Envisioning Future Mobility:

Co-developing Campus-Based Mobility as a Service with International Students

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B.A. Industrial Design with Honours (Monash University)



A thesis submitted for the degree of *Doctor of Philosophy* at

Monash University in 2026

Monash Art, Design and Architecture




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The journey we take together today is just a brief crossing in the river of ten thousand years, but in this crossing is a kind of eternity.

Our shared goal of redefining mobility, even if it seems like a small step in the grand scheme of things, is a huge change.

In this short moment that we all share, we set the course for a future that will last.

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Declaration

This thesis is original and based on my research; it does not include any material that has been accepted for any other degree or diploma. To the best of my knowledge, this manuscript does not contain any material previously published or written by another person, except where proper references are made in the text.

I acknowledge that Grammarly and ChatGPT were used solely for grammar refinement, clarity of expression, and structural formatting checks during the preparation of this manuscript. All substantive content, including the research design, data analysis, conceptual arguments, and written interpretations, are my own independent work.

signature

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Chenlizhe Yang, February 2026

Acknowledgement of the country

I wish to acknowledge and pay respect to the Elders and Traditional Owners of the Kulin Nations, on whose lands much of this research and creative practice was conducted. I acknowledge the Aboriginal connection to material and creative practices that have existed on these lands for more than 60,000 years and celebrate their enduring presence and knowledge of it. I pay my respects to their elders, past, present, and emerging.

Abstract

This practice-based design study investigates how a Mobility-as-a-Service (MaaS) platform conceived for a realistic five-year horizon might reduce private car use among international student drivers commuting to Monash University's Clayton campus. Following Brier (2005), the study focuses on mobility technologies and digital services that could reasonably be deployed within five years and avoids claims about more distant futures.

The study is situated within the ARC Linkage Net Zero Precinct initiative. Transport associated with the campus is treated as a major contributor to precinct emissions, and design practice may translate net zero ambitions into everyday travel decisions and mobility service experiences. Within this setting, the study focuses on international student drivers as a distinct commuter group whose transport choices are shaped by limited familiarity with local services, changing social routines, and the practical demands of studying, working, and living in a suburban environment.

The study adopts a practice-based design research approach and uses participatory design methods to develop an early-stage MaaS concept grounded in participants' lived commuting experiences. Evidence presented throughout the exegesis draws on two participatory design workshops, subsequent interviews, and iterative prototyping with ten international students from Chinese cultural backgrounds (refer to Chapters 4 and 8.1). The workshops enabled participants to map routine journeys, identify barriers and design opportunities across stages of travel, and explore future mobility scenarios collaboratively. These activities informed the iterative development of a Figma-based MaaS prototype and related service concepts (refer to Chapters 6 and 7). The design process therefore served as a means of investigating how multimodal and low-carbon commuting experiences might be reimagined within the Clayton campus.

Findings from the two design workshops and subsequent interviews identify several interconnected influences on participants' mode choices. These influences include preferences for convenience and independence, limited time and tightly structured daily schedules, suburban infrastructure that constrains multimodal options, and safety concerns that affect willingness to walk, cycle, or use public transport (refer to Chapter 4.5). The study documents interface features intended to mitigate these frictions and improve the platform's usability and relevance for the target group. The features include clearer journey guidance and real-time support, multimodal trip planning suited to short time windows, contextualised incentives and social feedback that make carbon savings tangible, and interface cues intended to support safety and confidence during uncertain stages of a journey.

By positioning participants as co-designers, the study indicates how user knowledge may shape early mobility service concepts and make net zero objectives more actionable within daily routines. The study contributes to sustainable mobility and MaaS scholarship in two respects. First, it identifies international student drivers as a strategically important yet underexplored niche population whose travel practices may remain open to reconfiguration during the early stages of settlement in a new suburban environment. Second, it develops an empirically grounded design proposition that specifies the functions and interaction strategies that a campus MaaS platform would require to support more sustainable travel choices in this context. Developed through participatory design activities and situated within the ARC Linkage *Net Zero Precinct initiative*, these contributions extend MaaS research beyond technological integration towards a context-sensitive account of how a digital platform might support low-carbon and multimodal commuting transitions at a suburban university campus.

The contribution is bounded by the limits of the proposed intervention. The platform does not alter suburban transport infrastructure, public transport frequency, land use, or pricing, and it does not control the services that it integrates. It operates within an existing network of institutional and transport partnerships and addresses the more circumscribed question of how digital design may support sustainable travel decisions among newly arrived international students at Monash University's Clayton campus. These boundaries distinguish a contextually grounded design intervention from the broader and unsupported claim that a digital platform could independently deliver systemic mobility change.

KEYWORDS

Mobility-as-a-Service (MaaS), sustainable mobility design, participatory design, international students, net-zero transition

Publications and conferences during enrolment

Yang, Chenlizhe, 2024. "Design workshop of the future Sustainable Mobility as a Service (S-MaaS) platform." Net zero showcase reveals Clayton living lab experiments in action, Monash Sustainable Development Institute, Melbourne, Australia. https://www.monash.edu/msdi/news-and-events/news/articles/2024/net-zero-showcase-reveals-clayton-living-lab-experiments-in-action

Yang, Chenlizhe, 2024. "Enhancing Sustainable Mobility: Participatory Design with International Student Drivers." Australian Transport Research Forum - PhD research student symposium, Melbourne, Australia. https://www.atrf2024.com/program/

Yang, Chenlizhe, 2025. "Enhancing Sustainable Mobility: Participatory Design with International Student Drivers." Intelligent Transport Systems - Mobility 2025 conference, Sydney, Australia. https://its-australia.com.au/events/mobility-2025/

Yang, Chenlizhe, 2025. "Enhancing Sustainable Mobility: Participatory Design with International Student Drivers." AutomotiveUI' 25 conference – Doctoral Colloquium, Brisbane, Australia.

Yang, Chenlizhe, 2025. "Enhancing sustainable campus mobility: a participatory design approach to co-develop early-concept of mobility-as-a-service digital platform with international students." The 2nd Asia Design and Innovation Conference, Shanghai, China. https://www.designsociety.org/publication/48735/enhancing_sustainable_campus_mobility_through_participatory_action_research_co-developing_a_maas_platform_with_international_students

Yang, Chenlizhe, 2026. "Enhancing Sustainable Mobility: A Participatory Design Approach to Co-Develop Early-Concept of the User-Interfaces of Mobility-as-a-Service Digital Platform With International Student Drivers." In Proceedings of the 19th Participatory Design Conference (PDC 2026), Vol. 2: Exploratory Papers and Doctoral Colloquium. (PDC 2026), 15–19 June 2026, Milan, Italy. ACM, New York, NY, USA. https://doi.org/10.1145/3789492.3796440

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This research was conducted as part of an Australian Research Council (ARC) Linkage-funded project, associated with the Net Zero Precinct at Monash University. I express my gratitude to the Net Zero Precinct team and collaborators for their receptiveness to this design-led enquiry within an applied precinct context, as well as for the practical assistance that facilitated the project's engagement with actual mobility restrictions and potential future in the Monash Clayton precinct.

