object of reflection and potential reconfiguration, whereas control participants enter phase 1 under a predominantly

observational framing. This does not entail psychological claims about “pro-change” dispositions; it implies, more narrowly, that treated participants begin phase 1 under conditions of activated behavioural awareness and anticipatory engagement with a subsequent intervention logic, conditions that, in TTM-consistent language, correspond to shifts in readiness even in the absence of immediate behavioural change.

The role of self-monitoring reinforces this interpretation. Both groups are exposed in phase 1 to app-based behavioural tracking, yet self-monitoring is not behaviourally neutral: it can disrupt automaticity, increase awareness of regularities and inconsistencies, and introduce micro-moments of reflection at the interface between routine and situational constraint. Within VTBC logic, self-monitoring is therefore a behavioural mechanism as well as a measurement procedure. Crucially, its behavioural meaning depends on the interpretative frame in which it is embedded. For treated participants, self-monitoring is nested within explicit VTBC framing and MaaS-related informational exposure; for control participants, it is framed primarily as a technical tracking requirement. Identical tracking technology may therefore generate different behavioural responses across groups not because of technological effects per se, but because of differentiated cognitive and motivational embedding.

This staged positioning of phase 1 clarifies an empirical regularity emerging from the descriptive evidence: treated and control participants appear to diverge more strongly in observed mobility behaviour during phase 1 than in the pre-tracking baseline. Once phase 1 is correctly interpreted as a first-stage exposure context, this pattern is neither anomalous nor theoretically problematic. It is consistent with two mechanisms that can operate within existing feasibility regimes without implying threshold crossings: first, bounded rebalancing within already-available behavioural repertoires as awareness and self-monitoring increase the salience of alternatives that were already feasible; second, mild anticipatory pre-adaptation induced by forward-looking engagement with the forthcoming intervention logic. Both mechanisms can amplify observable differentiation in phase 1 even when underlying feasibility architectures remain stable.

If phase 1 is already part of a staged intervention trajectory, then neither phase 1–phase 2 differences nor treated–control contrasts can be read through a simple before–after or treated–untreated logic. Any observed change must instead be evaluated against alternative, structurally embedded sources of variation. Phase-to-phase shifts may reflect internal rebalancing within stable feasibility regimes rather than behavioural change; they may reflect tracking-induced reactivity rather than substantive reconfiguration; and they may reflect engagement filters and attrition-driven compositional change rather than within-individual transformation. These mechanisms are expected to co-occur in a voluntary, app-based, longitudinal intervention implemented under real-world constraints. The analytical problem is therefore not to eliminate them, but to position observed mobility dynamics relative to them.

For this reason, the next step is to specify explicit, theory-consistent criteria for distinguishing behavioural change from internal rebalancing, measurement artefacts, and engagement filters. Only once these criteria are formalised does it become analytically defensible to interpret phase 2 dynamics as potential behavioural change in a VTBC-consistent sense, namely as shifts that exceed bounded redistribution within stable coping logics, persist beyond salience-driven perturbations, and cannot be reduced to selective engagement or compositional filtering.

Interpretative grid for distinguishing behavioural change from rebalancing, artefacts and engagement filters

In order to move from descriptive phase-to-phase differences to analytically defensible interpretations of behavioural dynamics, it is necessary to make explicit the criteria through which behavioural change is distinguished from alternative sources of variation that are structurally embedded in the VTBC experimental design. Within a feasibility-oriented and staged-intervention interpretation, observed mobility reconfigurations are not assumed a priori to reflect behavioural change. On the contrary, they are treated as potentially arising from multiple analytically distinct mechanisms that are expected to co-occur in a voluntary, app-based, longitudinal intervention implemented under real-world constraints.

More specifically, four classes of mechanisms must be kept analytically distinct.

- First, observed changes may reflect bounded internal rebalancing within stable feasibility regimes rather than threshold-crossing reconfiguration.
- Second, they may result from tracking-induced reactivity and self-monitoring effects, whereby behavioural salience and reflective attention perturb existing routines without altering their underlying organisational logic.
- Third, they may be artefacts of selective engagement and attrition-driven compositional change, whereby phase-to-phase differences reflect who remains observable rather than how individuals transform their behaviour.
- Fourth, only a restricted subset of observed dynamics may qualify as genuine behavioural reconfiguration consistent with VTBC mechanisms and with the staged logic of the intervention.

These mechanisms are not mutually exclusive. The analytical problem is therefore not to eliminate competing explanations, but to position observed mobility dynamics relative to them using theoretically grounded and empirically tractable criteria. This requires an explicit and deliberately selective choice of behavioural indicators. Rather than maximising descriptive coverage, the objective is to retain only those indicators that carry direct analytical meaning within a VTBC–TTM–MaaS framework and that can plausibly be interpreted as signals of reconfiguration of behavioural

feasibility regimes rather than as mechanical consequences of observation, attrition or bounded adaptation.

This selection principle reflects a core methodological commitment of the thesis. Behavioural change is not inferred from any observable variation in mobility metrics, but only from variations that are theoretically consistent with a weakening of routine dominance, an expansion or contraction of the effective feasible choice set, or a reorganisation of the functional architecture through which mobility is stabilised under constraint. Indicators that are highly sensitive to calendar effects, participation dynamics or tracking exposure are therefore treated as descriptive correlates or contextual diagnostics rather than as primary markers of behavioural reconfiguration.

Accordingly, the interpretative grid is constructed around a deliberately minimal set of behavioural dimensions that have already been mobilised in the preceding chapters and that map directly onto the conceptual frameworks. These include routine dominance, modal repertoire breadth, portfolio structure, the functional role of the car within travel chains, the organisational logic of intermodality, and the composite behavioural regime or profile type derived from the joint distribution of repertoire breadth and routine dominance. Each of these dimensions has a clear behavioural interpretation and a direct correspondence to feasibility margins, routine consolidation, compensatory stabilisation strategies and readiness for reconfiguration.

By contrast, a wide range of additional metrics produced by tracking data, such as trip volume, modal shares, spatial scale, administrative fragmentation or chain articulation, are intentionally not used as primary indicators of behavioural change. While analytically informative for characterising mobility contexts and organisational burden, these variables are highly sensitive to participation dynamics and observation effects and are therefore more plausibly interpreted as expressions of internal rebalancing, regime-consistent adaptation or measurement reactivity rather than as signals of regime-level reconfiguration.

Within this analytical framework, behavioural change is operationally defined as a specific subset of observed reconfigurations that exceed bounded adaptation within stable feasibility regimes, persist beyond tracking-induced salience effects, cannot be reduced to engagement filters or compositional change, and are directionally consistent with the staged VTBC–MaaS intervention logic. All other observed dynamics are treated as analytically meaningful in their own right, but as expressions of regime-preserving coping, salience-driven perturbation or feasibility filtering rather than as behavioural change in a strict VTBC sense.

On this basis, Table 74 formalises the interpretative grid through which observed mobility dynamics are read in the remainder of the chapter. The table translates the four analytical criteria discussed above into a structured set of indicators and decision rules. For each dimension of behavioural organisation, it specifies which observable patterns are to be interpreted as bounded rebalancing within stable feasibility regimes, as tracking-induced reactivity or measurement artefacts, as

engagement-filter effects, or as potential behavioural reconfiguration consistent with VTBC mechanisms. In doing so, the table does not introduce additional assumptions or post hoc rationalisations, but renders explicit the inferential logic already embedded in the feasibility-oriented interpretation developed throughout the thesis.

Table 74 Interpretative grid: indicators and criteria for distinguishing behavioural change from alternative sources of variation

Analytical dimension	Indicator	Behavioural meaning (VTBC-consistent)	Change-consistent signal	Rebalancing / artefact signal
<i>Routine dominance</i>	Share of trips accounted for by dominant chain	Degree of behavioural anchoring and automaticity	Systematic weakening of dominant chain	Minor redistribution across existing chains
<i>Modal repertoire breadth</i>	Number of distinct modal configurations	Effective feasible choice set	Expansion or rebalancing toward non-car configurations	Activation of already-used marginal options
<i>Portfolio structure</i>	Car-centred vs diversified	Organisational logic of mobility	Shift away from car-centred structure	Persistence of car-centred architecture
<i>Functional role of the car</i>	Backbone / terminal / situational	Compensatory vs integrative use	Weakening of backbone role	Continued backbone anchoring
<i>Intermodality logic</i>	Auxiliary vs integrative	Mode of organisational coping	Shift toward integrative intermodality	Terminal or accessory intermodality
<i>Behavioural regime (profile)</i>	Composite profile type (A–I)	Feasibility regime position	Transition across regime categories	Stability within regime category

Source 89 author's elaboration

Taken together, the interpretative grid formalised in Table 74 establishes the analytical conditions under which observed mobility dynamics can be read as behavioural change in a VTBC-consistent sense, rather than as regime-preserving adaptation, tracking-induced salience effects or artefacts of selective engagement and attrition. By specifying ex ante what would count as regime-level reconfiguration, within-regime rebalancing, measurement reactivity or compositional filtering, the grid stabilises the inferential logic required to move from descriptive phase-to-phase differences to analytically defensible interpretations of behavioural dynamics.

On this basis, the analysis now turns to observed mobility behaviour during pre-selection and tracking phase 1. This phase is not examined in order to test for behavioural change, but to characterise how pre-existing feasibility regimes interact with the first stage of differentiated exposure to the experimental context, composed of behavioural framing, anticipatory engagement and self-monitoring. The analytical task at this stage is therefore to position pre-selection and phase 1 mobility configurations relative to the interpretative grid, in order to clarify which observed differences reflect bounded rebalancing, salience-driven perturbation or regime-consistent stability, and to establish a

regime-specific reference point against which any subsequent reconfigurations observed in phase 2 can be meaningfully evaluated as potential behavioural change.

Observed behavioural dynamics under staged VTBC exposure

This section brings together the three empirical chapters that examine observed mobility behaviour under staged VTBC exposure, from the pre-selection baseline through the two tracking phases to post-experiment monitoring. Building on the scope conditions defined in the preceding chapter and on the interpretative grid introduced to distinguish behavioural change from regime-preserving adaptation, the analysis reconstructs how mobility regimes evolve, or fail to evolve, across the entire experimental trajectory.

Rather than evaluating intervention effects in terms of aggregate modal shifts, the focus is on regime-level dynamics: the stability of anchoring principles, the boundaries of feasible reconfiguration, and the forms of bounded internal reweighting through which behaviour adjusts under constraint. Read jointly, the three chapters document the behavioural corridor within which VTBC and MaaS exposure operates and establish the empirical basis for interpreting both the absence of regime crossing and the latent configurations analysed in the subsequent section.

Behavioural change vs. internal rebalancing: empirical anchoring to the pre-selection baseline

In order to characterise the behavioural baselines against which subsequent tracking-phase dynamics are interpreted, the pre-selection stage is operationalised using a deliberately restricted and theoretically targeted set of indicators. This choice reflects both the empirical constraints of the screening dataset and the analytical objective of identifying regime-consistent patterns of behavioural organisation rather than reconstructing full mobility portfolios.

Four dimensions are retained as analytically central within a VTBC and feasibility-oriented framework:

- the dominant mode anchoring routine university-related mobility;
- the frequency of private car use for non-systematic and discretionary mobility;
- the frequency of use of alternative modes (walking, cycling and public transport);
- the qualitative articulation between systematic and discretionary mobility domains.

The inclusion of the dominant mode for routine commuting is analytically decisive. Within both habit-based and feasibility-oriented accounts of travel behaviour, systematic mobility constitutes the core anchoring domain of behavioural organisation. It is in routine commuting that routines consolidate most strongly, cognitive automatisms are most entrenched, and feasibility evaluations are most rigidly stabilised. The dominant commuting mode therefore functions as a structural indicator of backbone-mode reliance and of the degree to which behavioural feasibility is anchored in routine consolidation versus modal flexibility.

By contrast, the frequency of private car use for non-systematic mobility captures the compensatory and adaptive dimension of behavioural organisation. Within constrained mobility contexts, discretionary trips are precisely the domain in which behavioural flexibility, trip chaining, risk management and feasibility margins are most actively negotiated. High car dependence in this domain therefore signals not only modal preference but a reliance on the private car as a compensatory feasibility device under situational uncertainty.

Finally, the reported frequencies of walking, cycling and public transport use provide a coarse but theoretically meaningful proxy for modal repertoire breadth and for the degree of already-enacted behavioural diversification. While these indicators do not capture chain articulation or intermodality, they allow the identification of whether alternative modes are behaviourally viable resources already embedded in everyday practice or merely latent options.

Taken together, these indicators make it possible to reconstruct regime-consistent pre-selection mobility profiles. Importantly, these profiles are not intended as behavioural typologies in a psychological sense. They are conceived as diagnostic representations of how behavioural feasibility is already anchored at baseline across the domains of systematic and discretionary mobility, before any exposure to VTBC framing, self-monitoring or MaaS-related informational inputs.

The pre-selection mobility profiles of the effective participants provide the only genuinely exogenous behavioural reference point available in the experiment.

Table 75 summarises the pre-selection mobility configuration of the 30 participants who later generated usable tracking data, distinguishing between treated and control groups.

Table 75 Pre-selection and tracking phase 1 mobility configuration of effective participants by group

<i>Analytical dimension</i>	<i>Treated – Pre-selection</i>	<i>Treated – Phase 1</i>	<i>Control – Pre-selection</i>	<i>Control – Phase 1</i>
<i>Main mode (systematic)</i>	PT-dominant	PT-dominant (stable)	PT-dominant	PT-dominant (stable)
<i>Share with distance ≥ 30 km</i>	High	High (stable)	High	High (stable)
<i>Car use (non-systematic)</i>	Very high	High (slightly reduced)	Very high	Very high (stable)
<i>PT use (non-systematic)</i>	High	High (stable or $\uparrow$)	Medium	Medium–low (stable or $\downarrow$)
<i>Walking (non-systematic)</i>	High	High (stable)	Medium	Medium (stable)
<i>Bicycle/micromobility (non-systematic)</i>	Low-medium	Low-medium (stable)	Low-medium	Low-medium (stable)
<i>Discretionary modal organisation</i>	Compensatory-diversified	Compensatory-diversified (reinforced)	Car-centred compensatory	Car-centred compensatory (stable)
<i>Regime anchoring principle</i>	Flexibility + redundancy	Flexibility + redundancy	Routine + control	Routine + control
<i>Direction of reconfiguration</i>	—	Bounded rebalancing within regime	—	No meaningful reconfiguration

Source 90 author's elaboration based on pre-selection and app-based tracking data.

Note: Arrows indicate relative direction within pre-selection and tracking phase 1.

Three analytically relevant features emerge immediately.

First, systematic mobility to the university is already overwhelmingly public-transport-based in both groups, with only a small minority relying primarily on the private car. This confirms that, for the effective sample, car dependence is not structurally anchored in routine university commuting. Instead, it is displaced toward discretionary and non-systematic mobility, where flexibility, trip chaining and uncertainty management are most salient.

Second, both groups operate under demanding spatial exposure conditions. Medium- and long-distance commuting is prevalent among two groups. Control participants also include a non-negligible share of very long-distance commuters. These figures indicate that, already at baseline, everyday mobility unfolds under non-trivial temporal, spatial and organisational constraints in both groups.

Third, frequent reliance on the private car for non-systematic mobility is already structurally embedded in both groups. In each group, a majority of participants report using the car several times per week or more for discretionary travel, and roughly one third report daily car use. This confirms that compensatory car dependence is a central feature of baseline mobility organisation among effective participants, even in the presence of public-transport-based commuting.

Against this common background, however, important group-level asymmetries are already visible prior to any tracking, VTBC framing or MaaS-related exposure. These differences do not concern

marginal variations in mode frequency, but the structural anchoring of behavioural feasibility across systematic and discretionary mobility domains.

Among treated participants, a larger share is positioned within mixed compensatory and articulated regimes, characterised by either public transport, or active-mode anchoring of routine commuting combined with situational reliance on the private car for non-systematic mobility. This configuration is consistent with a feasibility regime in which behavioural stability is already achieved through partial modal diversification and compensatory articulation rather than through full routine consolidation around a single backbone mode.

By contrast, control participants are more heavily concentrated in routine-anchored, car-centred configurations, in which both systematic commuting and discretionary mobility are stabilised through reliance on the private car. In these cases, behavioural feasibility is anchored in routine consolidation and backbone-mode control, with limited already-enacted diversification of the modal repertoire.

These pre-tracking asymmetries are analytically consequential. They indicate that the two experimental groups do not enter the VTBC experiment with identical baseline feasibility regimes, even prior to any experimental exposure. Rather than representing a failure of randomisation, this pattern reflects the combined effects of selective recruitment, self-selection into participation, and the small size of the experimental sample. Within a feasibility-oriented interpretation, these asymmetries must therefore be treated as part of the empirical reality of voluntary behavioural experimentation rather than as statistical noise.

A particularly important synthetic result of this comparison is that the pre-selection profiles already align closely with the regime-level behavioural architectures later reconstructed from tracking data. The treated group's pre-tracking configuration is more consistent with integration-oriented and articulated feasibility regimes, while the control group's profile is more consistent with routine-anchored, car-centred organisation. This continuity reinforces a central analytical point: later observed behavioural differences between treated and control participants are not generated *ex nihilo* by the intervention. They are filtered, shaped and bounded by pre-existing feasibility regimes that already structure how constraint, effort, risk and flexibility are distributed across everyday mobility practices.

For the purposes of behavioural-change interpretation, this baseline positioning has two direct implications.

First, any phase-to-phase differences observed during tracking must be read as reconfigurations occurring within these pre-existing feasibility corridors. Behavioural change, if and when it occurs, cannot be interpreted as a shift from a neutral starting point, but only as a modification of already differentiated organisational logics.

Second, the experiment does not test whether VTBC or MaaS mechanisms “create” multimodality or car-reduction *ex nihilo*. It tests whether, and under which conditions, already-available alternatives embedded in participants’ baseline repertoires can be behaviourally foregrounded, stabilised or reweighted under staged intervention exposure.

Furthermore, a particularly important synthetic result of this comparison is captured by the “direction of reconfiguration” row in Table 75. For both groups, the transition from pre-selection to tracking phase 1 does not reveal any evidence of regime-level behavioural change. Among treated participants, the observed differences are analytically consistent with bounded rebalancing within an already integration-prone feasibility regime. Among control participants, no meaningful reconfiguration is observed at all. This asymmetry is analytically central because it allows tracking phase 1 dynamics to be positioned unambiguously within the internal logic of the two baseline feasibility regimes.

For the treated group, phase 1 does not mark a shift away from the existing anchoring of feasibility in flexibility and redundancy. It marks, instead, a modest redistribution of behavioural weight within an already diversified and compensatory mobility architecture. Slight reductions in discretionary car use, stable or marginally increased use of public transport outside commuting, and the persistence of active mobility practices do not amount to a weakening of backbone-mode reliance, because no backbone mode exists in the first place in this group. Rather, they reflect the selective foregrounding and consolidation of behavioural configurations that were already feasible, already enacted and already embedded in the pre-selection repertoire. In VTBC-consistent terms, this pattern corresponds to within-regime adaptation rather than to regime-level reconfiguration.

For the control group, the picture is even more unambiguous. The transition from pre-selection to phase 1 shows no systematic weakening of routine dominance, no expansion of the discretionary modal repertoire, and no reorganisation of the functional role of the private car. Compensatory car dependence remains structurally intact, and discretionary alternatives remain weakly embedded. The absence of any meaningful reconfiguration indicates that the concentration-based, car-centred feasibility regime is not only already consolidated at baseline, but remains behaviourally inert under first-stage intervention exposure. In this group, phase 1 does not even produce bounded rebalancing; it produces near-complete regime stability.

Read through a feasibility-oriented lens, this result has two decisive implications. First, it confirms that phase 1 exposure, composed of behavioural framing, anticipatory engagement and self-monitoring, does not in itself generate behavioural change in a strict VTBC sense. Its behavioural effect, where present, is limited to bounded rebalancing within an already integration-prone regime and is entirely absent within a concentration-based regime. Second, it stabilises the analytical status of phase 1 as an intermediate reference configuration rather than as a behavioural baseline or an early treatment effect. What is observed in tracking phase 1 is not the emergence of new feasibility architectures, but the selective activation, reinforcement or inertia of pre-existing ones.

In this sense, the direction of reconfiguration is not a descriptive residual category. It is a diagnostic summary of how far first-stage intervention exposure can move mobility behaviour under feasibility constraints. It shows that, at this stage of the experiment, treated participants exhibit only regime-consistent rebalancing, while control participants exhibit no reconfiguration at all. This finding is analytically crucial because it defines, *ex ante*, the upper bound of what phase 1 can plausibly be expected to accomplish and, conversely, sharpens the inferential burden placed on phase 2: any behavioural change claim must rest on reconfigurations that go beyond the bounded, regime-consistent adjustments observed here.

From first-stage exposure to second-stage intervention: mobility reconfiguration between phase 1 and phase 2

Having established that the transition from pre-selection to tracking phase 1 does not in itself generate behavioural change in a strict VTBC sense, and that treated and control participants enter the experiment with differentiated baseline feasibility regimes, the analytical status of the phase 1–phase 2 comparison can now be specified more precisely. The differences observed, or not observed, between the two tracking phases must be read as reconfigurations occurring within these pre-existing feasibility corridors, rather than as shifts from a neutral starting point. Behavioural change, if and when it occurs, cannot be interpreted as a transition from baseline equilibrium to a new regime, but only as a modification of already differentiated organisational logics through which everyday mobility is stabilised under constraint.

The criteria through which behavioural change is distinguished from bounded rebalancing, tracking-induced reactivity and engagement filters have already been formalised in the interpretative grid introduced above and are therefore not restated here. The following analysis applies that grid directly to the observed mobility dynamics between tracking phase 1 and tracking phase 2, with the specific aim of determining whether any of the phase-to-phase reconfigurations exceed regime-consistent adaptation and qualify as behavioural change in a VTBC-consistent sense.

Accordingly, Table 76 summarises the mobility configuration of treated and control participants in tracking phase 1 and tracking phase 2 using only those behavioural dimensions that can plausibly signal regime-level reconfiguration rather than bounded adaptation or measurement reactivity. These include routine dominance, modal repertoire breadth, portfolio structure, the functional role of the car within travel chains, the organisational logic of intermodality, and the composite behavioural regime derived from the joint distribution of repertoire breadth and routine dominance. The table thus does not provide a descriptive summary of all observed dynamics between phases, but a diagnostic positioning of phase-to-phase mobility configurations relative to the feasibility-oriented criteria for behavioural change formalised in the interpretative grid.

Read in this way, Table 76 functions as the empirical hinge between the descriptive reconstruction of mobility regimes developed in the preceding chapter and the interpretative assessment of

behavioural change undertaken in the remainder of this section. It renders explicit, in a compact and theory-consistent form, whether any of the phase 1–phase 2 differences observed within and between experimental groups correspond to a weakening of routine anchoring, an expansion or contraction of the effective feasible choice set, a reorganisation of portfolio architecture, or a shift in the compensatory versus integrative role of the private car. In doing so, it establishes the necessary analytical precondition for distinguishing genuine behavioural reconfiguration from internal rebalancing within stable feasibility regimes, tracking-induced salience effects, or engagement-filter artefacts.

Table 76 Tracking phase 1 and phase 2 mobility configuration of effective participants by group (interpretative-grid indicators)

<i>Analytical dimension</i>	<i>Treated – Phase 1</i>	<i>Treated – Phase 2</i>	<i>Control – Phase 1</i>	<i>Control – Phase 2</i>
<i>Routine dominance</i>	Medium–low (heterogeneous)	Medium–low (stable or marginally redistributed)	High	High (stable)
<i>Modal repertoire breadth</i>	Medium–high	Medium–high (stable)	Low–medium	Low–medium (stable)
<i>Portfolio structure</i>	Diversified	Diversified (stable)	Car-centred	Car-centred (stable)
<i>Functional role of the car</i>	Situational / non-backbone	Situational / non-backbone (stable)	Backbone + terminal	Backbone + terminal (stable or reinforced)
<i>Intermodality logic</i>	Integrative	Integrative (stable)	Auxiliary	Auxiliary (stable)
<i>Composite behavioural regime</i>	Flexible / fragmented	Flexible / fragmented (stable)	Routinised stable	Routinised stable (stable)
<i>Regime anchoring principle</i>	Flexibility + redundancy	Flexibility + redundancy	Routine + control	Routine + control
<i>Direction of reconfiguration</i>	—	Bounded rebalancing within regime	—	No meaningful reconfiguration

Source 91 author's elaboration based on app-based tracking data.

Notes: Arrows and qualifiers indicate relative direction from tracking phase 1 to phase 2

At a first comparative level and read directly through the indicators specified in the interpretative grid (Table 76), the treated group exhibits visible internal movement between phase 1 and phase 2, whereas the control group displays near-complete regime stability, yielding an unambiguous result.

First, with respect to routine dominance, *treated participants do not exhibit a systematic weakening of dominant modal chains*. While individual-level dominance values fluctuate, and some participants experience a partial redistribution of weight across chains, no durable erosion of behavioural anchoring is observed. Dominant configurations remain behaviourally salient, and no individual transitions into a persistently weak-dominance regime. These movements therefore correspond to minor redistribution across existing chains rather than to a weakening of automaticity or routine consolidation. Among control participants, routine dominance remains high and stable, confirming the persistence of strongly anchored behavioural defaults.

Second, *modal repertoire breadth does not expand* in a way that would signal an enlargement of the effective feasible choice set. Among treated participants, repertoire size remains medium–high and stable, with only minor phase-to-phase variation driven by activation or deactivation of already-used marginal configurations. No new modal categories enter portfolios, and no systematic shift toward non-car or non-backbone configurations is observed because no backbone configuration exists in the first place. Among control participants, modal repertoires remain narrow and unchanged. In both groups, observed variation therefore corresponds to activation of already-enacted options rather than to the incorporation of new feasible alternatives.

Third, *portfolio structure does not undergo regime-level transformation* in either group. Treated mobility remains diversified and non-car-centred in both phases, while control mobility remains car-centred in both phases. No treated participant consolidates around a single dominant mode, and no control participant moves toward a diversified architecture. The organisational logic of mobility thus remains structurally invariant across phases.

Fourth, *the functional role of the private car does not exhibit change-consistent weakening*. Among treated participants, the car does not become less central because it was never central to begin with; its role remains situational and circumscribed, and the share of car-only trips does not decline further in a way that would indicate displacement. Among control participants, the car continues to function as a backbone mode. The observed shift from car-only to car-as-access/egress trips does not weaken this backbone role; it merely redistributes how car dependence is operationalised within chains. According to the interpretative grid, this pattern corresponds to continued backbone anchoring rather than to functional reconfiguration.

Fifth, *intermodality logic remains regime-consistent* in both groups. Among treated participants, intermodality continues to function as an integrative coping strategy through which spatial complexity and coordination effort are managed via modal combination. No shift toward terminal or accessory intermodality is observed. Among control participants, intermodality remains auxiliary and car-anchored, extending rather than challenging car-centred routines. In neither group does intermodality acquire a qualitatively new organisational role.

Finally, *composite behavioural regime positions remain stable*. Although some treated individuals move between adjacent composite profiles, these transitions occur within the same broad regime category (flexible / fragmented) and do not amount to regime crossing. No treated participant transitions from an integration-based to a concentration-based regime, and no control participant transitions in the opposite direction. According to the grid, this pattern corresponds to stability within regime category rather than to regime-level reconfiguration.

Taken together, the phase 1–phase 2 positioning of both groups across all grid-consistent indicators in Table 76 yields a coherent and non-contradictory pattern. None of the observed phase 1–phase 2 reconfigurations satisfy the criteria for behavioural change in a strict VTBC sense. All observed dynamics are analytically consistent with bounded internal rebalancing within stable feasibility

regimes, minor redistribution of behavioural weight across already-feasible configurations, tracking-induced salience effects, and regime-preserving functional adaptation.

This diagnosis is further reinforced by an independent and convergent piece of empirical evidence concerning actual engagement with MaaS-enabled services. Despite full second-stage exposure to the MaaS platform, personalised feedback and informational integration, treated participants made almost no use of the operational mobility services offered through the app. Over the entire duration of phase 2, only two MaaS services were purchased in total.

Within a VTBC-consistent and feasibility-oriented interpretation, this result is analytically consequential. If second-stage exposure had effectively lowered behavioural feasibility thresholds or altered the organisational calculus of everyday mobility, this would be expected to manifest not only in reweighting of observed modal chains, but also in at least minimal uptake of MaaS-enabled alternatives that were explicitly foregrounded as part of the intervention logic. The near-complete absence of such uptake therefore constitutes a negative behavioural signal that is fully consistent with the grid-based diagnosis of regime stability.

Importantly, this finding cannot be reduced to lack of interest in MaaS as a technological artefact. Within the staged VTBC–MaaS framework, MaaS functions as an operational feasibility device rather than as a standalone product. Its behavioural relevance lies in whether it becomes organisationally integrated into existing routines and compensatory strategies. The fact that it fails to do so—even among treated participants whose mobility regimes are already integration-prone and diversified—indicates that second-stage exposure does not cross the feasibility thresholds required for operational adoption.

In this sense, the negligible uptake of MaaS services does not contradict the bounded rebalancing observed in treated mobility; it corroborates it. Both patterns point to the same underlying mechanism: the intervention foregrounds and modestly reweights behavioural configurations that are already feasible and already enacted, but it does not generate sufficient reduction in perceived effort, coordination burden or behavioural risk to trigger the incorporation of new operational components into everyday mobility organisation.

Analytically, the MaaS non-uptake therefore functions as a complementary indicator of regime stability rather than as an outcome variable in its own right. It strengthens the conclusion that second-stage exposure produces internal redistribution within an integration-based feasibility regime without inducing regime-level reconfiguration or threshold-crossing behavioural change.

Taken together, the phase 1–phase 2 evidence establishes a clear and internally consistent empirical boundary for what the VTBC–MaaS intervention accomplishes within the observed feasibility corridor. Across all grid-consistent indicators, and reinforced by the near-complete absence of MaaS uptake, second-stage exposure does not produce regime-level behavioural reconfiguration in either

experimental group. What it produces, where any behavioural movement is observed at all, is bounded internal rebalancing within already stabilised feasibility architectures.

This finding does not imply that the intervention is behaviourally inert. It shows, rather, that its behavioural effects remain confined to the selective foregrounding, modest reweighting and internal redistribution of configurations that were already feasible, already enacted and already embedded in participants' baseline repertoires. In both groups, the organisational logic through which everyday mobility is stabilised under constraint remains structurally intact.

At the same time, the absence of regime-level reconfiguration during the tracking trajectory does not exhaust the behavioural relevance of the experimental exposure. Behavioural change, within a VTBC-consistent and stage-based interpretation, need not be manifested immediately as observable reorganisation of mobility practices. It may instead operate through slower shifts in awareness, readiness, perceived feasibility and evaluative orientation toward alternatives that only materialise behaviourally over longer time horizons or under changed situational conditions.

For this reason, the analysis now turns to the follow-up survey data. The next chapter examines whether staged exposure to VTBC framing, self-monitoring, personalised feedback and MaaS-enabled informational integration produces detectable changes in behavioural intentions, readiness, perceived constraints and self-reported mobility orientation in the short to medium term, even in the absence of immediate regime-level reconfiguration of observed practices. This allows the behavioural impact of the intervention to be assessed not only at the level of enacted mobility behaviour, but also at the level of latent cognitive and evaluative shifts that may condition future behavioural change.

Post-experiment monitoring: persistence of feasibility regimes beyond the intervention

In order to assess whether any delayed or medium-term behavioural reconfiguration emerges after the end of the experimental exposure, post-experiment monitoring data are analysed using exactly the same behavioural indicators employed for the pre-selection baseline and for the tracking phases. This deliberate replication of indicators serves a precise analytical purpose: it ensures strict comparability across observation windows and positions post-experiment mobility configurations within the same feasibility-oriented interpretative framework developed for tracking. In particular, systematic mobility anchoring, discretionary modal organisation and compensatory coping logics are reconstructed using identical dimensions, so that any apparent differences between pre-selection and monitoring cannot be attributed to shifts in measurement strategy or indicator definition. Monitoring indicators, as in the pre-selection stage, are reconstructed from survey self-reports rather than from continuous app-based observation. They are therefore treated as regime-diagnostic signals that are fully comparable in conceptual structure, though not in observational granularity, to the tracking measures.

Table 77 summarises the mobility configuration of treated and control participants at pre-selection and at post-experiment monitoring using this harmonised set of indicators. Read in conjunction with the tracking-phase results, the table provides a synthetic positioning of medium-term mobility behaviour relative to baseline feasibility regimes.

Table 77 Pre-selection and post-experiment monitoring mobility configuration of effective participants by group

<i>Analytical dimension</i>	<i>Treated – Pre-selection</i>	<i>Treated – Monitoring</i>	<i>Control – Pre-selection</i>	<i>Control – Monitoring</i>
<i>Main mode (systematic)</i>	PT-dominant	PT-dominant (stable or ↑)	PT-dominant	PT-dominant (stable or ↓)
<i>Share with distance ≥ 30 km</i>	High	High (stable)	High	High (stable)
<i>Car use (non-systematic)</i>	Very high	High–very high (↓)	Very high	Very high (stable)
<i>PT use (non-systematic)</i>	High	High (stable)	Medium	Medium–low (stable or ↓)
<i>Walking (non-systematic)</i>	High	High (stable or ↓)	Medium	Medium (stable)
<i>Bicycle/micromobility (non-systematic)</i>	Low–medium	Low–medium (stable)	Low–medium	Low–medium (stable or ↓)
<i>Sharing services use (non-systematic)</i>	-	Low / marginal (stable)	-	Low / marginal (stable)
<i>Discretionary modal organisation</i>	Compensatory-diversified	Compensatory-diversified (stable)	Car-centred compensatory	Car-centred compensatory (stable)
<i>Regime anchoring principle</i>	Flexibility + redundancy	Flexibility + redundancy	Routine + control	Routine + control
<i>Direction of reconfiguration</i>	—	Bounded rebalancing within regime	—	Bounded rebalancing within regime

Source 92 author's elaboration based on app-based tracking data.

Note: Arrows indicate relative direction within pre-selection and monitoring phases.

At the first descriptive level, Table 77 reveals a very high degree of stability across all core dimensions of behavioural organisation in both experimental groups. Where directional movement is observable, it is weak, asymmetric across groups, and confined to within-regime reweighting rather than to any reorientation of anchoring principles or portfolio logics.

With respect to systematic mobility, the dominant anchoring mode remains public transport in both groups, with no evidence of post-experiment reorientation. Among treated participants, the PT-dominant structure appears marginally reinforced, while among control participants it displays a slight weakening, without however altering the dominant anchoring principle. The persistence of a PT-based commuting backbone indicates that neither the experimental exposure nor the subsequent monitoring period induces any restructuring of the primary routine domain in which behavioural anchoring is typically most rigid. Similarly, the spatial exposure profile remains unchanged. The share

of participants travelling distances above 30 km remains high and stable in both groups, confirming that the structural constraints shaping daily mobility are invariant across the experimental and post-experimental phases.

Turning to discretionary mobility, the frequency of private car use remains structurally high in both groups, but with a weak and asymmetric directional signal. Among treated participants, car use decreases marginally, indicating a modest within-regime reweighting of compensatory car reliance. Among control participants, by contrast, car dependence remains very high and fully stable. In neither group does monitoring reveal a weakening of car reliance that could be interpreted as delayed displacement or substitution; the observed reduction among treated participants remains limited in magnitude and confined to the discretionary domain. Importantly, this movement does not alter the functional status of the car as a compensatory feasibility device: it indicates a marginal reduction in discretionary reliance, not a reconfiguration of how feasibility is secured.

Patterns of non-systematic public transport use and active mobility similarly display strong continuity. Among treated participants, public transport and walking remain highly embedded in discretionary mobility, with at most a slight downward redistribution that does not alter their compensatory-diversified organisation. Among control participants, these dimensions remain at medium or medium–low levels, with no sign of compensatory diversification and with only marginal drift that is more consistent with stability (or slight contraction of alternatives) than with any expansion of the feasible set. Bicycle and micromobility use remains low to medium and marginal in both groups, while the use of sharing services remains negligible. The absence of any post-experiment uptake of shared mobility services is particularly notable given their central role in the MaaS intervention logic.

At the level of organisational synthesis, these distributions translate into a high degree of regime continuity combined with limited internal reweighting. Discretionary modal organisation remains compensatory-diversified among treated participants and car-centred compensatory among control participants. The anchoring principles governing behavioural feasibility remain unchanged: flexibility and redundancy continue to structure treated mobility, while routine and control continue to anchor control mobility. Importantly, the direction of reconfiguration in Table 77 captures not regime crossing, but bounded within-regime reweighting. In the treated group this takes the form of a modest reduction in discretionary car reliance, whereas in the control group it primarily reflects marginal redistribution (or slight weakening) of non-car discretionary frequencies without any weakening of backbone anchoring.

Taken together, the pre-selection–monitoring comparison yields a coherent and internally consistent result. Across all analytically central dimensions, post-experiment mobility configurations reproduce the baseline feasibility regimes observed before any experimental exposure. Where movement is observed, it takes the form of weak, discretionary-level reweighting within already stabilised organisational logics, without any regime crossing, consolidation of alternative anchoring principles or restructuring of compensatory strategies.

In analytical terms, post-experiment monitoring does not reveal delayed behavioural reconfiguration in a strict VTBC sense. Instead, it documents the persistence of feasibility architectures combined with minor within-regime adjustments that remain insufficient to modify anchoring principles, backbone-mode reliance or portfolio structure. The intervention therefore appears unable to move participants beyond the internal margins of their existing feasibility regimes, even after experimental exposure has ceased.

Table 78 extends the tracking-phase analysis by positioning post-experiment monitoring configurations directly alongside tracking phase 1 and tracking phase 2, using exclusively the interpretative-grid indicators introduced earlier. In doing so, it allows the entire experimental trajectory to be read as a continuous behavioural sequence, from first-stage exposure through second-stage intervention to post-experiment observation, within a single feasibility-oriented analytical frame.

At this level of comparison, the monitoring data function as a direct test of persistence, consolidation and delayed reconfiguration. If behavioural change were to emerge only after the end of the intervention, through learning effects, gradual incorporation of new organisational strategies or delayed threshold crossings, this would be expected to manifest as systematic and directional shifts between phase 2 and monitoring along at least some of the regime-diagnostic dimensions specified in the interpretative grid.

Table 78 Tracking phase 1, tracking phase 2 and post-experiment monitoring mobility configuration by group (interpretative-grid indicators)

<i>Analytical dimension</i>	<i>Treated – Phase 1</i>	<i>Treated – Phase 2</i>	<i>Treated – Monitoring</i>	<i>Control – Phase 1</i>	<i>Control – Phase 2</i>	<i>Control – Monitoring</i>
<i>Routine dominance</i>	Medium–low (heterogeneous)	Medium–low (stable or marginally redistributed)	Medium–low (stable)	High	High (stable)	High (stable)
<i>Modal repertoire breadth</i>	Medium–high	Medium–high (stable)	Medium–high (stable)	Low–medium	Low–medium (stable)	Low–medium (stable)
<i>Portfolio structure</i>	Diversified	Diversified (stable)	Diversified (stable)	Car-centred	Car-centred (stable)	Car-centred (stable)
<i>Functional role of the car</i>	Situational / non-backbone	Situational / non-backbone (stable)	Situational / non-backbone (stable)	Backbone + terminal	Backbone + terminal (stable or reinforced)	Backbone + terminal (stable)
<i>Intermodality logic</i>	Integrative	Integrative (stable)	Integrative (stable)	Auxiliary	Auxiliary (stable)	Auxiliary (stable)
<i>Composite behavioural regime</i>	Flexible / fragmented	Flexible / fragmented (stable)	Flexible / fragmented (stable)	Routinised stable	Routinised stable (stable)	Routinised stable (stable)
<i>Regime anchoring principle</i>	Flexibility + redundancy	Flexibility + redundancy	Flexibility + redundancy	Routine + control	Routine + control	Routine + control
<i>Direction of reconfiguration</i>	—	Bounded rebalancing within regime	Bounded rebalancing within regime	—	No meaningful reconfiguration	Bounded rebalancing within regime

Source 93 author's elaboration based on tracking data and post-experiment monitoring survey.

Notes: Monitoring indicators are reconstructed from post-experiment survey data on dominant commuting mode, multimodality in systematic mobility and discretionary mode frequencies.

Table 78 yields a clear and internally coherent result. A key point is that, in this grid-based reading, bounded rebalancing does not require a change in categorical class (e.g., from medium–low to low routine dominance). It may occur as limited reweighting within the same class boundaries, which is why stability labels at the level of regime-diagnostic categories can coexist with a rebalancing diagnosis.

Across all six analytically central dimensions, both treated and control participants display a very high degree of regime continuity between tracking and monitoring, combined with only weak and circumscribed internal movements that remain confined within pre-existing feasibility architectures.

Among treated participants, routine dominance remains medium–low and heterogeneous, modal repertoire breadth remains medium–high, portfolio structure remains diversified, and intermodality continues to operate in an integrative mode. The functional role of the private car remains situational and non-backbone, and composite behavioural regimes remain firmly located within the flexible / fragmented category. The anchoring principle of feasibility remains unchanged, continuing to rely on flexibility and redundancy. Importantly, the direction of reconfiguration indicates not regime stability in a strict sense, but bounded rebalancing within regime: minor redistributions of behavioural weight

occur across phases, yet without any crossing of regime boundaries or modification of anchoring principles.

A comparable pattern is observed in the control group. Routine dominance remains high and stable, modal repertoires remain narrow, portfolio structure remains car-centered, and the private car continues to function as a backbone and terminal mode. Intermodality remains auxiliary and car-anchored, and composite regimes remain routinised and stable. The anchoring principle of routine and control persists unchanged. Here too, the direction of reconfiguration points to bounded rebalancing within regime rather than to complete inertia: small internal redistributions are observed between phases, but they remain fully regime-consistent and do not weaken backbone anchoring or routine consolidation.