I acknowledge Monash University Human Research Ethics Committee (MUHREC) approval for this research project (Approval No. 42308, Design workshop *of the future Sustainable Mobility as a Service (S-MaaS) platform*), which ensured that participant recruitment, workshop activities, interviews, data management, and reporting adhered to relevant ethical standards and participant welfare.

I also acknowledge Monash University Building and Property Division (BPD) for providing transport-related quantitative datasets that enhanced the design insights and contextualised the design process within quantifiable precinct circumstances. I also express gratitude to Monash Archives for granting access to historical campus documents and construction records, which enabled a more thorough baseline comprehension of the Clayton campus as a contextual mobility setting (refer to Appendix N. Monash University Archives agreement for copying of archival images).

I am grateful to my PhD peers and research colleagues from Monash Mobility Design Lab, for their continuous discussions, criticisms, and support, which were crucial in sustaining the work throughout field activities, critical analysis, and writing. I am also grateful to the broader community within Faculty of Art, Design and Architecture (MADA) for fostering a collaborative research atmosphere. I have felt a strong sense of belonging in MADA since I first joined as an undergraduate student in 2018, and this supportive environment has continued to shape my learning, practice, and research through to the completion of my PhD.

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A note on Terminology

When reviewing the policies and governance structures of various regions and countries, it becomes evident that the ***community***, ***neighbourhood***, and ***precinct*** have distinct descriptions or definitions. The boundary and differentiation of the three geographic units need further clarification. However, the descriptions of these terms may vary in different research projects depending on land use, population, or functionality within a specific field environment. Herein are generic definitions and descriptions of the key terms used throughout this exegesis, beginning with the three geographic units discussed above.

- **Community.** This term may describe the territorial and geographical context of a neighbourhood, town, or city. It is also commonly used to describe a group of people who share skills, interests, or characteristics (Gusfield, 1975; McMillan & Chavis, 1986).

- **Neighbourhood.** This term generally denotes the locality in which people live. Some studies define it as the walkable catchment surrounding local facilities (Barton et al., 2021).
- **Precinct.** In contrast to a neighbourhood, a precinct contains multiple local functions or dedicated purposes, which may include medical services, education, commerce, entertainment, and community facilities (refer to Chapter 2.2.4.1).

- **Monash Technology Precinct (MTP).** This National Employment and Innovation Cluster is the largest employment hub outside Melbourne's central business district (refer to Chapter 1.3.1.1). Monash University's Clayton campus, the university's largest campus, is located at the centre of MTP.

- **Building and Property Division (BPD).** This Monash University division is responsible for campus infrastructure, property, and transport planning. Its annual travel surveys and manual traffic counts provide the principal source of quantitative mobility data used in this study (refer to Chapter 2.8).

- **Net zero.** This term denotes reducing greenhouse gas emissions as close to zero as feasible and reabsorbing or offsetting residual emissions. It describes a dynamic balance between greenhouse gas emissions and carbon removal (refer to Chapter 1.1.1).

- **Electric vehicle (EV).** This term generally describes a vehicle powered by an electric motor. Four principal types are considered. Hybrid electric vehicles use electric

and petrol engines. Fuel cell vehicles use hydrogen, sometimes with a small battery or supercapacitor, to power an onboard electric motor. Battery electric vehicles require charging from an external source. Plug-in hybrid electric vehicles use rechargeable batteries supported by a petrol or diesel engine (Green Vehicle; National Transport Commission, 2022; AGL Next, n.d.).

- **Decarbonisation.** This term refers to the systematic reduction or mitigation of carbon dioxide emissions from primary energy use at the level of nations, organisations, or individuals (Ausubel, 1995; Wimbadi and Djalante, 2020).

- **Low Carbon Development (LCD).** This framework focuses on reducing the intensity of fossil fuel use across production and consumption in multiple economic sectors. It seeks to decouple economic growth from carbon dioxide emissions generated through production and consumption activities (Mirumachi et al., 2020; Mulugetta & Urban, 2010; and Nordensvärd, 2013).

- **Low Carbon Transition (LCT).** This term describes an evolutionary process that seeks to mitigate carbon dioxide emissions across sectors, including buildings, energy, and transport. LCT encompasses technical changes that improve energy efficiency and support a transition from conventional to sustainable energy sources. It also concerns everyday practices, markets, institutions, infrastructure, and economic and social relations (Bush et al., 2017; Castán Broto, 2012; F. W. Geels et al., 2016; F. W. Geels, 2018).

- **Mobility as a Service (MaaS).** This term refers to the integration of multiple public and private transport options within a single digital platform through which users may plan, book, and pay for multimodal journeys, generally through payment per use or a subscription. This study treats MaaS as a service design proposition and not solely as a technological product.

- **Net Zero Precinct (NZP).** This Monash University initiative seeks to achieve net zero emissions across the Clayton precinct and provides the institutional setting for the study.

- **Multimodal travel.** This term describes a journey completed using two or more transport modes in sequence, such as walking to a bus and cycling from the stop to campus. Modal shift denotes a change in the proportion of trips made by one mode in relation to another, commonly from private car use towards public, active, or shared modes.

- **Active travel or active mobility.** These terms describe human-powered movement undertaken for transport and not recreation, principally walking, cycling, and scooting.

- **Micromobility.** This term describes small, lightweight, low-speed vehicles used for short trips, including electric scooters, electric bicycles, and shared bicycles. These vehicles are often deployed to address first-mile and last-mile gaps.

- **International student.** For this study, the term refers to a student enrolled at Monash University on a student visa whose usual country of residence before enrolment was outside Australia.

- **Exegesis.** This term denotes the written component of a practice-based doctoral submission that situates, evidences, and reflects on the knowledge generated through the accompanying design practice.

- **Practice-based design research.** This term refers to research in which design practice constitutes the primary method of enquiry and the resulting artefacts operate as both outcomes and means of generating knowledge.

- **Participatory Action Design Research (PADR).** This study adopts PADR as its overarching methodological framework. The framework combines participatory design, action research, and design science cycles so that participants contribute to problem framing, ideation, and evaluation alongside the researcher (refer to Chapter 3.2).