Read longitudinally, the table shows that the behavioural regimes reconstructed during tracking are not transient artefacts of observation or intervention exposure. On the contrary, they persist in their core organisational logic after the end of the experimental setting. The integration-based regime observed among treated participants and the concentration-based regime observed among control participants are fully reproduced in the post-experiment monitoring window, with only limited internal reweighting and no evidence of delayed regime crossing, consolidation of alternative anchoring principles or restructuring of compensatory strategies.

Analytically, this continuity combined with bounded rebalancing is decisive. It indicates that the internal redistributions observed among treated participants during tracking phase 2 do not evolve into regime-level reconfiguration once experimental exposure ceases. Likewise, the regime inertia observed in the control group remains dominant, with only marginal internal adjustments that do not alter anchoring principles or backbone-mode reliance. Behavioural feasibility architecture thus appears not only robust during intervention, but highly persistent beyond it, allowing only limited within-regime adaptation.

In this sense, monitoring does not reveal latent behavioural change emerging after the experiment in a strict VTBC sense. It confirms, instead, the long-run stability of the coping logics and anchoring principles through which everyday mobility is rendered feasible under constraint, combined with weak regime-consistent reweighting that remains well below any threshold of organisational reconfiguration.

From a stage-based and readiness-oriented perspective, the absence of delayed regime-level reconfiguration in the monitoring phase is theoretically informative. Within the framework adopted in this study, behavioural change is expected to be preceded by shifts in readiness, perceived feasibility and evaluative orientation, which may remain latent before translating into observable reorganisation of practices. A delayed effect after the end of experimental exposure would therefore be plausible only insofar as such latent transitions subsequently materialised in regime-diagnostic behavioural signals.

The present design, however, imposes a strict analytical constraint. Latent cognitive and evaluative dimensions are observed only once, in the post-experiment monitoring survey. It is therefore not possible to reconstruct within-individual trajectories of readiness or motivational change across phases. The monitoring data do not allow the identification of dynamic stage progression, but only an assessment of whether the observed behavioural configurations are compatible with the presence of latent destabilisation at the end of the intervention.

Read in this light, the monitoring results acquire a precise interpretative status. The persistence of regime-level feasibility architectures beyond the end of the intervention, combined with only bounded rebalancing within regime, indicates not only the absence of behavioural change in a strict VTBC sense, but also the absence of behavioural evidence consistent with a delayed transition between feasibility regimes. If staged exposure had generated readiness shifts approaching a regime threshold, this would be expected to translate into sustained weakening of backbone anchoring, expansion of effective modal repertoires or restructuring of portfolio architectures. None of these signals emerge in the monitoring phase.

At the same time, the present analysis cannot exclude the possibility that more subtle cognitive or attitudinal effects may have occurred below the threshold of observable behavioural reconfiguration. With only a single post-experiment observation of latent constructs, such effects cannot be tracked longitudinally and may remain invisible in revealed mobility patterns over short and medium horizons.

In order to further qualify the motivational configuration associated with the persistence of feasibility regimes, the monitoring survey also included two direct expectation and necessity items concerning future car-use reduction and perceived necessity of the private car in everyday mobility. Although purely cross-sectional and not suitable for causal inference, these indicators provide an additional diagnostic window on participants' self-positioning along the readiness continuum.

At an aggregate level, treated and control participants display remarkably similar distributions in both dimensions. Expectations of reducing car use over the subsequent twelve months do not exhibit any systematic shift in favour of treated participants, nor do perceptions of the necessity of the private car differ in a way that would suggest differentiated movement toward action-oriented stages. Rather, in both groups the dominant configuration combines moderate expectations of future reduction with a high perceived necessity of the car for everyday mobility.

Read through a Transtheoretical Model perspective, this pattern is analytically revealing. The coexistence of declared openness to future reduction with persistent perceptions of necessity corresponds to a motivational configuration typical of late pre-contemplation or early contemplation stages, in which evaluative orientation toward change may be present but is not yet accompanied by a credible implementation horizon. In particular, high perceived necessity functions as a structural

brake on stage progression: even where intentions or expectations are articulated, readiness remains bounded by the anticipation of binding feasibility constraints.

Importantly, the absence of any systematic differentiation between treated and control participants reinforces the central conclusion of the monitoring analysis. Staged exposure to VTBC framing, self-monitoring and personalised feedback does not translate into a detectable upward shift in readiness for car-use reduction at the level of explicit future expectations or perceived behavioural indispensability. Read jointly with the stability of behavioural regimes and with the latent-construct profiles discussed above, these indicators confirm that participants remain positioned below the preparation–action threshold and that feasibility regimes continue to anchor both enacted practices and anticipatory orientations.

In this sense, expectation- and necessity-based indicators converge with the behavioural and latent-construct evidence in documenting a configuration of bounded readiness: openness to change coexists with persistent perceptions of constraint, and neither dimension displays the directional pattern that would be expected under delayed regime-level transition.

On this basis, the analytical focus now shifts from observed mobility behaviour to the cross-sectional structure of latent cognitive and evaluative dimensions measured at the end of the experiment. The following chapter examines whether staged exposure to VTBC framing, self-monitoring, personalised feedback and MaaS-enabled informational integration is associated with systematic differences in readiness, intentions, perceived constraints and mobility orientations between treated and control participants, even in the absence of observable behavioural reconfiguration.

Latent cognitive and habitual determinants of bounded rebalancing under feasibility constraints and regime stability

While the preceding sections have shown that post-experiment monitoring reveals no regime-level behavioural reconfiguration and only bounded rebalancing within stable feasibility architectures, this behavioural stability does not exhaust the analytical implications of the experiment. Within a dual-process and stage-based perspective, the persistence of enacted mobility regimes may coexist with, and in some cases be accompanied by, differentiated cognitive, motivational and habitual configurations that remain embedded in, and constrained by, pre-existing feasibility regimes.

Accordingly, the purpose of this section is not to infer behavioural change from motivational proxies, but to reconstruct the latent cognitive–habitual configuration within which regime stability and bounded rebalancing are reproduced at the end of the experimental sequence. To do so, the analysis draws on constructs derived from Haustein’s dual-process adaptation of the Theory of Planned Behaviour and from the integrated TTM–TPB framework developed in the theoretical part of the thesis.

In Haustein's model, behavioural change depends not only on attitudes, norms and intentions, but on the interaction between reflective motivation (System 2), automatic habit strength (System 1) and the joint configuration of perceived and actual behavioural control. These latent dimensions play a central role in determining whether reflective activation can translate into implementation or whether behavioural reorganisation remains blocked by persistent habits and binding feasibility constraints. Variation in these constructs may therefore function as a diagnostic signal of readiness, heightened awareness of constraints or emerging implementation barriers even when observable mobility behaviour remains stable and regime boundaries are not crossed.

In the present experiment, latent constructs were measured once, at the post-experiment monitoring stage. The analysis therefore does not reconstruct intra-individual cognitive trajectories over time, but compares treated and control participants at the end of the experimental sequence in order to assess whether the two groups display differentiated motivational, control-related or habitual profiles under otherwise comparable structural conditions. Any observed differences are interpreted cautiously as regime-consistent positioning and bounded internal reweighting rather than as direct indicators of intervention-induced change.

Following standard practice in behavioural evaluation with small samples and ordinal-scale constructs, group differences are assessed using non-parametric Mann–Whitney tests complemented by Cliff's delta as an effect-size measure. This combined strategy allows both statistical significance and substantive magnitude of differences to be evaluated, in line with the interpretative logic adopted throughout the thesis, which privileges regime-diagnostic and feasibility-oriented interpretation over purely distributional inference.

The analysis focuses on seven constructs: environmental attitude, social norms, current (actual) behavioural control, perceived behavioural control, attitude toward behavioural change, intention to change, and subjective car dependence as a proxy for habit strength and automaticity. Together, these dimensions reconstruct the latent motivational–habitual architecture within which the observed regime stability and bounded rebalancing are organised.

Table 79 reports descriptive statistics, distributional tests and effect sizes for each construct by experimental group and provides a complementary perspective to the behavioural analyses presented in the previous sections by documenting the cognitive, control-related and habitual conditions under which the persistence of feasibility regimes is reproduced after the end of the intervention.

Table 79 Latent constructs at post-experiment monitoring by experimental group

<i>Construct</i>	<i>Treated (mean)</i>	<i>Control (mean)</i>	<i>Mann– Whitney p</i>	<i>Cliff's δ</i>	<i>Substantive interpretation</i>
<i>Environmental attitude</i>	3.92	3.91	1.00	0.00	Full equivalence between groups
<i>Social norms</i>	2.81	2.49	0.23	+0.28	Weak positive shift among treated
<i>Current (actual) control</i>	3.63	3.53	0.78	+0.07	No meaningful difference
<i>Perceived behavioural control</i>	3.38	3.94	0.22	−0.28	Slightly lower perceived control among treated
<i>Attitude toward change</i>	3.65	3.75	0.64	+0.11	No meaningful difference
<i>Intention to change</i>	3.75	3.55	0.47	+0.17	Weak positive shift among treated
<i>Subjective car dependence</i>	3.06	3.70	0.095	−0.386	Moderate reduction of habit strength among treated

Source 94 author's elaboration based on post-experiment monitoring survey.

Notes: N = 27 (Treated = 16; Control = 11). Positive δ indicates higher values among treated participants. Mann–Whitney tests are two-sided.

At a general level, the results reveal a highly coherent pattern. Across most cognitive and motivational dimensions, treated and control participants display only weak differences, with small effect sizes and non-significant distributional shifts. This overall configuration closely mirrors the regime-level stability and bounded rebalancing documented in the behavioural analyses and suggests that latent motivational and control-related orientations remain largely structured by pre-existing feasibility regimes rather than being substantially reshaped by experimental exposure. At the same time, the joint configuration of control-related and habit-related constructs provides an empirically grounded illustration of the regime-consistent configurations hypothesised by Haustein's dual-process framework and by the integrated TTM–TPB model developed in the theoretical part (Part1).

Environmental attitudes are virtually identical in the two groups (mean 3.92 vs 3.91; δ = 0.00), indicating full equivalence in general pro-environmental orientation. This result is analytically important, as it confirms that treated and control participants do not differ in baseline value orientation and that the differentiated mobility regimes observed in the previous sections are not driven by attitudinal heterogeneity, but by structural and organisational feasibility conditions.

A similarly weak pattern emerges for attitudes toward behavioural change and for social norms. Attitude toward change shows no meaningful difference between groups (δ = +0.11), while social norms display only a small positive difference in favour of treated participants (δ = +0.28, p = 0.23). These differences remain modest and statistically non-significant and are fully consistent with the bounded rebalancing documented in tracking and monitoring. Rather than indicating a strong

intervention-induced shift, they appear to reflect minor positioning differences that remain embedded within already differentiated feasibility regimes.

Intentions to change follow the same pattern. Although treated participants report slightly higher intentions than controls (mean 3.75 vs 3.55; $\delta = +0.17$), the difference remains weak and non-significant. From a TPB and TTM perspective, both groups therefore occupy largely overlapping motivational positions, with treated participants displaying at most a marginally more advanced readiness profile that remains well below the threshold associated with action-oriented stages. This configuration is entirely consistent with the absence of regime crossing and with the persistence of stable anchoring principles documented in the behavioural analysis.

Taken together, these results indicate no strong cognitive or motivational differentiation between treated and control participants at the monitoring stage. Reflective System-2 activation remains limited in magnitude and largely constrained within pre-existing motivational and feasibility architectures. Latent motivational orientations thus reproduce, rather than override, the regime-level differentiation already observed in enacted mobility behaviour.

The most analytically informative configuration emerges from the joint reading of perceived and actual behavioural control, which represents a central innovation of Haustein's framework.

Current (actual) behavioural control shows full equivalence between groups (mean 3.63 vs 3.53; $\delta = +0.07$), indicating that treated and control participants face essentially identical objective feasibility conditions at the end of the experiment. Structural constraints related to accessibility, service quality, spatial configuration and time availability remain invariant across experimental status. This result is fully consistent with the behavioural analyses presented in the previous chapters, which documented persistent anchoring in stable feasibility regimes and unchanged spatial exposure profiles.

By contrast, perceived behavioural control exhibits a weak but directionally negative difference (mean 3.38 vs 3.94; $\delta = -0.28$), with treated participants reporting slightly lower perceived control than controls. Although non-significant, this pattern is theoretically informative when interpreted in conjunction with the regime-based analysis. Rather than reflecting a loss of confidence induced by the intervention, it is consistent with a more realistic appraisal of constraints among participants already operating in diversified but tightly bounded regimes. Increased behavioural salience and self-monitoring may therefore sharpen awareness of existing barriers without modifying the underlying opportunity structure.

Within Haustein's dual-process logic, this configuration is highly coherent. Reflective activation appears to operate primarily through increased salience of feasibility constraints rather than through inflated perceptions of empowerment. Perceived control converges toward actual control rather than diverging from it. This mechanism directly illustrates the analytical relevance of distinguishing

between perceived and actual behavioural control: reflective activation does not generate illusory feasibility, but reinforces the perception of binding structural limits.

In feasibility terms, perceived control appears to track the same constraint landscape that stabilises regime-level organisation, helping explain why observed movement remains confined to bounded reweighting rather than threshold-crossing reconfiguration.

From a TTM perspective, this pattern suggests that treated participants may advance in awareness and contemplation while remaining structurally blocked at the transition from preparation to action. Read jointly with the behavioural evidence, latent control orientations therefore reinforce the central conclusion of the chapter: motivational activation and reflective awareness remain insufficient to trigger behavioural reconfiguration when feasibility regimes remain unchanged.

A complementary perspective on feasibility constraints is provided by the self-reported importance of perceived barriers to reducing private car use, measured in the post-experiment monitoring survey (Table 80). Rather than being interpreted as intervention effects, these indicators are read as regime-diagnostic signals of how structural and organisational constraints are cognitively represented within the feasibility architecture documented in the behavioural analysis.

Table 80 Perceived barriers to reducing car use at post-experiment monitoring by experimental group

<i>Barriers</i>	<i>Treated (mean)</i>	<i>Control (mean)</i>	<i>Mann– Whitney p</i>	<i>Cliff's δ</i>	<i>Substantive interpretation</i>
<i>Lack of practical alternatives</i>	4.06	4.45	0.20	–0.28	Slightly stronger barrier among controls
<i>High public transport costs</i>	3.00	3.09	0.90	–0.03	Full equivalence
<i>Travel time inconvenience</i>	3.75	4.45	0.078	–0.39	Moderately stronger barrier among controls
<i>Public transport accessibility problems</i>	3.69	4.36	0.073	–0.42	Moderately stronger barrier among controls
<i>Physical limitations</i>	1.50	1.64	0.61	–0.11	No meaningful difference
<i>Organisational constraints</i>	3.81	3.91	0.70	–0.09	No meaningful difference

Source 95 author's elaboration based on post-experiment monitoring survey.

Notes: N = 27 (Treated = 16; Control = 11). Positive δ indicates higher values among treated participants. Mann–Whitney tests are two-sided.

Across all obstacle dimensions, treated and control participants report high and broadly comparable levels of perceived constraint, confirming that both groups operate under strongly binding feasibility conditions. In particular, lack of practical alternatives, travel time inconvenience and public transport

accessibility problems are rated as highly important barriers in both groups, with control participants systematically reporting slightly higher levels of constraint.

Two dimensions display moderate group differentiation with effect sizes close to the threshold of substantive relevance. Control participants assign higher importance to travel time inconvenience ($\delta = -0.39$, $p \approx 0.08$) and to accessibility problems of public transport ($\delta = -0.42$, $p \approx 0.07$), whereas treated participants report marginally lower constraint on these dimensions. These differences are analytically consistent with the regime-level positioning documented in the tracking analysis: control participants are predominantly embedded in car-centred compensatory regimes characterised by strong temporal rigidity and infrastructural dependence, whereas treated participants operate within more diversified and integration-based portfolios in which coordination and accessibility constraints are partially mitigated through redundancy and modal articulation.

Importantly, these patterns cannot be interpreted as effects of the intervention. The monitoring design provides no pre-intervention baseline for perceived barriers, and the observed differences are fully compatible with pre-existing regime architectures already documented at the behavioural level. Rather than signaling feasibility expansion, the obstacle profile indicates that perceived constraints remain tightly aligned with underlying feasibility regimes.

From a TTM and dual-process perspective, this configuration is theoretically consequential. High and persistent perceived barriers, combined with unchanged actual behavioural control, imply that participants remain structurally blocked at the preparation–action boundary. Even where motivational readiness and habit strength display limited internal reweighting, the cognitive representation of feasibility remains dominated by organisational, temporal and accessibility constraints. This alignment between perceived and actual barriers provides a direct explanation for the absence of regime-level behavioural reconfiguration observed in both tracking and monitoring phases.

In this sense, perceived barriers function not as mediators of intervention effects, but as stabilising components of feasibility regimes. They reinforce the central conclusion of the chapter: under strongly binding structural conditions, VTBC exposure may coexist with bounded internal rebalancing and modest latent differentiation, yet remain insufficient to unlock threshold-crossing behavioural change.

The clearest and theoretically most consequential difference between groups concerns subjective car dependence, used here as a proxy for habit strength and automaticity.

Treated participants report substantially lower car dependence than controls (mean 3.06 vs 3.70), with a moderate effect size ($\delta = -0.386$) and a p-value close to conventional significance thresholds ($p = 0.095$). Although statistical power is limited by sample size, the magnitude and direction of the effect are analytically salient.

However, this difference cannot be straightforwardly interpreted as a pure intervention effect. As documented in the tracking and monitoring analyses, treated and control participants are embedded in structurally different feasibility regimes: treated participants are predominantly located in integration-based and diversified mobility configurations, whereas control participants are anchored in car-centred compensatory regimes. Lower subjective car dependence among treated participants is therefore at least partly consistent with their pre-existing mobility portfolios and with a weaker backbone role of the private car already observed at the behavioural level.

Read in this light, the observed gap in subjective car dependence reflects not only a possible intervention-related weakening of habitual attachment, but also the persistent imprint of regime-level organisation on latent habit strength. In other words, habit intensity appears tightly coupled with portfolio structure and anchoring logic: car-centered regimes are associated with higher automaticity and affective attachment to the private car, whereas diversified and integration-based regimes are structurally less prone to strong car habit formation.

At the same time, the direction of the difference remains theoretically informative. Read jointly with the bounded rebalancing observed during tracking phase 2, lower reported car dependence among treated participants is compatible with weaker System-1 anchoring to the car within integration-based portfolios, potentially amplified by bounded reweighting during the experimental sequence, but not identifiable as a within-individual habit change.

Crucially, this pattern reinforces the central conclusion of the behavioural analysis. Even when habit strength appears weaker, and even where limited destabilisation is detectable at the latent level, the absence of changes in actual behavioural control and portfolio feasibility prevents translation into sustained behavioural change. Habit weakening alone, when not accompanied by structural reconfiguration of feasibility architectures, remains insufficient to trigger regime crossing.

Read jointly, the latent-construct profile documented in Table 79 offers a highly coherent explanation of the behavioural results presented in the previous sections.

First, *motivational readiness remains only weakly differentiated between groups*. Attitudes, norms and intentions display at most marginal shifts, placing treated participants only slightly ahead of controls along the readiness continuum.

Second, *feasibility constraints remain fully binding*. Actual behavioural control is unchanged, and perceived control converges toward objective limitations rather than expanding. This configuration directly explains the absence of regime crossing and the persistence of stable anchoring principles documented in the monitoring phase.

Third, *habit strength is the only dimension displaying a substantive difference between groups*. Subjective car dependence is lower among treated participants than among controls (mean 3.06 vs 3.70; $\delta = -0.386$), with a moderate effect size and a p-value close to conventional significance thresholds. The observed gap is therefore best read as regime-consistent positioning, possibly

combined with bounded internal reweighting, rather than as evidence of intervention-induced habit destabilisation.

Read in conjunction with the tracking and monitoring results, this pattern suggests that internal redistributions and minor portfolio adjustments occur within both groups, but remain confined within pre-existing feasibility regimes. Neither motivational thresholds nor feasibility thresholds are crossed, and habitual anchoring continues to structure behavioural organisation. Differences in reported car dependence thus appear as an expression of stable regime architectures and bounded rebalancing, rather than as evidence of regime-level habit destabilisation.

Within the integrated TTM–TPB–Haustein framework, treated participants can therefore be interpreted as occupying an intermediate readiness configuration, in which reflective awareness, motivational orientation and habitual anchoring are jointly shaped by the feasibility regimes within which individuals are embedded. Importantly, this configuration cannot be interpreted as the outcome of a dynamic transition induced by the intervention, since latent constructs are observed only at the post-experiment stage and no pre-intervention baseline is available. The observed profile instead reflects the joint outcome of pre-existing regime positioning and bounded internal reweighting during the experimental sequence.

From an evaluative perspective, these results are theoretically informative precisely because they do not point to a clear intervention effect. The absence of behavioural reconfiguration documented in the monitoring phase cannot be attributed to motivational indifference or attitudinal resistance, but neither can the observed differences in habit-related or control-related constructs be causally attributed to experimental exposure. Rather, the latent-construct profile suggests that treated and control participants remain anchored in distinct feasibility regimes, within which motivational orientations, perceived control and habit strength are jointly stabilised.

In Haustein's terms, the data do not allow one to conclude that the intervention perturbs System-1 automaticity or selectively activates System-2 implementation. Instead, they document a configuration in which habitual anchoring, reflective orientation and perceived feasibility remain mutually consistent with the underlying regime architecture. In TTM terms, participants appear distributed across similar readiness boundaries, with no evidence of systematic movement from preparation to action attributable to the intervention.

This configuration provides a direct empirical illustration of the intention–action and readiness–implementation gaps theorised in the behavioural literature under conditions of binding feasibility constraints. VTBC interventions may coexist with modest internal reweighting and regime-consistent differentiation, yet fail to induce observable behavioural reconfiguration when not accompanied by structural changes capable of shifting the feasibility architectures within which habits, control and motivation are jointly organised. In this sense, the experiment does not primarily test whether voluntary interventions can change behaviour, but rather delineates the feasibility boundaries within

which motivational activation, habit destabilisation and reflective engagement remain insufficient to translate into regime-level behavioural reconfiguration under binding feasibility constraints.

Behavioural change under feasibility constraints: answering RQ3 and RQ4

This chapter has examined the behavioural consequences of a MaaS-enabled VTBC intervention through a feasibility-oriented and regime-based analytical lens. Rather than asking whether participation “changes behaviour” in a generic sense, the analysis has evaluated whether staged exposure to VTBC framing, self-monitoring, personalised feedback and MaaS integration is capable of inducing regime-level reconfiguration under strongly binding structural constraints. On this basis, the chapter now provides integrated answers to Research Questions 3 and 4.

With respect to RQ3, the evidence points to a clear conclusion: participation in the MaaS-enabled VTBC intervention does not produce short-term observable behavioural change relative to the control condition. Across the full trajectory (pre-selection, tracking phase 1, tracking phase 2 and post-experiment monitoring) mobility organisation remains anchored within stable and sharply differentiated feasibility regimes. Treated participants persist within integration-based and diversified architectures organised around flexibility and redundancy, whereas control participants remain embedded in routine-anchored, car-centered compensatory regimes structured by backbone-mode reliance and routine consolidation. These anchoring principles remain invariant across observation windows.

Crucially, none of the regime-diagnostic indicators specified in the interpretative grid exhibits change-consistent signatures of threshold-crossing reconfiguration. There is no systematic weakening of routine dominance, no enlargement of the effective feasible choice set, no restructuring of portfolio architecture, and no transition across regime categories. Where behavioural movement is observed, it remains analytically bounded: selective foregrounding of already-feasible configurations, modest redistribution across existing chains, and minor discretionary-level adjustments that leave stabilising logics intact. The near-complete absence of MaaS service uptake during second-stage exposure provides a convergent negative signal: operational adoption fails to occur precisely at the point where informational integration would have had to translate into implementation and where feasibility regimes would therefore have had to shift.

Post-experiment monitoring confirms the persistence of these architectures beyond the experimental setting. The regimes reconstructed during tracking are reproduced after exposure ceases, with only weak within-regime reweighting and no delayed threshold crossing. Behavioural feasibility thus appears not only robust during intervention, but strongly persistent beyond it. The answer to RQ3 is therefore specific: under the observed real-world conditions, the MaaS-enabled VTBC intervention does not induce regime-level behavioural change; its behavioural imprint remains confined to bounded adaptation within stable feasibility regimes.

RQ4 asks whether these behavioural dynamics are associated with differentiated readiness, perceived control and habit-related configurations under binding feasibility constraints. Here the evidence converges on a coherent configuration that is theoretically consequential precisely because it is regime-consistent rather than intervention-attributable.

At the level of reflective motivation, treated and control participants remain largely overlapping. Attitudes, norms and intentions display only weak and unsystematic differentiation, placing both groups below the preparation–action boundary. No readiness configuration emerges that would be compatible with imminent regime crossing. In stage-based terms, the dominant profile is one of bounded readiness: evaluative openness is not absent, but it coexists with a cognitively salient expectation of constraint, which compresses the practical horizon of implementation.

The joint configuration of perceived and actual behavioural control constitutes the central interpretative hinge. Actual control is invariant across groups, confirming the structural stability of opportunity structures documented in the behavioural analysis. Perceived control does not diverge from this constraint landscape; if anything, it tracks it. Reflective activation therefore operates primarily as a feasibility-diagnostic mechanism rather than an implementation-enabling one. In Haustein's terms, System-2 activation appears to increase constraint-awareness without altering the binding interaction between habit-supported stabilisation and objective feasibility.

Perceived barriers exhibit the same regime-consistent alignment. High and persistent constraints related to alternatives, time and accessibility dominate in both groups, and moderate group differences map onto pre-existing portfolio architectures rather than indicating barrier attenuation. Barriers do not weaken; they stabilise the cognitive representation of feasibility. In this configuration, perceived obstacles function less as mediators of change than as components of the stabilisation logic through which regimes reproduce themselves.

The only latent dimension showing substantive group differentiation is subjective car dependence. Yet this difference cannot be read as intervention-induced habit destabilisation. The tracking and monitoring analyses indicate that habit strength is tightly coupled with portfolio architecture and anchoring logic: car-centred regimes tend to support stronger automaticity, whereas diversified and integration-based regimes are structurally less conducive to habit consolidation around the private car. Lower car dependence among treated participants therefore reflects regime-consistent positioning, possibly combined with bounded internal reweighting, but it is not identifiable as within-individual habit change.

Taken together, the latent configuration associated with behavioural stability is internally coherent. Motivational differentiation remains weak, perceived and actual control remains aligned with binding constraints, barriers remain salient, and habit strength remains anchored to regime architecture. No latent pattern consistent with readiness transition or implementation enablement emerges. The answer to RQ4 is therefore equally specific: short- to medium-term behavioural dynamics are

associated with regime-consistent configurations of readiness, control and habit strength, but not with differentiated readiness transitions, barrier weakening, or latent destabilisation that can be attributed to the intervention.

Read jointly, the answers to RQ3 and RQ4 converge on a single analytical conclusion. Under strongly binding feasibility constraints, MaaS-enabled VTBC exposure operates below the threshold required for regime-level reconfiguration. It may increase salience, foreground already-feasible options and induce bounded internal reweighting, but it does not alter anchoring principles, expand effective feasibility sets or enable implementation. Behavioural inertia does not arise from motivational indifference or attitudinal resistance; it emerges as the structural outcome of feasibility regimes within which habits, control and motivation are jointly organised.

This result has a precise theoretical status. It empirically specifies the intention–action and readiness–implementation gaps under regime-level constraint. Reflective activation, self-monitoring and informational integration are not behaviourally neutral, but their effects remain confined to regime-preserving adaptation unless accompanied by changes capable of shifting feasibility architectures. In this sense, the experiment does not primarily test whether voluntary interventions “work”; it delineates the boundary conditions under which they remain behaviourally insufficient.

From a VTBC perspective, this finding has two decisive implications. First, behavioural change does not emerge automatically from staged exposure to framing, monitoring and MaaS-enabled informational integration. These components act primarily on the interpretative and attentional layer of behaviour: they render trade-offs explicit and may prompt local experimentation within the already-feasible set. Yet they do not reconfigure the feasibility architecture that stabilises everyday mobility under constraint. Their behavioural imprint, where present, remains confined to internal redistribution within integration-prone regimes and is largely absent within concentration-based regimes anchored to routine consolidation and backbone-mode control.

Second, phase 2 does not constitute a threshold-crossing moment. If MaaS functions as an operational feasibility device within the VTBC logic, second-stage exposure would have had to translate into at least minimal organisational integration of MaaS-enabled services, precisely because operational uptake is the behavioural locus where informational integration becomes implementation. The near-zero uptake observed indicates that feasibility thresholds were not crossed. Phase 2 therefore marks not the onset of reconfiguration, but the upper bound of what the intervention can plausibly accomplish under real-world constraints: selective activation, reinforcement or modest reweighting of configurations that were already feasible and already enacted.

Within Haustein’s dual-process formulation, the results are consistent with a configuration in which reflective activation (System 2) can be elicited yet remains behaviourally downstream-blocked by unchanged actual control and habit-supported stabilisation. Where perceived control aligns with

objective constraints, reflective activation does not generate empowerment; it generates constraint-consistent appraisal. Within a TTM-oriented reading, the same configuration corresponds to a bottleneck at the preparation–action boundary: contemplation and limited preparation may coexist with bounded reweighting, but action presupposes a credible implementation horizon, which requires either expanded actual control or reduced coordination burden. Without such shifts, stage progression remains structurally suspended.

Within VTBC, these readings converge on a single mechanism: thresholds are feasibility thresholds. The decisive constraints on behavioural change are located in the points at which additional organisational burden, coordination effort, time unreliability and cognitive load outweigh the perceived gains of further modal integration or car displacement. Under such conditions, regimes persist not because individuals “resist change”, but because stabilisation logics minimise risk, protect schedule integrity and economise cognitive resources under constraint. Voluntary intervention can perturb attention and redistribute behaviour at the margin, but it cannot reconfigure the stabilisation logic unless it shifts the underlying feasibility calculus. This feasibility-calculus problem, and the conditions under which it can be structurally relaxed, provides the direct bridge to the overall research question addressed in the concluding chapter.

Answering the ORQ: MaaS-enabled choice contexts, feasibility regimes and the boundary conditions of VTBC

This concluding chapter addresses the overall research question of the thesis:

ORQ: *To what extent and through which mechanisms can a MaaS-enabled choice context support voluntary travel behaviour change toward more sustainable mobility practices in complex metropolitan urban systems?*

Rather than approaching this question as a problem of average treatment effects or generic behavioural responsiveness, the chapter reframes it as a problem of feasibility regimes, stabilisation logics and threshold dynamics. The central analytical issue is not whether individuals exposed to MaaS-enabled information, feedback and behavioural framing “change behaviour”, but whether and under which conditions such exposure is capable of reconfiguring the feasibility architectures that stabilise everyday mobility under structural constraint.

Across the preceding chapters, the experiment has been interpreted through a regime-based and feasibility-oriented lens that departs deliberately from standard intervention evaluation. Behavioural change has not been defined as any observable variation in modal shares or trip frequencies, but as regime-level reconfiguration: a weakening of routine anchoring, an expansion of the effective feasible choice set, a reorganisation of portfolio architectures, or a displacement of backbone-mode reliance. Within this perspective, the core empirical problem becomes one of thresholds. Voluntary interventions operate not on unconstrained choice sets, but within corridors of feasibility bounded by time budgets, spatial exposure, organisational burden and habit-supported stabilisation strategies. Behavioural change, when it occurs, requires not marginal redistribution within these corridors, but the crossing of feasibility thresholds that make alternative organisational logics implementable.

The purpose of this chapter is therefore synthetic and theoretical. It integrates the conceptual framework developed in Part I with the empirical evidence assembled in Part IV in order to specify the boundary conditions of MaaS-enabled voluntary travel behaviour change. The chapter advances three interconnected claims. First, under strongly binding feasibility constraints, staged VTBC and MaaS exposure operates primarily as a mechanism of salience and internal reweighting rather than as a driver of regime reconfiguration. Second, the decisive mechanisms limiting behavioural change are not located in deficits of motivation, awareness or intention, but in the structural alignment between habit-supported routines, perceived and actual behavioural control, and stabilised portfolio architectures. Third, the behavioural relevance of MaaS-enabled choice contexts is regime-contingent: their capacity to matter depends systematically on pre-existing feasibility regimes and on the extent to which they are coupled to institutional and infrastructural shifts capable of relaxing feasibility thresholds.

On this basis, the chapter does not offer a verdict on whether MaaS “works”. It specifies instead how, when and why MaaS-enabled choice contexts remain behaviourally effective or ineffective in metropolitan systems characterised by complex constraints, strong routine consolidation and heterogeneous feasibility architectures. In doing so, it reframes voluntary travel behaviour change not as a problem of persuasion, but as a problem of feasibility governance.

Reframing the ORQ: from behavioural responsiveness to feasibility regimes and thresholds

The overall research question of this thesis is conventionally formulated in causal terms: to what extent and through which mechanisms can a MaaS-enabled choice context support voluntary travel behaviour change toward more sustainable mobility practices in complex metropolitan urban systems? Read literally, this formulation invites an evaluation-oriented answer, centered on behavioural responsiveness to informational, technological or motivational stimuli.

The analytical trajectory of the thesis leads to a fundamentally different interpretation. Behavioural change is not treated as a direct outcome of exposure to a choice context, but as a structural transformation of the regimes through which everyday mobility is rendered feasible. Within this perspective, the relevant unit of analysis is not the isolated trip or the marginal modal decision, but the feasibility regime: the stabilised configuration of routines, compensatory strategies, portfolio architectures, control perceptions and habit-supported automatisms through which individuals manage constraint, uncertainty and organisational burden in daily mobility.

From this standpoint, the overall research question is more precisely reformulated as follows:

ORQ: *To what extent and through which mechanisms can a MaaS-enabled choice context alter the feasibility calculus that anchors existing mobility regimes, thereby enabling threshold-crossing reconfiguration rather than bounded internal rebalancing within stable stabilisation logics?*

This reframing has three decisive implications.

First, *behavioural change becomes a threshold phenomenon* rather than a continuous response variable. Under feasibility-oriented and regime-based accounts, small variations in awareness, intention or informational access do not accumulate smoothly into behavioural transformation. They remain behaviourally inert until a threshold is crossed at which an alternative organisational logic becomes implementable at acceptable levels of risk, effort and coordination cost. Below that threshold, interventions may generate salience effects, local experimentation and internal redistribution, yet leave anchoring principles intact.

Second, *behavioural inertia is no longer interpreted as resistance, conservatism or motivational deficit*. It appears instead as the *rational outcome of stabilisation strategies operating under constraint*. Routines, backbone-mode reliance and compensatory car use are not behavioural

pathologies to be corrected, but organisational devices that minimise schedule risk, economise cognitive resources and protect feasibility margins in complex metropolitan environments. In this sense, regimes persist not because individuals fail to change, but because regimes succeed in stabilising behaviour.

Third, the *behavioural relevance of MaaS-enabled choice contexts becomes intrinsically regime-contingent*. A choice context can only matter to the extent that it interacts with the feasibility architecture within which it is embedded. Where portfolios are already diversified and anchoring is weak, informational integration and feedback may amplify internal reweighting and marginal displacement. Where routines are strongly consolidated and the private car functions as a backbone feasibility device, identical exposure remains behaviourally ineffective unless it is coupled to structural changes capable of relaxing coordination, time or accessibility constraints.

Within this reframed problem, the central empirical task of the thesis is not to detect whether behavioural change occurs, but to specify the feasibility boundaries of voluntary intervention. The experiment is designed and interpreted as a staged exposure process that probes how far reflective activation, self-monitoring, personalised feedback and MaaS-enabled informational integration can move behaviour without altering the underlying opportunity structure. The question is therefore not whether VTBC mechanisms are present, but whether they are capable of shifting feasibility thresholds rather than merely redistributing behaviour within them.

The remainder of this concluding chapter builds on this reframing. The next section recalls the integrated theoretical framework as a theory of mechanisms under constraint. Subsequent sections synthesise the empirical evidence to specify the extent of behavioural change observed, the mechanisms through which regime stability is reproduced, and the regime-contingent conditions under which MaaS-enabled choice contexts can plausibly support sustainable mobility transitions in metropolitan systems.

The integrated VTBC framework as a theory of feasibility regimes and threshold mechanisms

The integrated theoretical framework developed in this thesis was originally structured around a set of core analytical dimensions derived from the Transtheoretical Model, the Theory of Planned Behaviour and Haustein's dual-process adaptation of TPB: the temporal nature of change, motivation formation, the role of cognition, the role of habits, behavioural control, intention–action translation and behavioural stabilisation. These dimensions were introduced as complementary lenses through which voluntary travel behaviour change could be interpreted beyond the limitations of single-theory approaches.

The empirical results of the experiment allow these dimensions to be reinterpreted and integrated more tightly into a unified theoretical configuration centered on feasibility regimes and threshold

mechanisms. Rather than operating as parallel explanatory layers, the six dimensions converge empirically on a single organising principle: behavioural change is governed not primarily by motivational dynamics, but by the structure and stability of feasibility regimes and by the thresholds that regulate transitions between them.

With respect to the temporal nature of change, the experiment substantially refines the stage-based logic inherited from the TTM. Behavioural trajectories do not unfold primarily as linear progressions across motivational stages. They unfold as trajectories within regimes. Across pre-selection, tracking, intervention and post-experiment monitoring, participants remain embedded in stable feasibility architectures, with only bounded internal reweighting and no regime crossing. Temporal change therefore manifests not as sequential stage progression, but as intra-regime redistribution under persistent stabilisation logics. This result adds a structural layer to the TTM interpretation: stage progression is not only a psychological process, but a regime-conditioned process. Readiness may evolve over time without producing behavioural change when feasibility thresholds remain intact. The temporal dimension of change is thus governed less by the accumulation of motivation than by the persistence or relaxation of regime boundaries.

The same regime conditioning emerges in the domain of motivation formation. In the integrated framework, motivation combines progressive activation across stages, attitudinal and normative determinants of intention, and moderation by habit strength. Empirically, motivational constructs remain weakly differentiated and clustered below the preparation–action boundary. More importantly, motivational activation does not translate into behavioural reorganisation even in the presence of self-monitoring and personalised feedback. Motivation forms, but it remains behaviourally downstream-blocked. The theoretical contribution of the present research is to identify feasibility-conditioned readiness as the central mechanism. Motivation is not only weakened by habits; it is structurally constrained by the feasibility calculus embedded in regimes. Even when reflective motivation is present, it cannot cross the preparation–action boundary unless organisational burden, coordination costs and actual behavioural control are relaxed. Readiness therefore becomes a regime-dependent variable rather than an individual attribute.

The role of cognition is refined in a similarly decisive way. Rather than operating primarily as a driver of deliberative optimisation, reflective activation under constraint functions as a feasibility-diagnostic mechanism. Perceived behavioural control converges toward actual control rather than diverging from it. Cognitive engagement sharpens awareness of barriers and trade-offs without generating empowerment or implementation. This finding extends Haustein’s dual-process model by showing that reflective activation need not destabilise habits. Under binding regimes, it may reinforce regime stability by producing constraint-consistent appraisal. Cognition thus emerges not only as a potential facilitator of change, but also as a regime-stabilising device when feasibility thresholds remain binding.

Habits, originally treated as barriers to intentional change and as stabilising mechanisms in the maintenance phase, are reinterpreted here as structural components of feasibility regimes. Subjective car dependence is tightly coupled with portfolio structure and anchoring logic. Car-centred regimes systematically support stronger automaticity, whereas diversified regimes structurally inhibit strong habit consolidation. Habit strength therefore appears not primarily as an individual trait, but as a regime property. The theoretical implication is crucial: habits are not merely obstacles to be disrupted by VTBC measures, but functional elements through which stabilisation is achieved under constraint. Disrupting habits without reconfiguring feasibility architectures remain insufficient to induce regime crossing. Habit destabilisation is a necessary but structurally insufficient condition for behavioural change.

The dimension of behavioural control becomes the central hinge of the entire framework. The distinction between perceived and actual control is empirically transformed from a determinant of intention into a threshold mechanism. Actual behavioural control remains invariant across groups, and perceived control tracks it closely. Control does not gradually increase until action occurs; it defines the feasibility thresholds that separate bounded rebalancing from regime reconfiguration. Below these thresholds, intentions and readiness remain behaviourally ineffective regardless of their intensity. This constitutes one of the core theoretical contributions of the thesis. Behavioural change is governed not by intention–control alignment alone, but by the crossing of organisational feasibility thresholds at which routines, portfolios and compensatory strategies become reorganisable at acceptable levels of effort and risk.

Within this configuration, the intention–action gap is no longer interpreted as a problem of self-regulation or motivational inconsistency. It is specified as a regime boundary phenomenon. Across all phases, intentions fail to translate into implementation not because of motivational weakness, but because participants remain positioned below feasibility thresholds. The preparation–action boundary identified in the TTM coincides empirically with a regime boundary: a point at which additional organisational burden outweighs perceived gains from further integration or car displacement. The contribution of the research is therefore to reconceptualise the intention–action gap as a threshold gap, generated by stabilisation logics operating under binding constraints.

Finally, behavioural stabilisation is reinterpreted as the reproduction of feasibility regimes over time. Post-experiment monitoring shows that regimes reconstructed during tracking persist after exposure ceases, with only bounded internal reweighting and no delayed reconfiguration. Stabilisation is not the endpoint of successful change; it is the default attractor of constrained mobility systems. VTBC interventions may perturb salience and induce internal redistribution, but unless anchoring principles are altered, regimes reproduce themselves.

Taken together, these extensions transform the integrated framework into a coherent regime–threshold theory of voluntary travel behaviour change. Change is not primarily driven by stage progression, motivational accumulation or habit disruption in isolation. It is governed by the stability

of feasibility regimes and by the thresholds that regulate transitions between them. VTBC mechanisms operate mainly below these thresholds, on the interpretative and attentional layer of behaviour, producing bounded rebalancing rather than regime reconfiguration. MaaS, conceived as an operational feasibility device, can in principle relax these thresholds, but only insofar as it effectively reduces coordination burden, uncertainty and organisational cost.