- **Double Diamond Framework (DDF).** This four-phase model of the design process comprises Discover, Define, Develop, and Deliver. It contains two cycles of divergent exploration followed by convergent decision making and provides the organising structure for the study's design process (refer to Chapter 3.3).

- **Service blueprint.** This diagram maps a service across time and organisational layers, including user actions, frontstage points of contact, backstage activities, and supporting infrastructure. The study uses a service blueprint to specify the proposed MaaS commuting experience.

- **Boundary object.** This term refers to an artefact, such as a map, storyboard, or prototype, that is sufficiently shared to coordinate work across groups while remaining open to different interpretations. In this study, workshop materials operated as boundary

objects that mediated dialogue between participants and the researcher (Star & Griesemer, 1989).

- **Theory of Planned Behaviour (TPB).** This behavioural model proposes that intention, which is shaped by attitude, subjective norms, and perceived behavioural control, predicts behaviour. The study applies TPB to interpret students' commuting mode choices (refer to Chapter 2.6.4).

- **Persuasive design.** This term describes the deliberate design of digital systems to influence attitudes or behaviours without coercion through mechanisms such as goal setting, feedback, reminders, social comparison, and rewards.

- **Wayfinding.** This term denotes the process through which people orient themselves and navigate a physical environment with support from signage, landmarks, spatial legibility, and digital navigation aids.

- **Five stages of travel.** This analytical framework divides a commuting journey into five consecutive phases. It locates demands, frictions, and service interventions within the journey and supports the organisation of service blueprints and MaaS interface functions. The five stages are set out below.

    - **Pretrip phase.** This stage comprises decision making and preparation before departure. Commuters establish intentions, evaluate alternatives and constraints, and select transport modes. Constraints may include time, cost, safety, and weather. Within a MaaS framework, the phase may encompass journey planning, service booking, incentive prompts, and assessments of expected duration and carbon emissions.
    - **First-mile phase.** This stage extends from the place of origin, such as a home or accommodation, to the primary transport link. It may involve walking, cycling, public transport, ride sharing, or carpooling and may expose barriers associated with distance, safety, service uncertainty, or inadequate connectivity.

    - **Travel phase.** This stage covers movement between the principal points of a journey. It includes time spent in a vehicle or in transit and any changes made during the journey, when real-time data, disruption management, navigation, and confidence-building support may be most important.

    - **Transfer and arrival phase.** At this stage, commuters change modes or move through precinct entry points, including the bus loop, stations, arrival zones, shuttle stops, and car parks. Interchange conditions,

waiting, coordination, and transfer logistics may shape the experience through their effects on time, clarity, and safety.

- **Last-mile phase.** This final stage extends from the last connection to the destination on campus. It may involve walking, cycling, or micromobility and commonly requires wayfinding under accessibility and time constraints. These conditions may influence commuters' evaluations of a route and their willingness to repeat it.

The structure of exegesis

The exegesis is structured through the Double Diamond Framework (DDF), since it correlates the exegesis with the procedural rationale of the practice-based design research undertaken in this project (refer to Chapter 3.3). The DDF provides a legible narrative arc (divergence and convergence) that outlines the progression of enquiry from an initial open-ended exploration of a complex mobility setting towards specific design framing, followed by iterative development and the consolidation of design outcomes. By using the Discover, Define, Develop, and Deliver framework as the organising structure, the exegesis makes the project's progression comprehensible as a cohesive research argument, where each part builds upon its predecessor and laying the foundation for the subsequent round.

The DDF supports methodological clarity by emphasising knowledge generation through design practice and by connecting techniques, findings, and outcomes. This study uses empirical investigation, participatory engagement, and iterative prototyping as interconnected methods of enquiry. Across successive cycles of expansion and convergence, contextual insights are translated into design opportunities and then materialised through design artefacts. Framing the process through the DDF enables readers to trace how evidence was collected, interpreted, and applied to design decisions across phases.

The design process is described through the UK Design Council's DDF (2023), subject to an important qualification. The framework is used descriptively to characterise the course of the enquiry, not organisationally to determine the structure of the exegesis. Process models document how design enquiry unfolds over time, whereas an exegesis must communicate and justify knowledge claims through a coherent sequence of argument and evidence. The exegesis therefore does not reproduce the design process chronologically. Where fidelity to the chronology conflicts with the clarity of the scholarly argument, the expository requirements of the exegesis take precedence. This approach enables each chapter to develop a distinct analytical contribution while maintaining the coherence of the research narrative.

The consequence is a deliberately uneven correspondence, in which a single chapter may report activity belonging to more than one phase and a single phase may extend across several chapters. The mapping set out below states that correspondence explicitly, so that the process remains traceable notwithstanding the divergence.

Discover comprised the narrative literature review, the BPD quantitative data review, the site-based mobility environment audit, and field observation with reflexive journaling. These activities are reported in Chapter 2 and Section 3.3.1, with the resulting problem framing carried forward into Chapter 4.

Define comprised participatory design Workshop 1, a targeted literature review, the MaaS case review, and thematic coding of the workshop data. These are reported in Chapter 4, which additionally carries Discover-phase contextual material specific to the participant group.

Develop comprised participatory design Workshop 2, iterative physical and digital prototyping, and the synthesis of design directions into the proposition and its constituent interventions. This phase extends across Chapters 5, 6 and 7, the division reflecting an analytical separation between the co-prototyping investigation (Chapter 5), the design proposition (Chapter 6), and the articulation of that proposition at service level in the future (Chapter 7).

Deliver comprised the semi-structured subsequent interviews, evaluative refinement of the prototype, and development of the service blueprint. Chapters 7 and 8 present these activities together with the evaluation and limitations of the design research.