This theoretical reinterpretation provides the lens through which the empirical findings of the experiment acquire their full meaning. Under the observed metropolitan constraints, the intervention does not succeed in relaxing feasibility thresholds. What emerges instead is a coherent configuration of regime stability, downstream-blocked readiness and bounded internal rebalancing that delineates the structural limits of MaaS-enabled voluntary travel behaviour change in complex urban systems.

Within this reinterpretation, the integrated framework can be read not as a set of parallel explanatory dimensions, but as a conditional mechanism map governing the possibility of behavioural reconfiguration under constraint. Across the seven analytical dimensions, a coherent causal ordering emerges. Where actual behavioural control remains unchanged, perceived control converges toward constraint rather than expanding; where perceived and actual control remain aligned with binding opportunity structures, readiness accumulates without consolidating into an implementable action horizon; where readiness remains downstream-blocked, reflective activation sharpens diagnostic awareness without destabilising routines; where habits are embedded in regime architectures, their weakening remains situational and reversible in the absence of feasibility reconfiguration. In this configuration, the critical transition identified by the Transtheoretical Model between preparation and action coincides empirically with a regime boundary: a threshold at which additional organisational burden, coordination effort and behavioural risk cease to be acceptable. Below that boundary, motivational activation, cognitive engagement and habit perturbation remain behaviourally ineffective, producing at most bounded internal reweighting within stable stabilisation logics. Behavioural change therefore does not fail because intentions are weak, information insufficient or habits resistant. It remains suspended because feasibility thresholds are not crossed.

This reading assigns a precise theoretical status to VTBC and MaaS mechanisms. Interventions that act primarily on motivation, salience and reflection operate upstream of the decisive constraint. They may modify interpretation and redistribute behaviour at the margin, but they cannot by themselves reconfigure regimes unless they are coupled to shifts in the organisational and institutional conditions that define actual behavioural control. Within this regime–threshold interpretation, the role of a MaaS-enabled choice context becomes analytically clear: its behavioural relevance depends not on its capacity to inform or persuade, but on its capacity to function as a feasibility device capable of relaxing coordination costs, uncertainty and implementation risk at the point where preparation must become action. It is this claim that structures the core conceptual contribution of the thesis.

MaaS-enabled choice context as a feasibility device: core conceptual claim

Within this regime–threshold perspective, the behavioural role of a MaaS-enabled choice context can be specified more precisely. A MaaS interface is not merely an informational environment in which alternatives are displayed and compared. It is a potential institutional and operational device through which the feasibility calculus of everyday mobility may, in principle, be modified. Its behavioural relevance lies not in the provision of choice as such, but in its capacity to alter the organisational conditions under which choices become implementable.

From this standpoint, the central conceptual claim of the thesis can be stated cautiously but explicitly. A MaaS-enabled choice context can support voluntary travel behaviour change only insofar as it operates as a feasibility device: that is, insofar as it produces credible, situated reductions in coordination costs, uncertainty, behavioural risk and organisational burden that are sufficiently large to shift the thresholds separating bounded adaptation from regime-level reconfiguration. Where such reductions do not occur, MaaS exposure remains confined to the interpretative layer of behaviour, producing salience effects, diagnostic awareness and internal reweighting within already feasible portfolios, but leaving anchoring principles intact.

This distinction clarifies the mechanisms through which MaaS may or may not become behaviourally consequential. Informational integration and personalised feedback primarily act on interpretation and attention: they render trade-offs more explicit, foreground latent alternatives and may stabilise sustainable practices that are already organisationally viable. Transactional and coordination integration, by contrast, operate directly on feasibility thresholds. Unified ticketing, fare integration, reliability guarantees, disruption management and assisted intermodality reduce the behavioural cost of implementation by lowering the cognitive and organisational effort required to assemble and maintain complex chains. Incentive alignment and operational support further condition whether reflective intentions can be converted into durable routines. Only at this operational level does a choice context acquire the capacity to affect regime boundaries rather than merely redistribute behaviour within them.

The metropolitan context in which these mechanisms operate is analytically decisive. In complex urban systems, feasibility constraints are not single-dimensional. They are composed of interacting temporal rigidities, spatial dispersion, trip-chaining requirements, reliability risks and institutional fragmentation. Under such conditions, feasibility thresholds are both high and heterogeneous across individuals and regimes. The same MaaS interface may function as a marginal convenience in a diversified, integration-prone regime and remain behaviourally irrelevant in a routine-anchored, car-centered configuration. Regime heterogeneity therefore becomes a central explanatory variable: the behavioural effect of MaaS cannot be inferred from average exposure, but only from its interaction with pre-existing feasibility architectures and anchoring logics.

This interpretation relocates the analytical status of MaaS within the VTBC framework. MaaS is neither a neutral technological layer nor a sufficient catalyst of behavioural change. It is an institutional interface whose behavioural relevance depends on whether it is embedded in, and coupled to, structural conditions capable of shifting the feasibility thresholds that stabilise everyday mobility. The empirical contribution of the thesis is to examine, within a real metropolitan feasibility corridor, how far such threshold shifts are observed when MaaS is deployed as part of a staged VTBC intervention, and, more importantly, where the boundaries of its behavioural effectiveness appear to lie.

Empirical synthesis as a regime-based threshold argument

Within this regime–threshold interpretation, the empirical evidence assembled in Part IV can be read as a structured test of the theoretical conditions under which a MaaS-enabled choice context could plausibly induce regime-level behavioural reconfiguration. Rather than being organised around individual chapters or experimental phases, the results acquire their analytical coherence when reconstructed along four interlocking dimensions: feasibility filtering through scope and engagement, the staged logic of exposure, the reconstruction of the observed feasibility corridor, and the inferential criteria used to distinguish bounded adaptation from genuine regime crossing.

A first decisive layer of constraint emerges already at the level of scope conditions and participation dynamics. Attrition, selective engagement and effective observability do not function merely as technical limitations of the experimental design. They operate as second-order feasibility thresholds that determine which mobility regimes become empirically accessible in the first place. Sustained participation in a longitudinal, app-based VTBC experiment requires tolerance of monitoring burden, organisational slack, technological compatibility and cognitive availability. These requirements selectively retain individuals for whom additional coordination and attention costs remain feasible, while excluding those operating closer to their organisational limits. Participation therefore constitutes an endogenous feasibility filter. The experimental sample is not a random cross-section of metropolitan mobility regimes, but a corridor of regimes already capable of sustaining additional organisational load.

This filtering effect is analytically consequential. It implies that the experiment does not test the full behavioural potential of MaaS-enabled VTBC in an unconstrained population, but probes its effectiveness within a pre-selected feasibility corridor in which extreme constraint regimes are under-represented. At the same time, this corridor remains structurally demanding: long-distance commuting, high attendance intensity and persistent discretionary car dependence remain dominant features of the effective sample. The experiment therefore operates not in a low-constraint niche, but within a bounded segment of metropolitan feasibility space in which stabilisation logics are already active and thresholds already salient. In this sense, attrition and engagement do not weaken the inferential value of the results. They sharpen it, by positioning the intervention precisely at the

margin where voluntary behavioural change would be most plausible if threshold relaxation were achievable through soft mechanisms alone.

A second critical dimension concerns the staged nature of exposure and the analytical non-neutrality of the first tracking phase. Tracking phase 1 cannot be interpreted as a behavioural baseline. From the outset, treated participants enter the tracking trajectory under activated framing, anticipatory engagement and asymmetric cognitive embedding relative to controls. Self-monitoring, feedback anticipation and VTBC-oriented training already constitute intervention components. This staged positioning creates a first empirical test of sub-threshold mechanisms: whether reflective activation and behavioural salience alone are sufficient to destabilise anchoring principles before any operational integration occurs.

The empirical pattern that emerges is highly diagnostic. Tracking phase 1 amplifies differentiation between groups without inducing regime crossing. Treated participants display bounded rebalancing within already diversified portfolios, while control participants remain behaviourally inert. This configuration is theoretically coherent. It demonstrates that salience, framing and self-monitoring can modulate behaviour within the margins allowed by existing feasibility regimes. Phase 1 thus functions not as an early treatment effect, but as an internal validity check of the regime–threshold model: cognitive activation generates visible movement only where anchoring is already weak and flexibility already embedded, and remains behaviourally ineffective where routines and backbone-mode reliance dominate.

The third and central analytical device of the empirical synthesis is the reconstruction of feasibility regimes and of the “feasibility corridor” observed in the experiment. By translating heterogeneous behavioural indicators into regime architectures (routine dominance, repertoire breadth, portfolio structure, car functional role and intermodality logic) the analysis establishes a regime-level map of conditions of possibility. Two sharply differentiated stabilisation logics dominate the observed corridor: an integration-based regime organised around flexibility and redundancy, and a concentration-based regime organised around routine consolidation and backbone-mode control. These regimes are already visible at pre-selection and persist through tracking and monitoring with remarkable structural continuity.

This reconstruction is analytically decisive for two reasons. First, it shows that later behavioural differentiation between treated and control participants is not produced *ex nihilo* by the intervention. It is filtered, bounded and shaped by pre-existing feasibility architectures. Second, it allows all subsequent phase-to-phase dynamics to be read not as isolated variations, but as movements within or across regime boundaries. Within this regime-coded space, the empirical finding is unambiguous: no crossing of regime boundaries is observed at any point in the experimental trajectory. Neither staged exposure nor operational integration nor post-experiment consolidation generates transitions from concentration-based to integration-based regimes, or vice versa.

The interpretative grid introduced in the analysis plays a crucial inferential role at this stage. Rather than searching *ex post* for traces of change, the thesis specifies *ex ante* what would count as regime-

level reconfiguration: weakening of routine anchoring, expansion of the effective feasible set, restructuring of portfolio architecture, displacement of backbone-mode reliance and transitions across composite regime categories. Against these criteria, all observed dynamics fall systematically below threshold. What emerges instead is a highly coherent pattern of bounded internal rebalancing: selective activation of marginal configurations, redistribution across already feasible chains, and minor discretionary-level adjustments that leave anchoring principles intact.

This inferential discipline is essential to the theoretical contribution of the thesis. Without it, the same empirical material could easily be read as partial success, modest treatment effects or noisy behavioural change. The regime–threshold framework shows instead that these movements are precisely the behavioural signature expected when interventions operate below feasibility thresholds: salience effects without reconfiguration, experimentation without consolidation, redistribution without crossing.

The fourth and perhaps most decisive empirical boundary emerges from the conjunction of phase 2 dynamics and post-experiment monitoring. If MaaS-enabled operational integration were capable of relaxing feasibility thresholds, the second-stage exposure would constitute the critical moment at which informational integration should become implementation. Two convergent signals indicate that this threshold is not crossed. First, across all regime-diagnostic dimensions, phase 1–phase 2 dynamics remain strictly regime-consistent. No weakening of backbone anchoring, no expansion of repertoires and no restructuring of portfolio logics occur in either group. Second, actual uptake of MaaS services is virtually absent. Operational adoption, the behavioural locus at which feasibility relaxation would necessarily materialise, does not occur even among participants embedded in diversified, integration-prone regimes.

Post-experiment monitoring further stabilises this diagnosis. Regimes reconstructed during tracking are fully reproduced after exposure ceases. No delayed reconfiguration emerges, no consolidation of alternative anchoring principles appears, and no sustained displacement of car reliance is observed. Internal reweighting persists, but regime boundaries remain intact.

Read longitudinally, this trajectory yields a highly informative empirical configuration. The experiment does not capture a failed transition. It captures the upper bound of what staged VTBC and MaaS exposure can plausibly accomplish within a concrete metropolitan feasibility corridor. Across all phases, the intervention perturbs attention, redistributes behaviour at the margin and weakens situational reliance on the car in selected cases. It does not, however, alter the organisational calculus through which routines, portfolios and compensatory strategies are stabilised.

In this sense, the empirical synthesis delivers a clear regime–threshold argument. Behavioural change does not fail because participants are unmotivated, uninformed or resistant. It remains suspended because feasibility thresholds are not relaxed. The experiment therefore functions less as a test of behavioural responsiveness than as a diagnostic probe of feasibility architecture. It shows, under real-

world metropolitan constraints, where the behavioural relevance of MaaS-enabled choice contexts begins and where it structurally ends.

This interpretation must be read in light of the empirical corridor within which it is produced. The experiment is based on a deliberately small and highly selected sample and on a limited observation horizon, and it is not intended to support statistical generalisation about the average effectiveness of MaaS-enabled interventions. Its analytical contribution lies instead in its capacity to illuminate, within a bounded segment of metropolitan feasibility space, the mechanisms through which voluntary behavioural change becomes enabled or blocked under binding constraints. In this sense, the observed configuration is not evidence of what MaaS generally does, but a theoretically informative boundary case about what staged VTBC and MaaS exposure can plausibly accomplish when feasibility thresholds remain high and heterogeneous.

Under these conditions, the mechanisms that most readily activate are those operating upstream of implementation (salience, diagnostic reflection and bounded internal reweighting) while regime-level reconfiguration remains contingent on feasibility gains that exceed what a choice context can deliver on its own. The experiment therefore does not delimit the effectiveness of MaaS in general. It delineates a specific feasibility regime within which the behavioural leverage of MaaS-enabled choice contexts appears structurally constrained.

Read jointly, these empirical layers allow the experiment to be interpreted not as a sequence of outcomes to be summarised, but as a structured probe of the regime–threshold model developed in the theoretical part of the thesis. The key analytical move is therefore to translate the observed configuration (feasibility filtering, staged salience effects, regime persistence and near-absent operational uptake) into explicit theoretical statements about the extent and mechanisms of MaaS-enabled voluntary travel behaviour change under metropolitan constraint. On this basis, the answer to the ORQ can now be stated in the form of a deliberately selective set of propositions that specify what MaaS-enabled choice contexts can plausibly accomplish, through which mechanisms, and under which boundary conditions.

Answering the ORQ: theoretical propositions on MaaS-enabled voluntary behavioural change under feasibility constraints

The empirical evidence assembled in this thesis supports a set of interrelated theoretical propositions that specify both the extent and the mechanisms through which a MaaS-enabled choice context can support voluntary travel behaviour change in complex metropolitan systems.

Taken together, these propositions provide a regime- and threshold-based answer to the overall research question.

Proposition 1 – bounded effectiveness: MaaS-enabled choice contexts primarily induce bounded rebalancing within existing feasibility regimes rather than regime-level reconfiguration.

Within the empirical corridor observed in this experiment, a MaaS-enabled choice context supports behavioural change mainly in the form of internal redistribution and selective reinforcement of configurations that are already feasible and already embedded in baseline mobility repertoires. It does not, under strongly binding structural conditions, induce systematic regime crossing, durable weakening of backbone-mode reliance, or sustained reorganisation of portfolio architectures. Behavioural adjustment remains largely confined within pre-existing stabilisation logics rather than producing threshold-crossing reconfiguration toward more sustainable regimes.

Proposition 2 – salience without reconfiguration: the primary behavioural mechanism of MaaS-enabled VTBC under constraint is salience-driven bounded internal reweighting.

Staged exposure increases attentional salience and foregrounds already-available configurations, redistributing behavioural weight across chains that are organisationally compatible with existing routines. Observable movement corresponds to selective activation and modest reweighting within existing repertoires rather than to the incorporation of new organisational logics or to transitions between anchoring principles. In this configuration, behavioural change operates at the margin of feasibility regimes and preserves their core stabilisation structure.

Proposition 3 – operational threshold: threshold crossing requires operational integration capable of reducing coordination burden and behavioural risk.

Operational uptake represents the critical locus at which informational integration becomes behavioural implementation. The near-zero uptake observed indicates that informational aggregation and service visibility are insufficient to induce organisational incorporation when coordination costs, uncertainty and implementation risk remain above acceptable thresholds. A MaaS-enabled choice context becomes behaviourally consequential only insofar as it materially reduces transaction costs, coordination burden and perceived unreliability. Without such reductions, feasibility thresholds remain binding and regime-level reconfiguration does not occur.

Proposition 4 – feasibility-diagnostic cognition: reflective activation under constraint operates primarily as a feasibility-diagnostic rather than an implementation-enabling mechanism.

Motivational differentiation remains weak and positioned below the preparation–action boundary, while perceived behavioural control converges toward actual control rather than diverging from it. Reflective engagement sharpens awareness of barriers and trade-offs without expanding perceived feasibility. In Haustein’s dual-process terms, System-2 activation functions mainly as a constraint-diagnostic device that reinforces regime-consistent appraisal rather than destabilising existing routines or enabling implementation.

Proposition 5 – habit as regime property: habit strength is structurally coupled with feasibility regime architecture rather than being an autonomous driver of change.

Automaticity and subjective car dependence align systematically with portfolio structure and anchoring logic. Car-centred regimes support stronger habit consolidation, whereas diversified regimes structurally inhibit strong automaticity. Where bounded reweighting weakens situational reliance on the car, it does so without altering anchoring principles. Habit destabilisation alone remains insufficient to induce regime crossing unless accompanied by reconfiguration of the feasibility architecture within which habits are embedded.

Proposition 6 – Threshold primacy: feasibility thresholds constitute the decisive limiting mechanism of voluntary behavioural change.

Thresholds emerge at the point where additional organisational burden, coordination effort, time unreliability and cognitive load outweigh the perceived gains of further modal integration or car displacement. In the metropolitan context observed here, these thresholds remain binding across experimental conditions. Behavioural change is therefore governed not by the accumulation of motivation or information, but by the relaxation of organisational feasibility constraints that make alternative regimes implementable at acceptable levels of risk and effort.

Proposition 7 – Regime contingency: the behavioural relevance of MaaS-enabled choice contexts is systematically conditioned by the regime of departure.

In regimes characterised by flexibility and redundancy, MaaS-enabled exposure may amplify internal reweighting and stabilise sustainable practices that are already feasible. In regimes anchored in routine consolidation and backbone-mode control, identical exposure remains behaviourally ineffective unless coupled to structural changes capable of relaxing feasibility thresholds. MaaS effects are therefore intrinsically regime-contingent rather than population-general.

Proposition 8 – Participation as threshold (second-order mechanism): engagement with VTBC itself constitutes a feasibility filter.

Selective engagement and attrition function as second-order thresholds that condition who becomes observable and who can plausibly benefit from intervention exposure. Participation requires additional organisational and cognitive capacity; individuals operating near feasibility margins are selectively filtered out. Voluntary interventions thus operate within a pre-selected feasibility corridor that already constrains their behavioural reach.

Taken together, these propositions yield a qualified and theoretically specific answer to the overarching research question.

A MaaS-enabled choice context can support voluntary travel behaviour change primarily by stabilising and reweighting sustainable configurations that are already feasible within existing regimes. Its capacity to induce regime-level transitions in complex metropolitan systems remains limited unless it operates as a genuine feasibility device — that is, unless it relaxes coordination burden, uncertainty and organisational risk sufficiently to shift feasibility thresholds and enable reorganisation of stabilisation logics.

More generally, MaaS-enabled VTBC should be conceived not as a primary driver of regime transformation, but as a complementary mechanism whose effectiveness depends on the surrounding feasibility architecture. Its principal role lies less in generating behavioural change ex nihilo than in amplifying, consolidating and accelerating transitions that are already structurally supported.

In this sense, the experiment does not test whether MaaS-enabled VTBC “works” in general. It delineates instead the boundary conditions under which MaaS-enabled choice contexts may begin to operate as levers of regime-level behavioural reconfiguration in complex metropolitan mobility systems.

Implications: designing MaaS-enabled VTBC for metropolitan feasibility architectures

The results of this thesis carry a set of design and policy implications that speak directly to the Travel Demand Management (TDM) tradition, to the Avoid–Shift–Improve (ASI) framework, and more broadly to contemporary approaches to mobility management, calling for a reorientation of MaaS-enabled VTBC within an integrated policy perspective in which informational, behavioural, operational, and institutional instruments are conceived as complementary components of a broader feasibility-oriented strategy.

Within this perspective, voluntary behavioural change does not appear as a substitute for structural transport policy, but as a context-sensitive demand-side instrument whose effectiveness depends on how it is embedded within wider mobility governance arrangements. If behavioural change is governed primarily by stabilisation logics and organisational feasibility rather than by motivational deficits alone, then the central policy challenge is not simply how to persuade users, but how to combine soft measures with enabling structural conditions capable of selectively relaxing feasibility constraints. In this sense, MaaS-enabled VTBC can be interpreted as a core component of mobility management strategies aimed at supporting Avoid and Shift objectives by acting on the behavioural interface between individuals and transport systems.

The first implication concerns *targeting and segmentation*. The empirical analysis shows that behavioural responsiveness to identical VTBC and MaaS exposure varies systematically across regimes of departure. Participants embedded in flexibility- and redundancy-based regimes exhibit bounded rebalancing and internal redistribution, whereas participants anchored in routine- and control-based regimes remain largely inert. From a TDM and mobility management perspective, this finding suggests that uniform, population-average intervention strategies are unlikely to be efficient or equitable.

Effective policy design therefore requires regime-sensitive targeting. Rather than segmenting users primarily by socio-demographic characteristics or attitudinal readiness, interventions should classify

travellers according to the stabilisation logics through which their mobility is organised: backbone-mode reliance versus diversified portfolios, routine consolidation versus compensatory articulation, and the degree of redundancy already embedded in everyday practice. In this configuration, VTBC and MaaS components can be selectively deployed where feasibility thresholds are already close to being crossed, thus increasing the probability that soft measures translate into durable behavioural adjustments. Importantly, this does not imply excluding more constrained regimes from intervention, but rather recognising that in such regimes behavioural instruments must be coupled more tightly with structural and organisational measures if they are to contribute meaningfully to Avoid and Shift strategies.

A second implication concerns the *nature of the constraints* that must be addressed to enable regime crossing. The empirical evidence converges on a limited but robust set of binding thresholds: travel time reliability, coordination burden across modes, tariff fragmentation, perceived behavioural risk, and the organisational effort associated with trip chaining and contingency management. These constraints correspond closely to the barriers that TDM and sustainable mobility policies identify as central obstacles to mode shift and car-use reduction.

From this perspective, the contribution of MaaS should not be interpreted narrowly as informational integration, but more broadly as part of an integrated package of operational and organisational measures aimed at reducing implementation costs and behavioural risk. Reliability guarantees, real-time disruption management, integrated ticketing and fare capping, assisted intermodality, and institutionalised service commitments emerge not as optional enhancements, but as enabling conditions that allow soft measures to become behaviourally effective. Informational and motivational components remain important, but primarily insofar as they are embedded in policy configurations that also deliver credible reductions in coordination burden and uncertainty. In this sense, MaaS-enabled VTBC operates most effectively not in isolation, but as part of a coordinated mobility management strategy combining soft instruments with selective “hardening” of service integration.

A third implication concerns the *internal architecture of VTBC programs and their role within demand management*. The results indicate that motivational activation and reflective engagement are not absent, but remain behaviourally downstream-blocked when feasibility architectures remain unchanged. This finding does not undermine the relevance of soft measures, but clarifies their functional role. Within a TTM–TPB–Haustein perspective, the critical bottleneck lies at the preparation–action boundary. From a policy standpoint, this boundary corresponds to the point at which Avoid and Shift strategies must become practically implementable in everyday routines.

Designing VTBC for this boundary requires complementing persuasion and information with implementation-oriented support: concrete action planning, personalised routing assistance, situational incentives aligned with specific chains, reliability guarantees that protect schedule integrity, and feedback mechanisms that reduce uncertainty rather than increasing awareness. In this

configuration, soft measures become instruments of behavioural facilitation rather than persuasion alone. They operate as micro-level mobility management tools that translate system-level policy objectives into feasible individual practices. Their effectiveness, however, remains conditional on the availability of operational and institutional support capable of sustaining new routines once initial experimentation has occurred.

A fourth implication concerns *governance and metropolitan complexity*. The experiment highlights that feasibility architectures in metropolitan systems are not individual artefacts, but institutional and infrastructural constructions shaped by fragmentation across operators, tariff regimes, service standards and responsibility layers. Under such conditions, MaaS cannot be expected to compensate autonomously for systemic fragmentation. Institutional integration becomes itself a central component of the feasibility architecture that conditions behavioural change.

For policy, this implies that MaaS-enabled VTBC should be embedded within broader governance reforms aimed at aligning contracts, data standards, fare systems and operational responsibilities. Without such alignment, behavioural interventions remain structurally confined to regime-preserving rebalancing. At the same time, this does not imply that behavioural measures are ineffective per se. Rather, it suggests that their leverage is inherently relational: soft measures derive their effectiveness from the degree to which institutional and infrastructural arrangements already support, or are being reoriented toward, Avoid and Shift objectives.

Taken together, these implications point toward an integrated conception of MaaS-enabled VTBC within sustainable mobility policy. Effective voluntary behavioural change in metropolitan systems does not primarily depend on intensifying persuasion, nor on replacing soft measures with purely structural interventions. It depends on the coordinated design of integrated policy packages in which behavioural instruments, operational integration, service quality improvements and governance reforms jointly contribute to relaxing feasibility thresholds.

Within the ASI framework, MaaS-enabled VTBC thus appears most plausibly as an enabling device for Avoid and Shift strategies, operating at the interface between individual routines and system-level transition goals. Its role is not to drive regime transformation on its own, but to function as a mobility management instrument that consolidates, accelerates and stabilises transitions precisely where institutional and infrastructural conditions have already begun to open regime boundaries. In this configuration, MaaS becomes neither a purely technological solution nor a purely behavioural one, but a context-enabling governance tool through which integrated sustainable mobility policies can be operationalised in everyday metropolitan travel behaviour.

Research agenda: what the ORQ still requires empirically

The concluding results of this thesis delineate a coherent set of boundary conditions for MaaS-enabled voluntary travel behaviour change, but they also identify a series of empirical requirements that remain open for advancing the overall research question. If behavioural change is governed by feasibility regimes and threshold dynamics rather than by smooth motivational accumulation, then future research must be designed explicitly to observe regime transitions, threshold crossings and the slow processes through which stabilisation logics are eventually destabilised.

A first and central priority concerns the *longitudinal reconstruction of latent trajectories* of readiness, perceived control and habit strength. In the present design, latent constructs are observed only once, at the post-experiment stage, which precludes any direct observation of stage progression, habit destabilisation or delayed implementation effects. From a TTM and dual-process perspective, this represents a critical limitation: readiness transitions and intention–action dynamics are inherently temporal processes. Future designs must therefore incorporate repeated measurements of motivational, control-related and habitual constructs across pre-intervention, intervention and post-intervention phases in order to reconstruct within-individual trajectories and to test whether latent destabilisation precedes, accompanies or follows regime-level behavioural reconfiguration.

Closely related to this requirement is the need for *experimental and quasi-experimental designs* that manipulate actual behavioural control and operational feasibility more directly. The present experiment shows that reflective activation and informational integration remain behaviourally downstream-blocked when objective opportunity structures are unchanged. A decisive next step for the ORQ is therefore the systematic testing of MaaS configurations that alter not only perceived feasibility but actual coordination costs, reliability, tariff integration and risk exposure. Only interventions that experimentally relax operational constraints can test whether and how threshold crossing becomes behaviourally attainable within the VTBC–Haustein framework.

A further and crucial methodological reinforcement concerns *sample size, observation horizons and the temporal scale of regime dynamics*. The present experiment operates on a deliberately small and intensively observed sample and on a relatively short temporal window. While this design is analytically appropriate for reconstructing feasibility regimes and threshold mechanisms, it necessarily limits the detection of rare transitions, delayed effects and slow regime drift. From a regime–threshold perspective, this limitation is not merely statistical but theoretical. Regime crossing is expected to be a low-frequency, discontinuous and temporally extended phenomenon. Threshold dynamics imply that long periods of bounded rebalancing and apparent inertia may precede sudden reconfiguration once feasibility conditions are relaxed or external shocks occur. Small samples and short observation windows are therefore structurally biased toward observing stability rather than transition.

Future research should therefore combine regime-oriented analytical frameworks with substantially larger samples and extended longitudinal observation horizons. Larger samples are required not

primarily to increase statistical power in the conventional sense, but to ensure adequate representation of heterogeneous feasibility regimes and to capture the rare events in which regime boundaries are actually crossed. Longer follow-up periods are equally essential to detect delayed transitions, consolidation dynamics and post-intervention stabilisation processes that cannot be observed within short experimental cycles. Only designs capable of tracking mobility organisation over extended horizons can empirically test whether bounded rebalancing accumulates into regime-level reconfiguration, whether latent destabilisation eventually translates into behavioural change, and whether MaaS-enabled feasibility devices produce durable transitions rather than transient perturbations.

A fourth priority concerns *regime-stratified experimental designs*. The results of this thesis demonstrate that behavioural responses are strongly contingent on baseline feasibility regimes. Future interventions should therefore abandon population-average treatment logics and explicitly target differentiated regime profiles, testing whether identical MaaS-enabled choice contexts produce qualitatively different effects in flexibility–redundancy regimes versus routine–control regimes. Such designs would allow direct testing of regime contingency as a core mechanism of voluntary behavioural change.

Finally, advancing the ORQ requires *comparative research across metropolitan contexts* characterised by different degrees of spatial fragmentation, service reliability, institutional integration and organisational burden. Feasibility thresholds are not universal constants; they are shaped by the structural properties of metropolitan mobility systems. Cross-city and cross-system comparisons are therefore necessary to identify how institutional architectures, governance arrangements and infrastructural reliability condition the behavioural relevance of MaaS-enabled choice contexts.

Taken together, this research agenda reframes future evaluation not as the search for stronger persuasive interventions, but as the empirical investigation of feasibility architectures and threshold mechanisms. Progress on the ORQ will depend less on refining motivational models than on developing experimental and observational infrastructures capable of capturing slow dynamics, rare regime transitions and the institutional conditions under which voluntary behavioural change becomes organisationally feasible in complex metropolitan systems.

Taken together, the thesis provides a qualified answer to the overall research question by relocating voluntary travel behaviour change from the domain of persuasion to the domain of feasibility governance. In complex metropolitan systems, MaaS-enabled choice contexts appear able to activate reflection, increase salience and stabilise sustainable practices that are already organisationally viable, but they remain unlikely to produce regime-level reconfiguration unless they operate as genuine feasibility devices, reducing coordination burden, uncertainty and implementation risk at the point where preparation must become action. The experiment can therefore be read less as a test of whether MaaS “works” and more as a boundary specification of what staged VTBC mechanisms can accomplish under binding feasibility constraints. In this sense, the central implication is not that

voluntary interventions are irrelevant, but that their behavioural leverage is structurally conditional: MaaS can support sustainable transitions to the extent that institutional, infrastructural and operational conditions relax feasibility thresholds and make alternative stabilisation logics implementable. Where those conditions are absent, behavioural regimes tend to persist, not because change is rejected, but because feasibility remains the decisive constraint on what everyday mobility can credibly become.

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Appendices

Appendix 1: RP survey questionnaire

A1 In quale Università studia/lavora?

- Politecnico di Bari (1)
- Università di Cagliari (2)
- Università di Milano-Bicocca (3)
- Università di Napoli Federico II (4)
- Università di Padova (5)

A2 Quale è la sede universitaria prevalente in cui studia/lavora?

- Milano - Campus Bicocca (Piazza dell'Ateneo Nuovo 1) (27)
- Monza - ASST, Polo ospedaliero di Monza, (Via G. B. Pergolesi 33) (25)
- Bergamo - ASST "Papa Giovanni XXIII" (Piazza Organizzazione Mondiale della Sanità 1) (7)
- Carate Brianza - Istituti Clinici Zucchi - Presidio Riabilitativo (Piazza Madonnina 1) (21)
- Desio - ASST Monza , Polo ospedaliero di Desio (Via Giuseppe Mazzini 1) (22)
- Faedo Valtellino (Sondrio) - ASST Valtellina e Alto Lario (Via Stelvio 25) (23)
- Lecco - ASST Lecco (Via dell'Eremo 9/11) (24)
- Pavia - (Corso Strada Nuova 65) (26)

A4 Qual è il suo ruolo all'interno dell'Università?

- Studente (1)
- Dottorando di ricerca o specializzando (2)
- Docente/ricercatore (3)
- Docente a contratto (4)
- Assegnista di ricerca (5)
- Borsista, collaboratore (6)
- Personale tecnico-amministrativo (7)

A5 A quale delle seguenti aree disciplinari appartiene?

▼ Area 1 - Scienze matematiche e informatiche (1) ... Area 14 - Scienze politiche e sociali (14)

A6 A quale ambito disciplinare appartiene il suo corso di studi?

▼ Agrario (7) ... Scientifico (1)

A7 A quale corso di studi è iscritto/a?

- Triennale (1)
- Magistrale (2)
- Magistrale a ciclo unico (3)
- Master o altro (4)

A8 A quale anno accademico è iscritto/a (incluso quello attuale)?

- Primo anno (1)
- Secondo anno (2)
- Terzo anno (3)
- Quarto anno (4)
- Quinto anno (5)
- Sesto anno (6)
- Fuori corso (7)

A9 Qual è la sua attività prevalente?

- Lo studio (svolgo al massimo lavori saltuari) (1)
- Lo studio e il lavoro (lavoro con contratto part time) (2)
- Il lavoro (studio nel tempo libero) (3)

A10 È uno studente o studente-lavoratore fuorisede*? * è fuori sede chi, vivendo lontano da dove studia o lavora, non rientra la sera presso l'abitazione di residenza ma rimane presso un domicilio provvisorio più accessibile dall'Università

- Sì (1)
- No (2)

A11_S Nell'ultima settimana di lezione trascorsa quanti giorni ha frequentato l'Università?

- ☒ 5 o più giorni (1)
- ☒ 4 giorni (2)
- ☒ 3 giorni (3)
- ☒ 2 giorni (4)
- ☒ 1 giorno (5)

A11_S_b Solitamente, quanti giorni alla settimana frequenta l'Università **nei periodi senza lezioni**?

- ☒ 5 o più giorni (1)
- ☒ 4 giorni (2)
- ☒ 3 giorni (3)
- ☒ 2 giorni (4)
- ☒ 1 giorno (5)

A11_PTA_D Nell'ultima settimana trascorsa, quanti giorni alla settimana è stato/a presente in Università?

- 5 o più giorni (1)
- 4 giorni (2)
- 3 giorni (3)
- 2 giorni (4)
- 1 giorno (5)

A12 Nell'ultimo spostamento abituale a che ora è partito/a da casa per recarsi alla sede universitaria?

- prima delle 6 (1)
- tra le 6 e le 7 (2)
- tra le 7 e le 8 (3)
- tra le 8 e le 9 (4)
- dopo le 9 (specifica, es.: 13:30) (5) _____

A13 Nell'ultimo spostamento abituale a che ora è uscito/a dall'Università, terminate le attività che doveva svolgere, **per tornare a casa**?

- prima delle 13 (1)
- tra le 13 e le 15 (2)
- tra le 15 e le 17 (3)
- tra le 17 e le 19 (4)
- dopo le 19 (5)

A15 Quant'è flessibile il suo orario di lavoro?

- rigido (1)
- mezz'ora (2)
- un'ora (3)
- due ore o più (4)

B2 Nell'ultimo spostamento abituale, con quale mezzo/modalità ha percorso la maggior parte della distanza **per raggiungere** l'Università?

- Piedi per almeno 5 minuti (1)
- Bicicletta (2)
- Bike sharing (3)
- Monopattino (4)
- Monopattino in sharing (5)
- Moto/scooter (6)
- Moto/scooter in sharing (7)
- Auto come conducente (8)
- Auto come passeggero (9)
- Car sharing (10)

- Bus urbano (11)
- Bus extra-urbano (12)
- Navetta di Ateneo (13)
- Tram/Filobus (14)
- Metro e metro leggera (15)
- Treno/Passante ferroviario (16)
- Battello/Traghetto (17)
- Funicolare (18)
- Altro (specificare) (19) _____

B3 Quali altri mezzi/modalità ha utilizzato **oltre al principale** per raggiungere l'Università?

- ☒ Nessun altro (20)
- Piedi per almeno 5 minuti (1)
- Bicicletta (2)
- Bike sharing (3)
- Monopattino (4)
- Monopattino in sharing (5)
- Moto/scooter (6)
- Moto/scooter in sharing (7)
- Auto come conducente (8)
- Auto come passeggero (9)
- Car sharing (10)
- Bus urbano (11)
- Bus extra-urbano (12)
- Navetta di Ateneo (13)
- Tram/Filobus (14)
- Metro e metro leggera (15)
- Treno/Passante ferroviario (16)
- Battello/Traghetto (17)
- Funicolare (18)
- Altro (specificare) (19) _____

A16 Nell'ultimo spostamento abituale quali tra le seguenti alternative modali **aveva a disposizione** (da sole o in integrazione), comprese quelle utilizzate, **per raggiungere** l'università?

- Piedi per almeno 5 minuti (1)
- Bicicletta (2)
- Bike sharing (3)
- Monopattino (4)
- Monopattino in sharing (5)
- Moto/scooter (6)
- Moto/scooter in sharing (7)
- Auto come conducente (8)
- Auto come passeggero (9)
- Car sharing (10)
- Bus urbano (11)
- Bus extra-urbano (12)
- Navetta di Ateneo (13)
- Tram/Filobus (14)
- Metro e metro leggera (15)
- Treno/Passante ferroviario (16)
- Battello/Traghetto (17)
- Funicolare (18)
- Altro (specificare) (19) _____

B11 I mezzi/modi di trasporto che ha utilizzato per il ritorno sono stati gli stessi?

- Sì (1)
- No (2)

B12 Con quale mezzo/modalità ha percorso **la maggior parte della distanza per tornare a casa** dall'Università?

- Piedi per almeno 5 minuti (1)
- Bicicletta (2)
- Bike sharing (3)
- Monopattino (4)

- Monopattino in sharing (5)
- Moto/scooter (6)
- Moto/scooter in sharing (7)
- Auto come conducente (8)
- Auto come passeggero (9)
- Car sharing (10)
- Bus urbano (11)
- Bus extra-urbano (12)
- Navetta di Ateneo (13)
- Tram/Filobus (14)
- Metro e metro leggera (15)
- Treno/Passante ferroviario (16)
- Battello/Traghetto (17)
- Funicolare (18)
- Altro (specificare) (19) _____

B12_bis Quali altri mezzi/modalità ha utilizzato, **oltre al principale, per tornare a casa** dall'Università?

- ☒ Nessun altro (20)
- Piedi per almeno 5 minuti (1)
- Bicicletta (2)
- Bike sharing (3)
- Monopattino (4)
- Monopattino in sharing (5)
- Moto/scooter (6)
- Moto/scooter in sharing (7)
- Auto come conducente (8)
- Auto come passeggero (9)
- Car sharing (10)
- Bus urbano (11)
- Bus extra-urbano (12)
- Navetta di Ateneo (13)
- Tram/Filobus (14)
- Metro e metro leggera (15)
- Treno/Passante ferroviario (16)
- Battello/Traghetto (17)
- Funicolare (18)
- Altro

A16_bis Nell'ultimo spostamento abituale quali tra le seguenti alternative modali **aveva a disposizione** (da sole o in integrazione), comprese quelle utilizzate, **per tornare a casa** dall'università?

- ☒ Le stesse che avevo all'andata (20)
- Piedi per almeno 5 minuti (1)
- Bicicletta (2)
- Bike sharing (3)
- Monopattino (4)
- Monopattino in sharing (5)
- Moto/scooter (6)
- Moto/scooter in sharing (7)
- Auto come conducente (8)
- Auto come passeggero (9)
- Car sharing (10)
- Bus urbano (11)

- Bus extra-urbano (12)
- Navetta di Ateneo (13)
- Tram/Filobus (14)
- Metro e metro leggera (15)
- Treno/Passante ferroviario (16)
- Battello/Traghetto (17)
- Funicolare (18)
- Altro

B17

Nell'ultimo spostamento abituale, durante il tragitto casa-Università (e viceversa), ha effettuato tappe intermedie?

	Percorso di andata (1)	Percorso di ritorno (2)
Si, per accompagnare i figli e/o altre persone (1)	–	–
Si, per fare acquisti e commissioni (2)	–	–
Si, per far visita ad altre persone (3)	–	–
Si, per svolgere attività del tempo libero (4)	–	–
Si, per svolgere un'attività lavorativa (5)	–	–
Si, per altri motivi (specificare) (6)	–	–
☒ No, nessuna (7)	–	–

B18 Per andare / tornare dall'Università con quante persone ha viaggiato?

	Percorso di andata (1)	Percorso di ritorno (2)
☒ Da solo (1)	–	–
☒ 1 (2)	–	–
☒ 2 (3)	–	–
☒ 3 (4)	–	–
☒ 4 o più (5)	–	–

B19

Con chi ha viaggiato?

	Percorso di andata (1)	Percorso di ritorno (2)
Familiari/parenti (1)	–	–
Vicini di casa/di quartiere (2)	–	–
Amici (3)	–	–
Colleghi/compagni di Università (4)	–	–

B20 Quanto tempo ha impiegato **per raggiungere** l'Università e quanto **per tornare a casa**?

	Per raggiungere l'Università (1)	Per tornare a casa (2)
☒ fino a 15 minuti (1)	–	–
☒ da 16 a 30 minuti (2)	–	–
☒ da 31 a 60 minuti (3)	–	–
☒ da 1 ora a 2 ore (4)	–	–
☒ oltre 2 ore (5)	–	–

B21 Indicativamente quanti chilometri percorre per raggiungere l'Università da casa? Quanti per tornare?

	Percorso di andata (1)	Percorso di ritorno (2)
☒ Fino a 2 km (1)	–	–
☒ Da 3 a 5 km (2)	–	–
☒ da 6 a 10 km (3)	–	–
☒ da 11 a 25 km (4)	–	–
☒ da 26 a 50 km (5)	–	–
☒ da 51 a 100 km (6)	–	–
☒ da 101 a 200 km (7)	–	–
☒ oltre 200 km (specifica) (8)	–	–

B13 Utilizza solitamente gli stessi mezzi di trasporto nei diversi periodi dell'anno?

- Sì (1)
- No (2)

B14 Se no, quali mezzi/modalità utilizza per raggiungere l'Università?