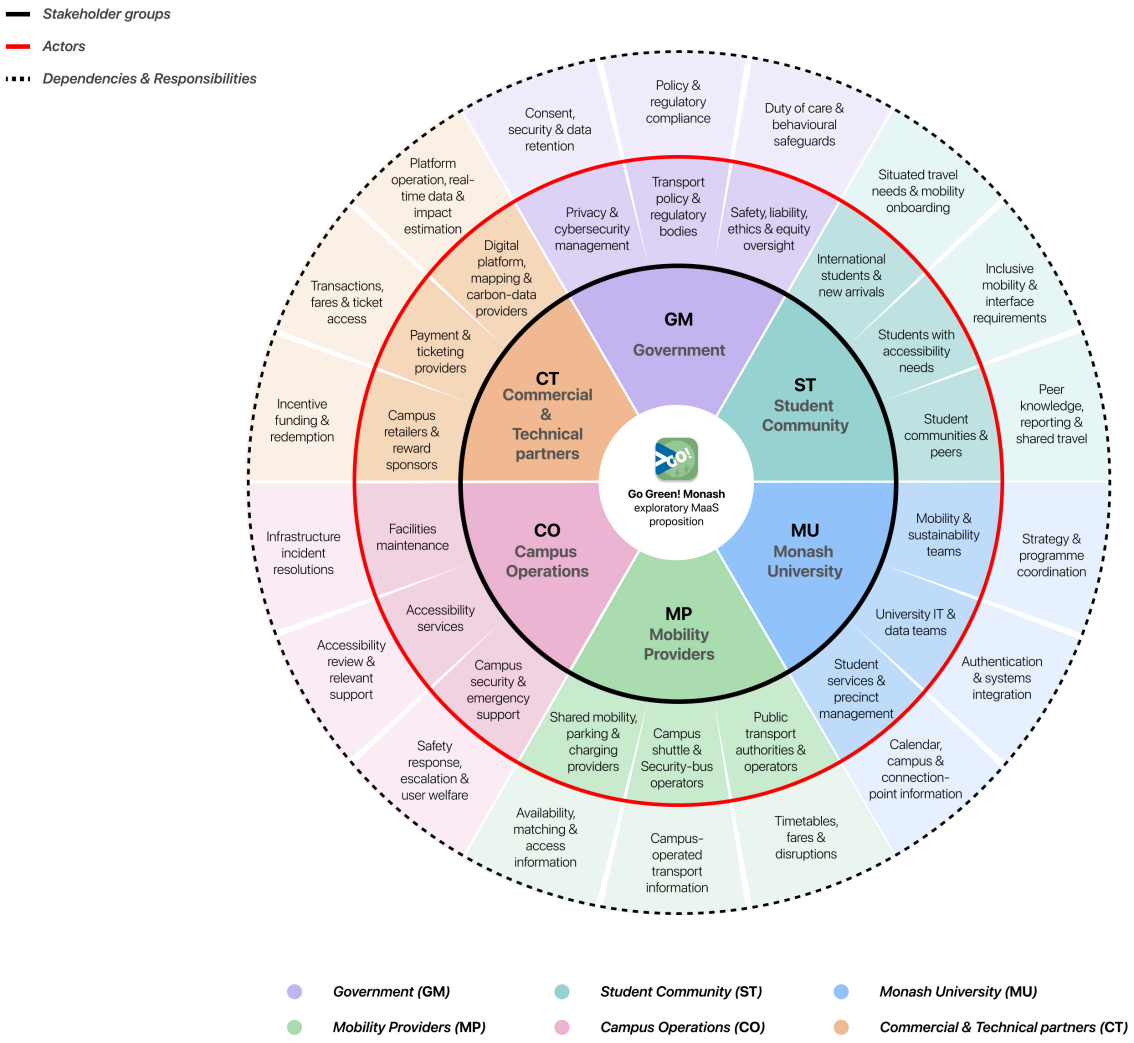
Who are the stakeholders in this research?

The primary empirical participants were international student drivers commuting to Monash University's Clayton campus. The study examined their experiences of local transport services, driving, and sustainable travel options. Their contributions informed the identification of mobility barriers and the iterative development and evaluation of the proposed *Go Green! Monash* platform and service blueprint.

This boundary distinguishes three groups. They comprise (i) research participants who contributed empirical evidence, (ii) target users for whom the design proposition was developed, and (iii) proposed implementation **actors** whose future involvement would be required if the platform progressed beyond the research prototype. The distinction clarifies the scope of the evidence and how international students informed the design outcomes. It also prevents the proposed platform from being interpreted as a validated MaaS system, a complete response to campus car dependency, or a technological solution to campus mobility. The platform is conceived as one component within a broader socio-technical ecosystem in which the capacity to reduce private car use also depends on local transport infrastructure, institutional policy, mobility service providers, and coordination among multiple stakeholders.

This participant-centred perspective reflects the practice-based and participatory character of the study. International student drivers commuting to Monash University's Clayton campus encounter a distinct combination of mobility challenges, including unfamiliarity with local transport systems, changing social networks, evolving travel routines, and the practical demands of studying and living in a suburban environment (refer to Chapters 2.5 and 4.5.2). These commuting experiences provided the empirical foundation for the participatory workshops, prototype development, and design evaluation. Participants' contributions shaped the features of the *Go Green! Monash* platform and informed the broader account of how a campus MaaS ecosystem might support more sustainable commuting practices.

The broader organisations and stakeholder groups shown in the system map, including university units, transport operators, technology providers, commercial partners, campus services, and governance bodies, were not substantially engaged as research participants. They are represented as proposed implementation actors and dependencies identified through the literature review (refer to Chapter 2.3), contextual analysis (refer to Chapter 2.8), and reflection on the requirements of the design outcome (refer to Chapter 7.1). Their inclusion supports consideration of a future implementation strategy for the MaaS proposition but does not imply that they formed the empirical focus of the enquiry (refer to Chapter 9.6).


Stakeholder groups
Actors
Dependencies & Responsibilities
GM
Government
ST
Student Community
CT
Commercial & Technical partners
CO
Campus Operations
MP
Mobility Providers
MU
Monash University
Go Green! Monash
exploratory MaaS proposition
Policy & regulatory compliance
Duty of care & behavioural safeguards
Consent, security & data retention
Situated travel needs & mobility onboarding
Platform operation, real-time data & impact estimation
Transport policy & regulatory bodies
Privacy & cybersecurity management
Safety, liability, ethics & equity oversight
Inclusive mobility & interface requirements
International students & new arrivals
Digital platform, mapping & carbon-data providers
Transactions, fares & ticket access
Payment & ticketing providers
Students with accessibility needs
Peer knowledge, reporting & shared travel
Incentive funding & redemption
Campus retailers & reward sponsors
Student communities & peers
Mobility & sustainability teams
Strategy & programme coordination
Infrastructure incident resolutions
Facilities maintenance
University IT & data teams
Accessibility services
Authentication & systems integration
Accessibility review & relevant support
Student services & precinct management
Campus security & emergency support
Calendar, campus & connection-point information
Shared mobility, parking & charging providers
Campus shuttle & Security-bus operators
Public transport authorities & operators
Safety response, escalation & user welfare
Timetables, fares & disruptions
Availability, matching & access information
Campus-operated transport information
Government (GM)
Student Community (ST)
Monash University (MU)
Mobility Providers (MP)
Campus Operations (CO)
Commercial & Technical partners (CT)

1. Introduction

CHAPTER OVERVIEW

This chapter establishes the background of the research project by explaining why transportation matters in the context of sustainability and urban transformation. It further delineates the essential role of mobility within university communities, where commuting patterns influence environmental outcomes and student experiences. The chapter frames the research problem by emphasising the role of road transportation in carbon emissions and positioning the Clayton Precinct as an experimental location for a sustainable transition. Within the framing, it defines the boundaries of the precinct as the research field and identifies the potential opportunities for enhancing sustainable transportation design practice. The chapter ends with the structure of the exegesis, which shows how the next chapters will be organised.