	Stagione autunnale/invernale Periodo esami (2)	Stagione primaverile/estiva Periodo di lezione (3)	Stagione primaverile/estiva Periodo esami (4)
Piedi per almeno 5 minuti (1)	—	—	—
Bicicletta (2)	—	—	—
Bike sharing (3)	—	—	—
Monopattino (4)	—	—	—
Monopattino in sharing (5)	—	—	—
Moto/scooter (6)	—	—	—
Moto/scooter in sharing (7)	—	—	—
Auto come conducente (8)	—	—	—
Auto come passeggero (9)	—	—	—
Car sharing (10)	—	—	—
Bus urbano (11)	—	—	—
Bus extra-urbano (12)	—	—	—
Navetta di Ateneo (13)	—	—	—
Tram/Filobus (14)	—	—	—
Metro e metro leggera (15)	—	—	—
Treno/Passante ferroviario (16)	—	—	—
Battello/Traghetto (17)	—	—	—
Funicolare (18)	—	—	—
Altro (specificare) (19)	—	—	—

B15 Quale di questi è il principale (quello con cui percorre la distanza più lunga)?

	Stagione autunnale/invernale Periodo esami (2)	Stagione primaverile/estiva Periodo di lezione (3)	Stagione primaverile/estiva Periodo esami (4)
☒ Piedi per almeno 5 minuti (1)	—	—	—
☒ Bicletta (2)	—	—	—
☒ Bike sharing (3)	—	—	—
☒ Monopattino (4)	—	—	—
☒ Monopattino in sharing (5)	—	—	—
☒ Moto/scooter (6)	—	—	—
☒ Moto/scooter in sharing (7)	—	—	—
☒ Auto come conducente (8)	—	—	—
☒ Auto come passeggero (9)	—	—	—
☒ Car sharing (10)	—	—	—
☒ Bus urbano (11)	—	—	—
☒ Bus extra-urbano (12)	—	—	—
☒ Navetta di Ateneo (13)	—	—	—
☒ Tram/Filobus (14)	—	—	—
☒ Metro e metro leggera (15)	—	—	—
☒ Treno/Passante ferroviario (16)	—	—	—
☒ Battello/Traghetto (17)	—	—	—
☒ Funicolare (18)	—	—	—
☒ Altro (specificare) (19)	—	—	—

A14_bis_TA_D Se no, quali mezzi/modalità utilizza per raggiungere l'Università nella stagione primaverile/estiva?

- Piedi per almeno 5 minuti (1)
- Bicletta (2)
- Bike sharing (3)
- Monopattino (4)
- Monopattino in sharing (5)
- Moto/scooter (6)
- Moto/scooter in sharing (7)
- Auto come conducente (8)
- Auto come passeggero (9)
- Car sharing (10)
- Bus urbano (11)
- Bus extra-urbano (12)
- Navetta di Ateneo (13)
- Tram/Filobus (14)

- Metro e metro leggera (15)
- Treno/Passante ferroviario (16)
- Battello/Traghetto (17)
- Funicolare (18)

B15_PTA_D Quale di questi è il principale (quello con cui percorre la distanza più lunga)?

- ☒ Piedi per almeno 5 minuti (1)
- ☒ Bicicletta (2)
- ☒ Bike sharing (3)
- ☒ Monopattino (4)
- ☒ Monopattino in sharing (5)
- ☒ Moto/scooter (6)
- ☒ Moto/scooter in sharing (7)
- ☒ Auto come conducente (8)
- ☒ Auto come passeggero (9)
- ☒ Car sharing (10)
- ☒ Bus urbano (11)
- ☒ Bus extra-urbano (12)
- ☒ Navetta di Ateneo (13)
- ☒ Tram/Filobus (14)
- ☒ Metro e metro leggera (15)
- ☒ Treno/Passante ferroviario (16)
- ☒ Battello/Traghetto (17)
- ☒ Funicolare (18)
- Altro (specificare) (19) _____

E1 Per quale motivo ha scelto di utilizzare il mezzo prevalente che ha indicato per il tragitto casa-università? Ordini fino a 3 tra le motivazioni principali assegnando un numero da 1 (più importante) a 3 (meno importante).

- _____ Economicità (1)
- _____ Difficoltà del parcheggio (2)
- _____ Sicurezza personale (aggressioni, furti, ...) (3)
- _____ Sicurezza della modalità di trasporto (incidenti, ...) (4)
- _____ Alternativa meno stressante (5)
- _____ Salute (6)
- _____ Tempo di viaggio (7)
- _____ Comfort (8)
- _____ Accompagnamento di persone (9)
- _____ Autonomia di movimento (10)
- _____ Mancanza di alternative valide (11)
- _____ Servizio pubblico non efficiente (12)
- _____ Rispetto dell'ambiente (13)
- _____ Attività extralavorative (14)
- _____ Mancanza di percorsi ciclabili (15)

Altro

E3

Quanto è soddisfatto/a in media degli spostamenti casa – università che ha effettuato nell'ultima settimana trascorsa?

Le chiediamo di esprimere la sua valutazione da "estremamente insoddisfatto/a" (valore basso, 1) a "estremamente soddisfatto/a" (valore alto, 5)

	Estremamente insoddisfatto/a (11)	Abbastanza insoddisfatto/a (12)	Neutrale (13)	Abbastanza soddisfatto/a (14)	Estremamente soddisfatto/a (15)
Valutazione (1)	–	–	–	–	–

E4

Quali delle seguenti difficoltà ha incontrato nel percorso casa-Università e viceversa?

- Congestione da traffico (1)
- Difficoltà a trovare parcheggio (2)
- Costo elevato del parcheggio (3)
- Spesa elevata del viaggio (4)
- Scarso comfort del viaggio (5)
- Presenza di barriere fisiche (6)

- Pericolosità del viaggio (scarsa sicurezza personale: aggressioni, furti, ...) (7)
- Pericolosità del viaggio (scarsa sicurezza della modalità di trasporto) (8)
- Assenza e/o scarsa presenza di percorsi ciclabili sicuri (9)
- Assenza e/o scarsa disponibilità di spazi per le biciclette (10)
- Scarsa sicurezza delle rastrelliere per le biciclette (11)
- Scarsa puntualità dei mezzi di trasporto pubblico (12)
- Assenza, inaccessibilità (distanza delle fermate) e/o scarsa frequenza/regolarità dei mezzi di trasporto pubblico (13)
- Eccessivo affollamento dei mezzi di trasporto pubblico (14)
- Nessuna difficoltà (15)
- Altro (specificare) (16) _____

T_MobAsist Le chiediamo ora di rispondere riferendosi agli spostamenti che effettua **al di là della necessità di raggiungere l'università** per motivi di studio/lavoro.

E5

Quanto spesso utilizza i seguenti mezzi per spostamenti che **NON riguardano** la mobilità casa-università (e ritorno)?

NB: se lasciate vuote le opzioni non compilate verranno considerate come "mai" utilizzate.

Piedi per almeno 5 minuti (1)	▼ Mai (1) ... Diverse volte al giorno (8)
Bicicletta (2)	▼ Mai (1) ... Diverse volte al giorno (8)
Bike sharing (3)	▼ Mai (1) ... Diverse volte al giorno (8)
Monopattino (4)	▼ Mai (1) ... Diverse volte al giorno (8)
Monopattino in sharing (5)	▼ Mai (1) ... Diverse volte al giorno (8)
Moto/scooter (6)	▼ Mai (1) ... Diverse volte al giorno (8)
Moto/scooter in sharing (7)	▼ Mai (1) ... Diverse volte al giorno (8)
Auto come conducente (8)	▼ Mai (1) ... Diverse volte al giorno (8)
Auto come passeggero (9)	▼ Mai (1) ... Diverse volte al giorno (8)
Car sharing (10)	▼ Mai (1) ... Diverse volte al giorno (8)
Bus urbano (11)	▼ Mai (1) ... Diverse volte al giorno (8)
Bus extra-urbano (12)	▼ Mai (1) ... Diverse volte al giorno (8)
Tram/Filobus (14)	▼ Mai (1) ... Diverse volte al giorno (8)
Metro e metro leggera (15)	▼ Mai (1) ... Diverse volte al giorno (8)
Treno/Passante ferroviario (16)	▼ Mai (1) ... Diverse volte al giorno (8)
Battello/Traghetto (17)	▼ Mai (1) ... Diverse volte al giorno (8)
Funicolare (18)	▼ Mai (1) ... Diverse volte al giorno (8)

Q91 Abbiamo quasi finito

Q76

Le chiediamo ora di esprimere liberamente delle opinioni rispetto ad alcune affermazioni relative a servizi ed esperienze di mobilità.

F7 Quanto è d'accordo con le seguenti affermazioni?

	Completamente in disaccordo (1)	Abbastanza in disaccordo (2)	Né d'accordo né in disaccordo (3)	Abbastanza d'accordo (4)	Completamente d'accordo (5)
Scelgo di viaggiare con i mezzi pubblici o di condividere lo spostamento (ad es.: carpooling) per ridurre i costi del viaggio (1)	—	—	—	—	—
Non mi interessa quale mezzo di trasporto utilizzare, purché sia adatto alle mie esigenze di viaggio (14)	—	—	—	—	—
Sono disposto a provare nuovi modi di viaggiare (15)	—	—	—	—	—
I servizi di mobilità innovativi (come Uber, BlaBlaCar, bike-sharing, ...) mi entusiasmano (16)	—	—	—	—	—
Di tanto in tanto cerco delle alternative al possesso di un'auto (17)	—	—	—	—	—
Se avessi a disposizione un'app con informazioni aggiornate su trasporto pubblico e mobilità condivisa userei meno l'auto privata (18)	—	—	—	—	—
Preferisco pagare le corse tramite un'applicazione (per smartphone), o digitalmente, rispetto al biglietto cartaceo (19)	—	—	—	—	—
Sono disponibile a provare nuove applicazioni per smartphone (20)	—	—	—	—	—
Utilizzerei un'applicazione per smartphone se questa mi desse facile accesso (pagamento, informazioni, percorsi, tempi, etc.) all'uso di tutti modi di trasporto (21)	—	—	—	—	—
Utilizzo spesso applicazioni per smartphone per avere informazioni sui servizi di trasporto e pianificare i miei viaggi (22)	—	—	—	—	—

F8

Quanto è d'accordo con le seguenti affermazioni relative a possibili servizi di trasporto innovativi e integrati?

(si intendono servizi di sharing, a chiamata, ... che possono essere acquistati in combinazione tra loro e con il Trasporto Pubblico per compiere uno stesso spostamento con un unico titolo di viaggio/abbonamento)

	Completamente in disaccordo (1)	Abbastanza in disaccordo (2)	Né d'accordo né in disaccordo (3)	Abbastanza d'accordo (4)	Completamente d'accordo (5)
Sarei disposto a sottoscrivere un unico piano di abbonamento (settimanale o mensile) che includa l'uso di più servizi di trasporto (trasporto pubblico, sharing, taxi, etc.) (6)	—	—	—	—	—
Sarei disposto a provare nuove modalità di trasporto che non utilizzavo in precedenza se il mio abbonamento a servizi di mobilità integrati le includesse (8)	—	—	—	—	—
Sarei disposto ad utilizzare o utilizzare maggiormente i mezzi di trasporto sostenibile se ci fosse un'unica applicazione che ne consentisse un facile accesso (pagamento, informazioni, percorsi, tempi, etc.) (9)	—	—	—	—	—
È facile per me trovare il mezzo/punto di accesso al servizio se è visualizzato su una mappa nell'applicazione (per smartphone) (10)	—	—	—	—	—
Penso che sarebbe facile per me diventare abile nell'utilizzo di un'applicazione che offre servizi di mobilità innovativi e integrati (11)	—	—	—	—	—
Penso che imparare ad utilizzare i nuovi servizi di mobilità innovativi e integrati sarebbe facile per me (12)	—	—	—	—	—
Un piano di abbonamenti a servizi di mobilità innovativi e integrati sarebbe utile per la mia mobilità quotidiana (13)	—	—	—	—	—
Un piano di abbonamenti a servizi di mobilità innovativi e integrati permetterebbe di compiere i miei spostamenti quotidiani in maniera più rapida (14)	—	—	—	—	—
L'uso di un piano di abbonamenti a servizi di mobilità innovativi e integrati aumenterebbe l'efficacia della mia mobilità quotidiana (15)	—	—	—	—	—

F9

Quali caratteristiche ritiene più importanti per un'app su trasporto pubblico e mobilità condivisa?

Le chiediamo di ordinare, trascinandole, le opzioni dalla più importante (valore 1) alla meno importante (valore 5).

- _____ Disponibilità di informazioni affidabili e aggiornate (1)
- _____ Disponibilità di informazioni/alert relative al mio spostamento abituale (2)
- _____ Possibilità di acquistare biglietti (3)
- _____ Possibilità di prenotare un veicolo condiviso (4)
- _____ Presenza di valutazioni sulle alternative modali espresse da altri utenti (5)

F10 Ha scaricato e/o utilizzato l'applicazione **MaaS4UNI**, sviluppata dall'Università di Napoli Federico II?

- Sì (1)
- No (2)

C1 Con che tipo di combustibile è alimentato il mezzo di trasporto privato che di solito utilizza nel tragitto casa - Università?

- Benzina (1)
- Diesel (2)
- GPL (3)
- Metano (4)
- Energia elettrica (5)
- Ibrida (senza presa elettrica) (6)
- Ibrida plug-in (7)
- Altro (8)
- Non so (9)

C2 A quale segmento di mercato appartiene il mezzo di trasporto che di solito utilizza nel tragitto casa - Università?

- City car (1)
- Utilitaria (2)
- Berlina (3)
- SUV/crossover (4)
- Station Wagon (5)
- Altro (6)
- Non so (7)

C3 In quale anno è stato immatricolato il mezzo di trasporto privato che di solito utilizza nel tragitto casa - Università?

- Prima del 1997 (classe Euro 1) (1)
- Tra il 1997 e il 2000 (classe Euro 2) (2)
- Tra il 2001 e il 2006 (classe Euro 3) (3)
- Tra il 2007 e il 2009 (classe Euro 4) (4)
- Tra il 2010 e il 2014 (classe Euro 5) (5)
- Tra il 2015 e il 2017 (classi Euro 6A e 6B) (6)
- Tra il 2018 e il 2019 (classe Euro 6C) (7)
- Dopo il 2019 (classe Euro 6D) (8)
- Non so/Non applicabile (9)

D1 Possiede un abbonamento ai seguenti servizi di trasporto?

- Abbonamento Trasporto Pubblico Locale (Bus, metro...) (1)
- Abbonamento Treno extraurbano (2)
- Abbonamento integrato a tutti i trasporti pubblici (locale ed extraurbano) (3)
- Abbonamento bike sharing (4)
- Abbonamento car sharing (5)
- Abbonamento scooter sharing (6)
- Abbonamento monopattino sharing (7)
- Abbonamento parcheggio (8)
- Nessuno (9)

D2 Quanto paga all'anno per l'abbonamento/i ai servizi di trasporto citati?

	Abbonamento Trasporto Pubblico Locale (Bus, metro...) (1)	Abbonamento Treno extraurbano (2)	Abbonamento integrato a tutti i trasporti pubblici (locale ed extraurbano) (3)	Abbonamento bike sharing (4)	Abbonamento car sharing (5)	Abbonamento scooter sharing (6)	Abbonamento monopattino sharing (7)	Abbonamento parcheggio (8)
☒ Tra 0 e 50 euro (1)	—	—	—	—	—	—	—	—
☒ Tra 51 e 150 euro (2)	—	—	—	—	—	—	—	—
☒ Tra 151 e 250 euro (3)	—	—	—	—	—	—	—	—
☒ Tra 251 e 350 euro (4)	—	—	—	—	—	—	—	—
☒ Tra 351 e 450 euro (5)	—	—	—	—	—	—	—	—
☒ Tra 451 e 550 euro (6)	—	—	—	—	—	—	—	—
☒ Tra 551 e 650 euro (7)	—	—	—	—	—	—	—	—
☒ Tra 651 e 750 euro (8)	—	—	—	—	—	—	—	—
☒ Più di 750 euro (9)	—	—	—	—	—	—	—	—
☒ Non so/non ricordo (10)	—	—	—	—	—	—	—	—

D3 Si avvale di agevolazioni e sconti sull'abbonamento ai servizi di trasporto citati?

	Abbonamento Trasporto Pubblico Locale (Bus, metro...) (1)	Abbonamento Treno extraurbano (2)	Abbonamento integrato a tutti i trasporti pubblici (3)	Abbonamento bike sharing (4)	Abbonamento car sharing (5)	Abbonamento scooter sharing (6)	Si, Abbonamento monopattino sharing (7)	Si, Abbonament o parcheggio (8)
☒ Sì, offerto dall'Università (1)	—	—	—	—	—	—	—	—
☒ Sì, offerto dalla Società di trasporti (2)	—	—	—	—	—	—	—	—
☒ Sì, offerto dall'Ente locale/territoriale (3)	—	—	—	—	—	—	—	—
☒ Sì, del "Bonus Trasporti" (9)	—	—	—	—	—	—	—	—
☒ No, non esiste alcuna agevolazione (4)	—	—	—	—	—	—	—	—
☒ No, ma sono a conoscenza delle agevolazioni (5)	—	—	—	—	—	—	—	—
☒ Non sono a conoscenza di agevolazioni (6)	—	—	—	—	—	—	—	—
☒ Altro (7)	—	—	—	—	—	—	—	—

D4 Possiede la patente di guida di tipo B o superiore valida?

- Sì, e mi capita di guidare (1)
- Sì, ma non guido mai (2)
- No (3)

G1 Sesso

- Maschio (1)
- Femmina (2)

G2 Età

G3 Con chi vive nel suo attuale domicilio?

- Vivo da sola/o (1)
- Vivo da sola/o con i miei figli (2)
- Vivo con coniuge/partner senza figli (3)
- Vivo con coniuge/partner con figli (4)
- Vivo con i genitori (5)
- Vivo con i genitori e i miei figli (6)
- Vivo con i genitori/suoceri, coniuge/partner e i nostri figli (9)
- Vivo con altri studenti/amici/coinquilini (appartamento condiviso, studentato, etc.) (7)
- Altro (8)

G4 Quante persone vivono nel suo domicilio (Lei compreso/a)?

G5 Nella sua abitazione ci sono una o più persone che non sono in grado di spostarsi autonomamente e che quindi necessitano di un accompagnamento per i propri spostamenti?

- Sì, accompagnate da me (1)
- Sì, accompagnate da altre persone (2)
- Sì, io stesso (4)
- No (3)

G6 Quanti/e figli/e ha?

- Non ho figli/e (1)
- Fino a 3 anni (2) _____
- Fra i 4 e i 5 anni (3) _____
- Fra i 6 e i 10 anni (4) _____
- Fra gli 11 e i 14 anni (5) _____
- Fra i 15 e i 18 anni (6) _____
- Maggiori di 18 anni (7) _____

G8 In quale provincia/città metropolitana abita?

▼ Provincia di Alessandria (1) ... Provincia di Viterbo (97)

G9 Comune di abitazione: * si prega di scrivere il nome del comune completo (senza abbreviazioni), ad esempio "Sesto San Giovanni" o "Grisignano di Zocco", ecc...

G10 CAP abitazione:

G11 Indirizzo abitazione: * si prega di scrivere l'indirizzo per esteso (senza abbreviazioni), ad esempio "piazza Italia 27" o "viale Garibaldi 12" o "via San Giuseppe 5b", ecc...

R1

Le chiediamo se sarebbe disponibile in futuro ad essere ricontattato/a per partecipare a una seconda e più breve indagine sul tema dei servizi di mobilità innovativi. Nel caso la preghiamo di scrivere il suo indirizzo e-mail di contatto nella casella apposita.

A coloro che prenderanno parte a questa seconda breve indagine verrà riconosciuto un omaggio, per ringraziare della disponibilità!

- Sì (1) _____
- No (2)

Q81

Per agevolare la pseudoanonimizzazione delle risposte le chiediamo di indicare:

- Le PRIME TRE LETTERE del NOME (es.: MARIO = MAR) (4) _____
- Le PRIME TRE LETTERE del COGNOME (es.: ROSSI = ROS) (5) _____
- Il giorno di nascita (es.: 9 gennaio 1990 = 09) (6) _____

Appendix 2: SP survey questionnaire

ruolo	2.Indichi qual è il suo ruolo all'Università
1	Docente
2	Personale Tecnico Amministrativo
3	Studente
modo	3.Indichi quale mezzo utilizza prevalentemente per recarsi all'Università
1	Auto privata
2	Trasporto pubblico (Autobus, Metropolitana, Treno, etc.)
3	Bicicletta personale
4	Piedi
distanza	4.Indichi qual è la distanza tra casa sua e la sede principale di lavoro/studio.
1	Minore o uguale a 15 km
2	Compresa tra 15 e 30 km
3	Compresa tra 30 e 60 km
4	Maggiore o uguale a 60 km
q324	5.Indichi il comune del suo domicilio.
q344	6.Indichi la via e il numero civico del suo domicilio.
q345	7.Quale è la sede universitaria prevalente in cui studia/lavora?
1	Milano - Campus Bicocca (Piazza dell'Ateneo Nuovo 1)
2	Monza - ASST, Polo ospedaliero di Monza, (Via G. B. Pergolesi 33)
3	Bergamo - ASST "Papa Giovanni XXIII" (Piazza Organizzazione Mondiale della Sanità 1)
4	Carate Brianza - Istituti Clinici Zucchi - Presidio Riabilitativo (Piazza Madonnina 1)
5	Desio - ASST Monza , Polo ospedaliero di Desio (Via Giuseppe Mazzini 1)
6	Faedo Valtellino (Sondrio) - ASST Valtellina e Alto Lario (Via Stelvio 25)
7	Lecco - ASST Lecco (Via dell'Eremo 9/11)
8	Pavia - (Corso Strada Nuova 65)
9	Altro
frequenza	8.Indichi con quale frequenza si reca all'Università durante il semestre delle lezioni
1	Due volte al mese
2	Una volta alla settimana
3	Due volte alla settimana
4	3/4 volte alla settimana
5	Ogni giorno
q346	9.Indichi che ora esce di casa abitualmente per recarsi presso all'Università
1	Prima delle 06:00
2	Tra le 06:00 e le 07:00
3	Tra le 07:00 e le 08:00
4	Tra le 08:00 e le 09:00
5	Dopo le 09:00
q326	10.Indichi il suo sesso
1	Maschio
2	Femmina
3	Preferisco non rispondere
eta	11.Indichi la sua età
Patente	12.Ha la patente di guida di categoria B?
1	Sì
2	Sì, ma non guido
3	No
q325	13.Indichi uno o più mezzi privati che ha a disposizione per effettuare i suoi spostamenti:
1	Auto
2	Moto/scooter

3	Monopattino
4	Bicicletta
5	Nessuno
q348	14. Indichi quante auto sono disponibili nel suo nucleo familiare:
1	Nessuna
2	Una
3	Due
4	Tre
5	Quattro o più
q349	15. Indichi da quante persone è costituito il suo nucleo familiare, incluso lei:
1	Una
2	Due
3	Tre
4	Quattro o più
q347	16. Nella sua abitazione ci sono una o più persone che non sono in grado di spostarsi autonomamente e che quindi necessitano di un accompagnamento per i propri spostamenti?
1	Sì, accompagnate da me
2	Sì, accompagnate da altre persone
3	Sì, io stesso
4	No
Discrezionali	17. Effettua spostamenti durante la settimana per attività discrezionali (visita ad amici/parenti, spesa, sport, etc.)?
1	Sì, almeno uno a settimana
2	Sì, un paio a settimana
3	Sì, più di due a settimana
4	No
q350	18. Possiede un abbonamento al trasporto pubblico?
1	No
2	Sì, mensile
3	Sì, annuale
4	Altro
Buono	19. Indichi quale dei seguenti buoni preferirebbe ricevere
1	Buono sconto di 10 € per una cena al ristorante
2	Buono sconto di 10 € per spesa al supermercato
3	Buono sconto di 10 € per abbonamento mensile in palestra
4	1 ingresso al cinema gratis

6 scenari di scelta SP

Psico-attitudinali

q321	20. Se avesse potuto scegliere lei i mezzi di trasporto da includere in un ipotetico pacchetto di mobilità più incline a soddisfare le sue esigenze, quali avrebbe scelto di includere?
1	Trasporto pubblico urbano
2	Trasporto pubblico extra-urbano
3	Trasporto pubblico integrato urbano+extraurbano
4	Car Sharing
5	Bike Sharing
6	Scooter Sharing
7	Taxi
8	Nessuna
9	Non saprei
q322	20b. Sarebbe disposto a valutare la possibilità di vendere l'automobile che usa, quindi rinunciare al suo possesso e ai costi ed esso correlati, qualora ci fossero dei pacchetti di mobilità per lei convenienti?
1	Sì
2	No
3	No, l'auto non è di mia proprietà

4	No, condivido l'auto con altri componenti della mia famiglia
5	Non saprei
q316	21. Indichi il suo livello di accordo/disaccordo (1=Completamente in disaccordo, 5=Completamente d'accordo) con ognuna delle seguenti affermazioni
Row	1. Scelgo di viaggiare con i mezzi pubblici o di condividere lo spostamento (ad es.: carpooling) per ridurre i costi del viaggio
Row	2. Non mi interessa quale mezzo di trasporto utilizzare, purché sia adatto alle mie esigenze di viaggio
Row	3. Sono disposto a provare nuovi modi di viaggiare
Row	4. I servizi di mobilità innovativi (come Uber, BlaBlaCar, bike-sharing, ...) mi entusiasmano
q317	22. Indichi il suo livello di accordo/disaccordo (1=Completamente in disaccordo, 5=Completamente d'accordo) con ognuna delle seguenti affermazioni
Row	1. Se avessi a disposizione un'app con informazioni aggiornate su trasporto pubblico e mobilità condivisa userei maggiormente il trasporto pubblico
Row	2. Preferisco pagare le corse tramite un'applicazione (per smartphone), o digitalmente, rispetto al biglietto cartaceo
Row	3. Sono disponibile a provare nuove applicazioni per smartphone
Row	4. Utilizzerei un'applicazione per smartphone se questa mi desse facile accesso (pagamento, informazioni, percorsi, tempi, etc.) all'uso di tutti i modi di trasporto
Row	5. Utilizzo spesso applicazioni per smartphone per avere informazioni sui servizi di trasporto e pianificare i miei viaggi
q318	23. Quanto è d'accordo con le seguenti affermazioni relative a possibili servizi di trasporto innovativi e integrati? (1=Completamente in disaccordo, 5=Completamente d'accordo)
Row	1. Sarei disposto a sottoscrivere un unico piano di abbonamento (settimanale o mensile) che includa l'uso di più servizi di trasporto (trasporto pubblico, sharing, taxi, etc.)
Row	2. Sarei disposto a provare nuove modalità di trasporto che non utilizzavo in precedenza se il mio abbonamento a servizi di mobilità integrati le includesse
Row	3. Sarei disposto ad utilizzare o utilizzare maggiormente i mezzi di trasporto sostenibile se ci fosse un'unica applicazione che ne consentisse un facile accesso (pagamento, informazioni, percorsi, tempi, etc.)
Row	4. È facile per me trovare il mezzo/punto di accesso al servizio se è visualizzato su una mappa nell'applicazione (per smartphone)
Row	5. Penso che sarebbe facile per me diventare abile nell'utilizzo di un'applicazione che offre servizi di mobilità innovativi e integrati
Row	6. Penso che imparare ad utilizzare i nuovi servizi di mobilità innovativi e integrati sarebbe facile per me
Row	7. Un piano di abbonamenti a servizi di mobilità innovativi e integrati sarebbe utile per la mia mobilità quotidiana
Row	8. Un piano di abbonamenti a servizi di mobilità innovativi e integrati permetterebbe di compiere i miei spostamenti quotidiani in maniera più rapida
Row	9. L'uso di un piano di abbonamenti a servizi di mobilità innovativi e integrati aumenterebbe l'efficacia della mia mobilità quotidiana

Appendix 3: Personalised Travel Plan (PTP)

Il suo comportamento di mobilità

Sulla base dei dati raccolti tramite l'applicazione Mobility Company, abbiamo analizzato i suoi spostamenti effettuati nel periodo compreso tra il 25 e il 28 giugno 2025.

Nel corso di questi quattro giorni, ha effettuato complessivamente 4 spostamenti, tutti unimodali (cioè compiuti con un solo mezzo di trasporto).

Nel complesso, l'auto privata è risultata l'unico mezzo utilizzato, sia per numero di segmenti sia per distanza percorsa (oltre 20 km). Emerge quindi un profilo di mobilità fortemente dipendente dall'automobile, senza combinazioni con altri mezzi o modalità sostenibili.

Inoltre, nessuno spostamento è stato diretto verso la sede dell'Università degli Studi di Milano-Bicocca.

Dal punto di vista temporale, i suoi spostamenti si distribuiscono in modo equilibrato tra giorni feriali (2 spostamenti) e fine settimana (2 spostamenti), mentre non sono stati rilevati spostamenti nei giorni festivi. Questo pattern suggerisce una mobilità legata sia ad attività quotidiane sia a esigenze del tempo libero.

Dal punto di vista territoriale, la mobilità osservata nel periodo considerato si configura come prevalentemente locale, con una netta predominanza di spostamenti intracomunali all'interno del comune di Monza e Città Metropolitana di Milano.

In sintesi:

- 3 spostamenti si sono svolti interamente all'interno dello stesso comune (spostamenti intracomunali);
- 1 spostamento ha interessato comuni diversi, configurandosi come spostamento intercomunale;
- Non sono stati rilevati spostamenti interamente nel Comune di Milano;
- 2 spostamenti si sono svolti all'interno della Città Metropolitana di Milano, pur coinvolgendo territori esterni ai confini comunali del capoluogo;
- 2 spostamenti si sono svolti all'interno della Regione Lombardia (con origine o/e destinazione al di fuori della Città Metropolitana di Milano);
- Non sono stati rilevati spostamenti fuori regione.

Piano Personalizzato di Mobilità (PTP)

Alla luce di quanto descritto, le proponiamo un Piano Personalizzato di Mobilità (PTP), elaborato secondo le metodologie validate dei programmi di *Voluntary Travel Behaviour Change*, finalizzati a promuovere una mobilità più efficiente e sostenibile.

L'obiettivo generale è quello di favorire una graduale riduzione dell'uso dell'auto privata, incentivando modalità di trasporto più sostenibili e intermodali, in linea con le risorse e i servizi a lei disponibili.

Azioni suggerite:

- Iniziare a integrare i propri spostamenti con soluzioni di trasporto pubblico e mobilità attiva, anche solo in alcune tratte;
- Valutare l'impiego di parcheggi di interscambio ([elenco dei parcheggi di interscambio di ATM](#)) per integrare l'uso dell'auto con il trasporto pubblico locale e regionale, in modo da limitare l'uso dell'auto ai tratti meno serviti e ridurre congestione e impatto ambientale;
- Combinare gli spostamenti quotidiani con tratte a piedi o in bicicletta, sfruttando anche i servizi di bike sharing presenti in città, soprattutto per i collegamenti con le stazioni della metropolitana (a Milano) e dei treni regionali, le fermate degli autobus e nodi di interscambio.

Sfruttare le potenzialità dell'app Mobility Company, sviluppata da Movesion, per:

- Acquistare biglietti per il trasporto pubblico urbano (per spostamenti all'interno della Città metropolitana di Milano) e interurbano;
- Accedere con facilità e a prezzi agevolati ai servizi di mobilità condivisa, come car sharing, bike sharing e scooter sharing, diffusi nel Comune di Milano;
- Monitorare l'andamento dei propri spostamenti, potendo consultare feedback personalizzati sui benefici ambientali delle scelte compiute (es. risparmio di CO₂, chilometri sostenibili).

Il PTP è pensato per accompagnarla nella sperimentazione di alternative più sostenibili, considerando il contesto in cui ha mostrato di muoversi abitualmente e l'opportunità di ridurre gradualmente l'utilizzo dell'auto privata.

Prossimi passi

La invitiamo a mettere in pratica le indicazioni contenute nel Piano Personalizzato di Mobilità nel periodo compreso tra il **23 luglio e il 3 agosto**. In questo arco temporale le chiediamo di continuare a **registrare i suoi spostamenti** tramite l'app Mobility Company. Gli eventuali cambiamenti della sua mobilità saranno monitorati direttamente attraverso l'applicazione, e contribuiranno concretamente allo sviluppo e al successo della sperimentazione *Track2Change*.

Appendix 4: Follow-up survey questionnaire

Progetto "Track2Change"

Benvenuto/a!

Grazie per aver preso parte alla sperimentazione **Track2Change**, promossa dall'Università degli Studi di Milano-Bicocca nell'ambito del progetto **MOST – Centro Nazionale per la Mobilità Sostenibile**.

Questo questionario è l'ultimo passo del percorso e ti permette di partecipare all'estrazione di premi fino a **200 euro** di valore.

La compilazione richiede circa **10 minuti** e ti chiediamo di completarla **entro il 30 settembre**.

Al termine riceverai una mail all'indirizzo istituzionale con le istruzioni per il ritiro del premio.

Trattamento dei dati personali

I dati raccolti saranno trattati nel pieno rispetto della normativa vigente (Regolamento UE 2016/679 – GDPR) ed esclusivamente per le finalità legate alla sperimentazione. La partecipazione è volontaria e potrai interromperla in qualsiasi momento.

Per maggiori dettagli, consulta l'informativa completa disponibile a questo [link](#).

1. Per proseguire è necessario il tuo consenso all'uso dei dati. Questi verranno raccolti e gestiti secondo le più recenti norme di tutela della privacy, come descritte nell' **Informativa privacy**.
 - Dichiaro di aver preso visione dell'informativa sulla Privacy
2. Indica l'indirizzo email **DOVE hai ricevuto** l'invito di compilazione dell'indagine. *
3. Indica il tuo indirizzo email istituzionale (@campus.unimib.it) *
4. Normalmente con quale mezzo/modalità percorri la maggior parte della **distanza** per raggiungere l'Università?
 - Piedi (5 min e oltre)
 - Bicicletta
 - Bike sharing
 - Monopattino
 - Monopattino in sharing
 - Moto/scooter
 - Moto/scooter in sharing
 - Auto come conducente Auto come passeggero
 - Car sharing
 - Bus
 - Navetta di Ateneo
 - Tram/Filobus
 - Metro e metro leggera
 - Treno/Passante/Battello/Traghetto
 - Funicolare Altro:
5. Normalmente usi altri mezzi/modalità oltre al principale per raggiungere l'Università?
Sì
No
6. Normalmente quali altri mezzi/modalità utilizzi oltre al principale per raggiungere l'Università?
 - Piedi (5 min e oltre)
 - Bicicletta
 - Bike sharing
 - Monopattino
 - Monopattino in sharing

- Moto/scooter
- Moto/scooter in sharing
- Auto come conducente Auto come passeggero
- Car sharing
- Bus
- Navetta di Ateneo
- Tram/Filobus
- Metro e metro leggera
- Treno/Passante/Battello/Traghetto
- Funicolare Altro:

7. Quanto spesso utilizzi i seguenti mezzi per spostamenti che **NON riguardano** la mobilità casa-università (e ritorno)?

In caso di compilazione da smartphone si suggerisce di ruotare in orizzontale il dispositivo per una visualizzazione ottimale delle opzioni di risposta.

Modalità di risposta: Mai, Una volta al mese o meno, Due volte al mese, Una volta alla settimana, Diverse volte alla settimana, Una o più volte al giorno.

- Piedi
- Bicicletta
- Auto / moto propria
- Trasporto pubblico (autobus, metropolitana, treno, tram ecc)
- Servizi in sharing

8. Se dovessi descrivere l'applicazione Mobility Company con **solo 3 parole**, quali sarebbero?

Scrivile una di seguito all'altra separandole con una virgola

9. L'app Mobility Company sarà messa a disposizione di tutta la comunità accademica. Pensi di utilizzarla per acquistare servizi di mobilità?

Sì

No

10. Se non pensi di utilizzare l'app Mobility Company, quanto sono importanti le seguenti motivazioni?

Su una scala da 1 a 5 dove 1 = Per niente importante e 5 = Molto importante

In caso di compilazione da smartphone si suggerisce di ruotare in orizzontale il dispositivo per una visualizzazione ottimale delle opzioni di risposta

- Preferisco altri canali di acquisto per servizi di mobilità (biglietterie fisiche, siti web, altre app).
- I servizi disponibili non rispondono alle mie esigenze di mobilità.
- I costi dei servizi offerti sono troppo elevati.
- Difficoltà d'uso o interfaccia poco intuitiva.
- Preoccupazioni per la privacy o la sicurezza dei dati.
- Mancanza di fiducia/affidabilità del servizio.
- Mancanza di abitudine nell'uso di questo tipo di applicazioni.
- Scarso interesse in generale verso le nuove tecnologie digitali.
- Problemi tecnici con l'applicazione (ad es. scarsa fluidità, malfunzionamenti, ...).

11. Quanto ritieni che l'uso dell'auto privata sia necessario per i tuoi spostamenti quotidiani?

- Per nulla necessario
- Poco necessario
- Abbastanza necessario
- Molto necessario
- Indispensabile

12. Quanto sei d'accordo con le seguenti affermazioni?

Su una scala da 1 a 5 dove 1 = Completamente in disaccordo e 5 = Completamente d'accordo

In caso di compilazione da smartphone si suggerisce di ruotare in orizzontale il dispositivo per una visualizzazione ottimale delle opzioni di risposta

- Il mio stile di vita dipende dal possedere un'auto.
- Non mi soffermo a pensare a come spostarmi: prendo l'auto e vado.
- Vorrei usare meno l'auto, ma non ci sono alternative davvero pratiche.
- Mi impegno attivamente per ridurre l'utilizzo della mia auto.
- Non ho interesse a diminuire l'uso della mia auto.

13. Quanto ritieni siano importanti per te i seguenti ostacoli nel ridurre l'uso dell'auto nella tua mobilità quotidiana?

Su una scala da 1 a 5 dove 1 = Per niente importante e 5 = Molto importante

In caso di compilazione da smartphone si suggerisce di ruotare in orizzontale il dispositivo per una visualizzazione ottimale delle opzioni di risposta

- Mancanza di alternative pratiche
- Costi elevati dei trasporti pubblici
- Inconvenienti legati ai tempi di viaggio
- Problemi di accessibilità dei mezzi pubblici
- Limitazioni fisiche personali o di persone a me vicine
- Necessità organizzative

14. Date le condizioni attuali, in quale misura sei disposto a sostituire, almeno in parte, l'uso dell'auto con modalità di trasporto alternative (ad esempio trasporto pubblico, bicicletta...) per i tuoi spostamenti quotidiani?

- Per niente disposto
- Poco disposto
- Abbastanza disposto
- Disposto
- Molto disposto

15. Quanto ritieni probabile che ridurrai l'uso dell'auto privata nella tua mobilità quotidiana nei prossimi 12 mesi?

- Per niente probabile
- Poco probabile
- Abbastanza probabile
- Probabile
- Molto probabile

16. Quanto sei d'accordo con le seguenti affermazioni?

Su una scala da 1 a 5 dove 1 = Completamente in disaccordo e 5 = Completamente d'accordo

In caso di compilazione da smartphone si suggerisce di ruotare in orizzontale il dispositivo per una visualizzazione ottimale delle opzioni di risposta

- Mi sentirei a disagio se usassi l'auto quando so che la maggior parte delle persone nel mio ambiente utilizza mezzi di trasporto più sostenibili.
- Credo che utilizzare mezzi di trasporto più sostenibili sia una mia responsabilità morale.
- Ridurre l'uso dell'auto non farà differenza sui problemi di congestione perché la maggior parte delle persone non ridurrà l'uso dell'auto.
- Non credo che il mio tentativo di ridurre l'uso dell'auto abbia un impatto significativo sull'ambiente.
- Sono convinto che ogni piccolo cambiamento nel mio comportamento di viaggio possa fare la differenza.

17. Quanto sei d'accordo con le seguenti affermazioni?

Su una scala da 1 a 5 dove 1 = Completamente in disaccordo e 5 = Completamente d'accordo

In caso di compilazione da smartphone si suggerisce di ruotare in orizzontale il dispositivo per una visualizzazione ottimale delle opzioni di risposta

- L'uso dei mezzi pubblici è complicato dalla loro scarsa disponibilità e affidabilità.
- Le difficoltà con i mezzi pubblici rendono l'uso dell'auto la mia opzione preferita.
- Trovo difficile usare i mezzi di trasporto alternativi a causa della mancanza di infrastrutture adeguate.
- Ho facile accesso a fermate o stazioni del trasporto pubblico vicino a casa o al lavoro/studio.

- Le infrastrutture per la mobilità attiva (piste ciclabili, marciapiedi) lungo i miei percorsi quotidiani sono sicure e ben mantenute.
- Le mie condizioni fisiche mi permettono di camminare o andare in bicicletta per gli spostamenti quotidiani.
- Ho le competenze (conoscenze del servizio, competenze digitali...) per utilizzare in autonomia i servizi di trasporto pubblico.
- Posso organizzare facilmente e in modo flessibile le mie attività quotidiane.

18. Quanto sei d'accordo con le seguenti affermazioni?

Su una scala da 1 a 5 dove 1 = Completamente in disaccordo e 5 = Completamente d'accordo

In caso di compilazione da smartphone si suggerisce di ruotare in orizzontale il dispositivo per una visualizzazione ottimale delle opzioni di risposta

- Mi sento più motivato a utilizzare la bicicletta o a camminare quando vedo altre persone farlo.
- Le aspettative della mia cerchia sociale riguardo ai miei comportamenti di trasporto influenzano le mie decisioni.
- Se più persone nel mio gruppo di amici usassero i trasporti pubblici e i mezzi in sharing, sarei più incline a fare lo stesso.
- Mi sento orgoglioso quando faccio scelte di trasporto che aiutano a preservare l'ambiente.
- Adottare comportamenti sostenibili è una componente chiave della mia identità.
- Ritengo di avere una buona comprensione dei diversi impatti ambientali associati ai vari mezzi di trasporto.