1.1. Background

1.1.1. Issues of climate change

With the rapid development of modern society, from the first and second industrial revolutions to the global industrialisation and modernisation trend in the new century, transportation road networks and internal combustion engine vehicles have become the most essential core in the construction of modern cities (Newman, 2015). These advancements facilitate the movement of people and goods, as well as significantly influence urban planning and economic growth. However, the rapid acceleration of global industrialisation has led to significant environmental challenges, including the intensification of extreme weather and the escalation of greenhouse gas emissions, both of which contribute to global warming and pose severe threats to ecological stability.

In response to these pressing climate change issues, numerous countries and international organisations, particularly those under the United Nations framework, have since the 1990s initiated comprehensive strategies to mitigate environmental degradation. The United Nations Framework for Climate Change Convention (UNFCCC) reached the Paris Agreement (United Nations, 2015a) in 2015, which set targets for keeping the increase of human-induced global warming to well below 2°C and to continue pursuing efforts to limit warming to 1.5°C. In addition, it aims to address the net zero carbon dioxide emissions target by around 2050. In 2015, all United Nations Member States proposed "the 2030 Agenda for Sustainable Development" with 17 sustainable development goals (SDGs) to address the requirements of decarbonisation for people worldwide (see Figure 1.1).

The United Nations' Sustainable Development Goals (UN SDGs) encompass an extensive array of societal challenges. These primarily involve the following thematic domains, including the promotion of health and well-being (SDG 3); the attainment of affordable, dependable, and sustainable energy sources (SDG 7); the cultivation of sustainable economic growth and the

fostering of productive employment (SDG 8); the enhancement of infrastructure resilience (SDG 9); the construction of inclusive, safe, resilient, and sustainable urban environments (SDG 11); the cultivation of responsible patterns of consumption and production (SDG 12); the mitigation of climate change (SDG 13); the safeguarding, restoration, and sustainable utilisation of terrestrial ecosystems (SDG 15); and the rejuvenation of global partnerships in support of sustainable development (SDG 17) (United Nations, 2015a).

Net Zero describes the balance achieved when the amount of Greenhouse Gas (GHGs) emitted into the atmosphere equals the amount removed, with any remaining emissions re-absorbed by natural environments, such as forests and oceans (United Nations, 2023). The greenhouse gases that are reported under the National Greenhouse and Energy Reporting Scheme (NGER) include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), sulphur hexafluoride (SF6) and specified kinds of hydrofluorocarbons and perfluorocarbons (NGER, 2023). Carbon dioxide (CO2) emissions are the biggest contributor to Greenhouse Gas emissions, comprising approximately 68% of total emissions in Australia (Commonwealth of Australia, 2023) and over 75% worldwide (EPA, 2021) (see Figure 1.2). Furthermore, carbon dioxide emissions arise from the extraction and burning of fossil fuels, wildfires, and natural processes (NASA, 2023). Due to the impact of COVID-19 in 2020, there was a notable and precipitous reduction in global carbon dioxide emissions. Nevertheless, in the subsequent period following the mitigation of the pandemic's effects, the amount of carbon dioxide emissions from energy combustion and industrial processes returned and even reached the highest position on a global scale (IEA, 2023).



Figure 1.1. The sustainable development goals (United Nations, 2015b)

GHG emissions may be attributed to three main categories, including imports (see Figure 1.3), energy purchased for daily life, consumption of business activities and the support of industrial chains (Seto et al.. 2021). Bonsu (2020) similarly argues that addressing the issues of GHG emissions requires clarification of the relevant factors, for instance, manufacturing infrastructure, distribution, or sales activities, and energy use. At the same time, Fankhauser et al. (2022) break net-zero theory into seven attributes based on three primary references, which are the urgency of "zero", the integrity of "net", and consistency with sustainable development objectives (see Figure 1.4).

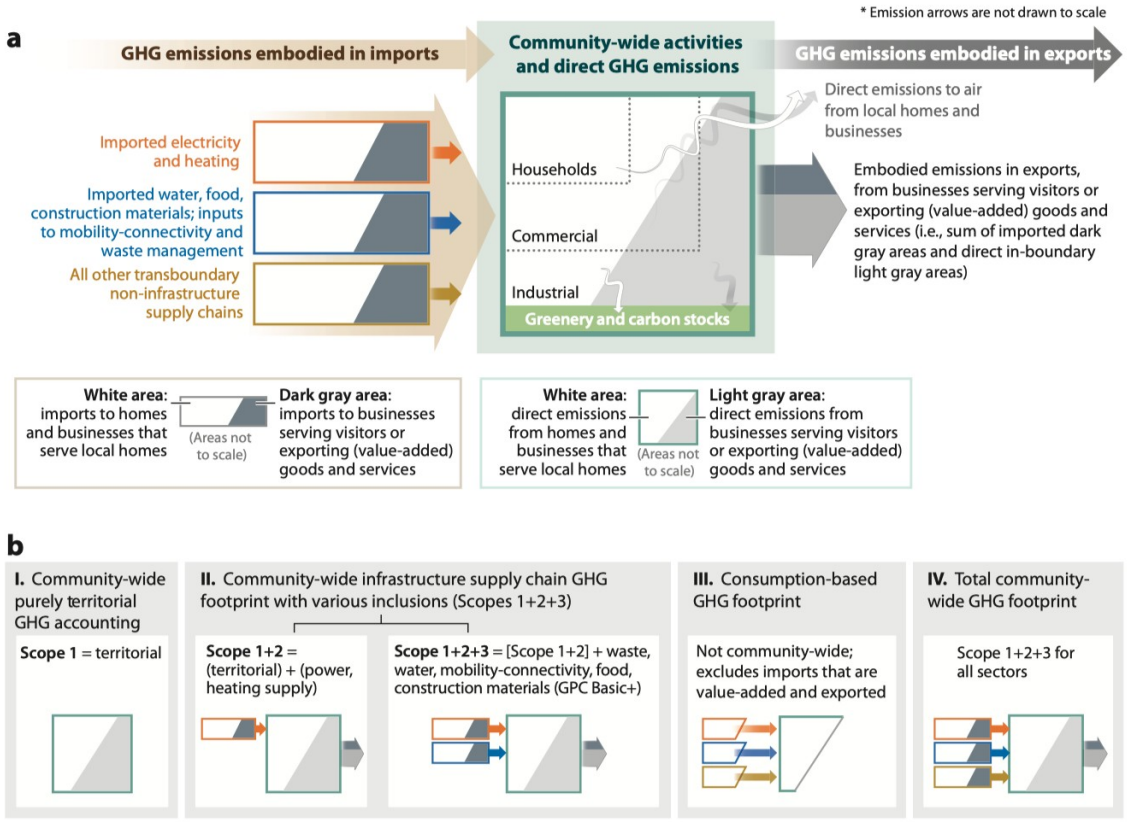


Figure 1.2. The flow map (a) and components (b) of urban GHG (Seto et al.. 2021, p. 383)

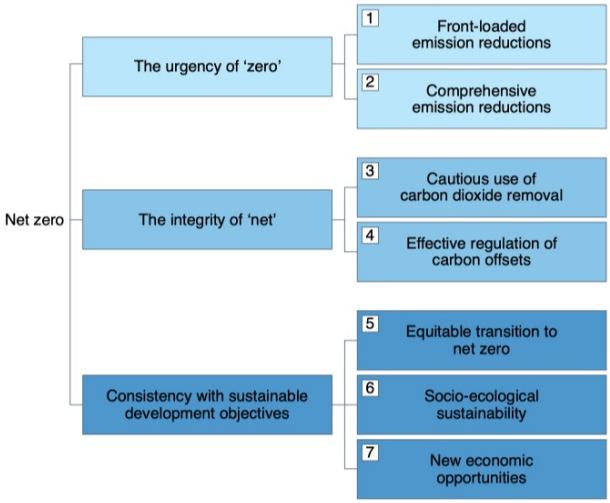


Figure 1.3. Attributes of net zero as a frame of reference (Fankhauser et al., 2022, p. 18)

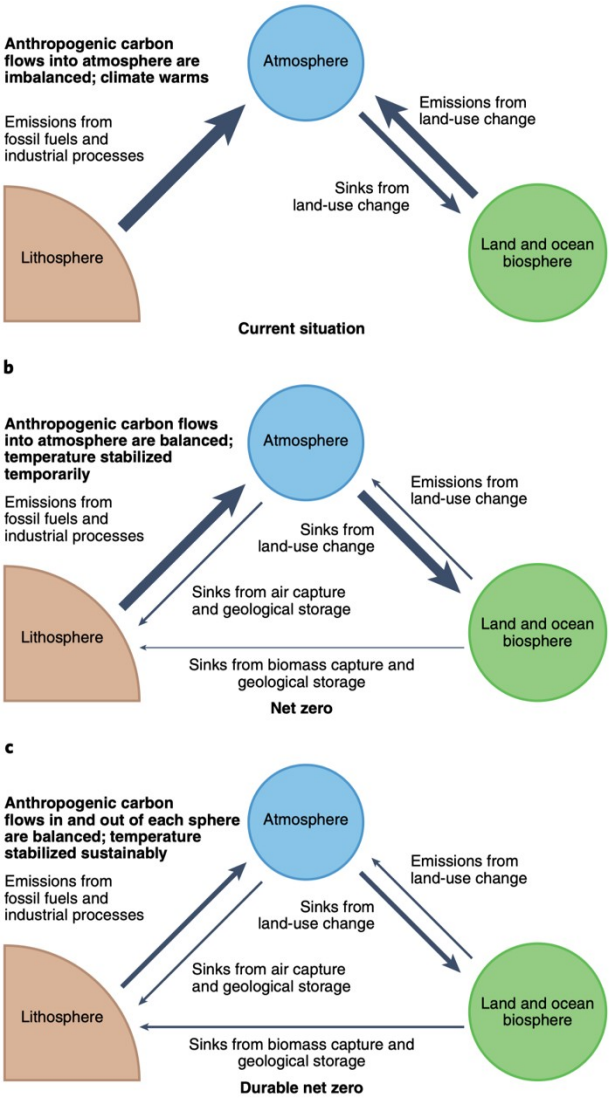


Figure 1.4. Net-zero balance of carbon emissions and removals in three phases, including current situation, net zero, and durable net zero (Fankhauser et al., 2022, p. 16)

The realisation of the net-zero concept necessitates interdisciplinary collaboration. Fankhauser et al. (2022) emphasised the importance of aligning this concept with equitable net-zero transitions, socio-ecological sustainability, and a comprehensive range of financial support mechanisms to achieve zero emissions. Seto et al. (2021) further highlight the necessity of engaging in multidirectional city-level cooperation, including supply chain management and urban planning, to effectively attain net-zero emissions goals. Additionally, Wimbadi and Djalante (2020) underscore that achieving the net-zero target requires the continued implementation of key activities encompassing mitigation, adaptation, and conservation of greenhouse gas sinks and reservoirs, as well as the utilisation of market- and non-market-based approaches to achieve mitigation outcomes through Nationally Determined Contributions (NDCs). Rogelj et al. (2021) have visually represented this concept through two diagrams (refer to Figure 1.5) that illustrate the trajectory of global greenhouse gas emissions before and after the realisation of net-zero carbon dioxide and overall greenhouse gas targets.

To facilitate the progression towards achieving net-zero emissions, a comprehensive and well-structured framework is fundamental to guide the interdisciplinary decarbonisation process. In this regard, several critical components of decarbonisation may be identified (Bunning et al., 2013; Seto et al., 2021; Rogelj et al., 2021), encompassing the key elements set out below.

1. Evaluation of Carbon Footprint (CF), as the initial step, involves systematically assessing the existing carbon footprint within the defined boundaries (Mulrow et al., 2019; Yañez et al., 2020; Bannour et al., 2021). The scope-based CF accounting standards (scope 1, scope 2, and scope 3) were established by the World Business Council for Sustainable Development (WBCSD) and the World Resource Institute (WRI) to comprehensively examine the GHG emissions from human activities (Onat et al., 2014; Kucukvar et al., 2015; Radonjič & Tompa, 2018). The three scopes of greenhouse gas emissions may be distinguished as follows. ***Scope one*** emissions are represented by the emissions from operations that are owned or controlled by the reporting companies or organisations. Scope two emissions describe emissions from the generation of purchased or acquired energy, including electricity, steam, heating, or cooling by the reporting entities. ***Scope three*** emissions include all indirect emissions except for scope two, such as emissions from sold products, the use of sold products, transportation, or distribution (Greenhouse Gas Protocol, n.d.).
2. Mitigation of Greenhouse gas emissions represents a pivotal element in the structure of the decarbonisation process. Addressing the impact of climate change necessitates contributions from interdisciplinary fields, encompassing but not confined to domains such as energy efficiency in various industries (Li et al., 2016; Talaei et al., 2019; Akdag & Yıldırım, 2020), residential and commercial buildings (Subramanyam et al., 2017; Zhong et al., 2021; Sandberg et al., 2021), urban transportation (Woodcock et al., 2009; Grischkat et al.,

2014; Chang et al., 2021), and agriculture (Shakoor et al., 2021; Bin et al., 2022).

3. Balancing external emissions requires addressing emissions originating from sources outside of the reporting companies or organisations. This external carbon balance can be achieved through various measures, including the creation of natural ecosystems within the biosphere to absorb or offset emissions, as suggested by Bunning et al. (2013).

contribution. To achieve the goal of net zero and take action to mitigate global warming and extreme weather events, the implementation of deep decarbonisation in urban areas will play an essential and significant role.

Transportation is a vital element of modern society, influencing economic development, social interaction, and environmental impact (Epicoco & Falagario, 2022; Heidari et al., 2024; Kang & Lee, 2019; Merchan et al., 2019).

In conclusion, Net Zero is a scientific concept (Fankhauser et al., 2022) that requires multidisciplinary innovation and

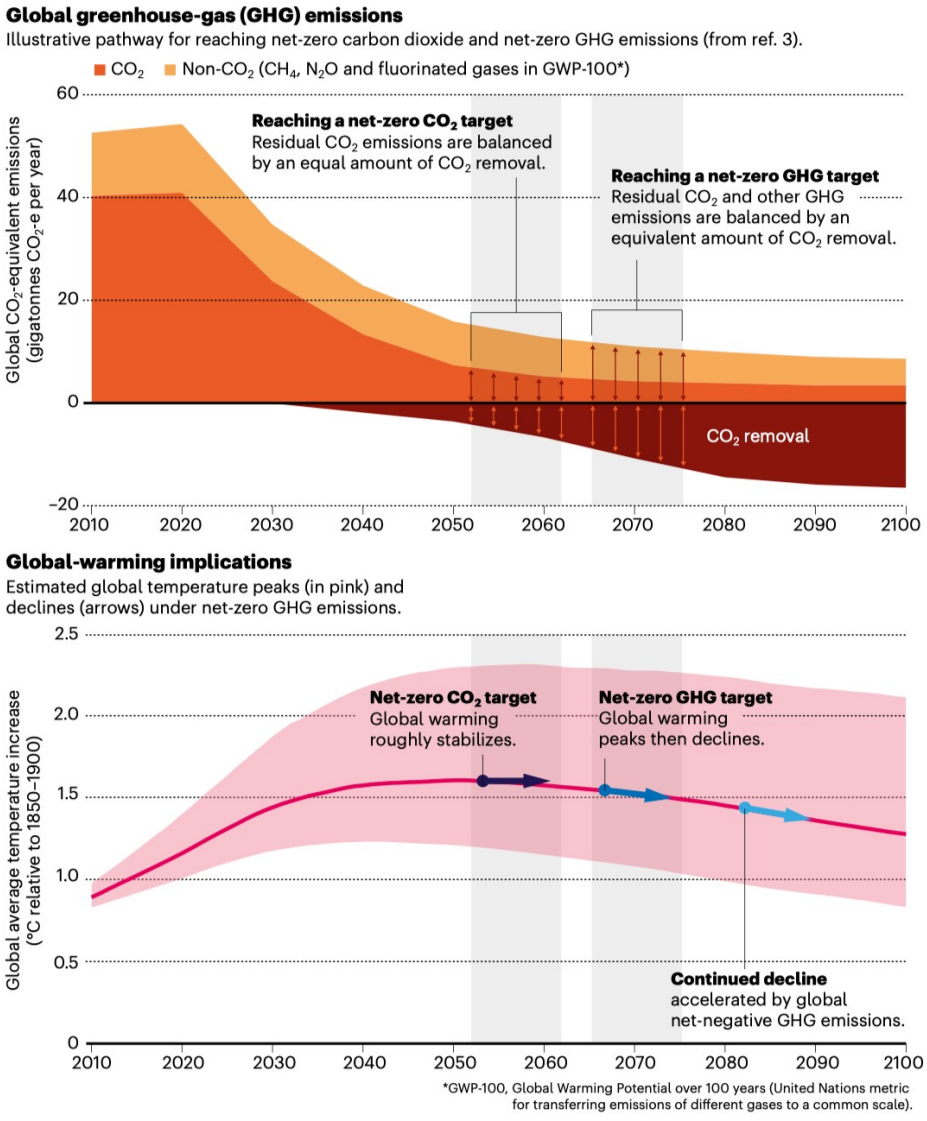


Figure 1.5. Global greenhouse gas (GHG) emissions and Global-warming implications (Rogelj et al., 2021)

Transportation can be considered a facilitator of mobility for people and goods, for instance, access to jobs and markets (Croce et al., 2019), or enhancing connectivity and accessibility (C. Ferrari et al., 2019). It is also a generator of externalities for environmental impact (Feitelson, 2002), social and economic costs (Cavallaro, 2018; D'Alfonso & Catalano, 2021; Macharis et al., 2012), and urban land use (Chaudhry et al., 2025; Loreto et al., 2025), positioned at the convergence of human behaviours, infrastructure supply, and regulatory frameworks (Macharis et al., 2012; Mattauch et al., 2016). The International Energy Agency (IEA) reports that, by 2022, the transportation sector accounted for approximately 25% of energy-related carbon dioxide (CO_2) emissions worldwide (see Figure 1.6). Road transport constituted the largest single contributor to that share (Minarta & Ko, 2024; Tang et al., 2023). However, the transportation system is an essential contributor that facilitates accessibility, inclusion, and participation in urban life.

The significance of transportation transcends environmental issues. Mobility influences the extent to which people might access education, employment, healthcare, and cultural activities. In both urban and rural environments, transportation infrastructures and services significantly influence the reinforcement or mitigation of socioeconomic inequalities. For instance, inadequate public transit services may lead to "forced car ownership", making people or families depend on private cars despite financial or environmental costs owing to absent or unreliable local mobility alternatives (Mattioli, 2017). Consequently, transportation constitutes a social and political domain as well as a technical and logistical system, and it influences the functioning and sustainable development of communities.

At the same time, transportation systems reflect cultural values and everyday practices. The choices of commuting

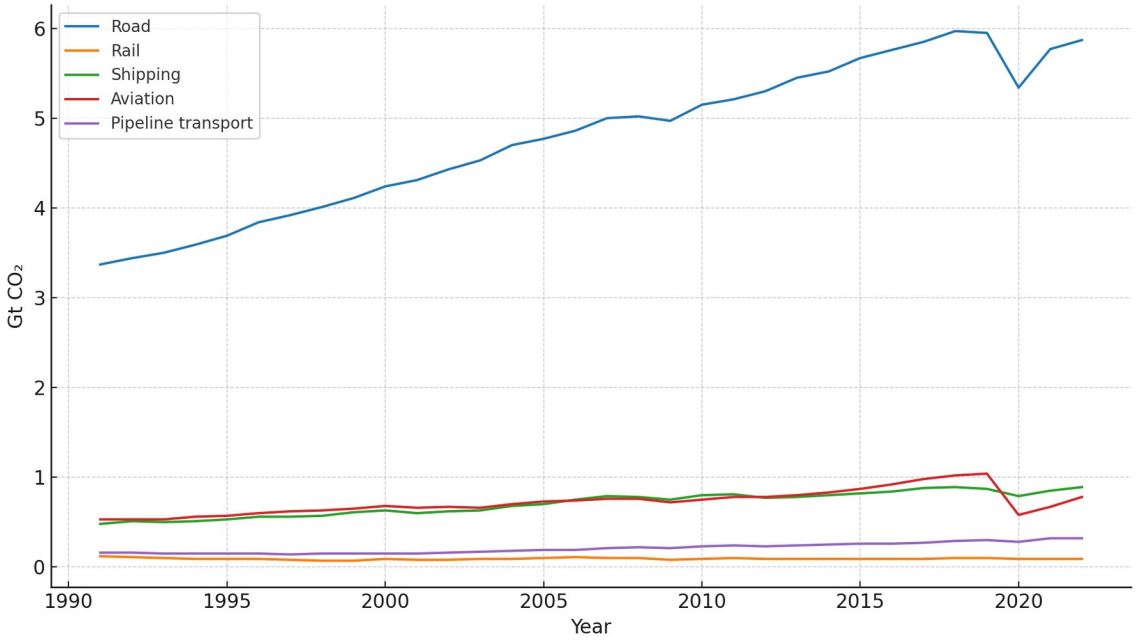


Figure 1.6. Global carbon dioxide emissions from the transportation sector from 1990 to 2022, redrawn from (IEA, 2023).

modes are often influenced by perceived convenience, cost, and safety, as well as by habit, identity, and social norms (Schwanen et al., 2011a). Everyday mobility patterns appear substantially resistant to change, even where sustainable alternatives are available and accessible, owing to the embeddedness of broader socio-technical systems of infrastructure, governance, and behavioural norms. Understanding transportation requires consideration of macro-level changes, such as policy transitions towards net zero emissions, and micro-level behaviours, including daily travel decisions.

This study emphasises transportation due to its environmental implications and its specific role in shaping the experiences of international students in suburban university contexts. The design of the mobility service system for the university community needs to acknowledge transportation as an essential domain of sustainable transition, where interventions can generate ecological and social benefits.

1.2. Transportation in university communities

Transportation systems in university communities are essential to campus life, especially influencing students' daily commuting, access to their educational destinations, and general wellbeing. Universities typically operate as comprehensive socio-spatial contexts where mobility requirements are varied, time-dependent, and shaped by the institutional, infrastructural, and cultural attributes of the campus and its adjacent metropolitan or suburban settings. Mobility patterns within university environments also diverge from those of the broader population, attributable in part to the demographic makeup of students, the spatial arrangement of campuses, and the temporal dynamics of academic schedules (Balsas, 2003; Delmelle & Delmelle, 2012).

Universities are consistently identified as significant trip generators, contributing substantial daily traffic flows that place considerable strain on local transportation systems (Alogdianakis et al., 2024a; J. Kim & Lee, 2023; Matas-Monroy et al., 2025a; Rodrigues da Silva et al., 2024; Simonn et al., 2025a). These higher education institutions attract large numbers of students, faculty, staff, and visitors, resulting in high volumes of trips to and from the campuses, which can lead to congestion, reduced air quality, noise pollution, and increased accident rates in surrounding areas (Lodi et al., 2024; Ruiz-Padillo & de Oña, 2024; Stein & Rodrigues da Silva, 2018). The effect of high volume traffic is especially substantial in university areas, where the daily routines of academic communities significantly influence urban mobility, particularly during peak times before and after classes (Matas-Monroy et al., 2025b; Sarangi & Manoj, 2020).

Large suburban university campuses, particularly in Australia, the UK, and North America, are frequently located in car-oriented settings with limited public transportation connectivity or coverage, leading to elevated private car use by

students and staff in recent decades (Gatersleben & Appleton, 2007; Shannon et al., 2006). Conversely, urban campuses situated in high-density, transit-accessible environments generally promote more sustainable transportation patterns among students and staff, including walking, cycling, and public transit, which are more prevalent in their travel behaviours (Alogdianakis et al., 2024b; Bai et al., 2022; Pérez-Neira et al., 2020). The geographical location of a university therefore appears to exert a substantial influence on the transport mode choices of students, highlighting the necessity of integrating campus development with sustainable transport systems for suburban university campuses.

Higher education institutions increasingly frame their sustainability commitments around lowering students' dependence on private cars, recognising that everyday travel behaviour is important in campus-related carbon emissions (see Figure 1.4). University precincts serve a pivotal function in comprehensive urban decarbonisation agendas, as they embody regulated settings where policy interventions, infrastructure enhancements, and behavioural modification programmes can be systematically coordinated and assessed on a large scale (Hickman & Banister, 2014a).



Figure 1.7. A 1927 Detroit Free Press cartoon illustrating student responses to a campus vehicle ban and its unintended policy effects (source, University of Michigan, Bentley Library).

1.3. The problem framing

1.3.1. Research site

1.3.1.1. Boundaries of the Clayton Precinct

Prior to examining the sustainable transition experiment at the Clayton Precinct, it is essential to delineate the definitions and parameters of the precinct pertinent to the research project. Three definitions of the Clayton precinct are relevant here, namely the administrative unit, the master plan of the Clayton activity centre precinct, and the Monash Technology Precinct.

Clayton (postcode 3168, 19 kilometres south-east of Melbourne's CBD) represents an administrative unit that encompasses 788 hectares within the city of Monash, with a population of 18,988 in 2021, and a population density of 24.77 persons per hectare (Australian Bureau of Statistics, 2021a). The suburb of Clayton contains public service institutions, public transportation, neighbourhoods, educational institutions, and local activity centres.

The second definition, the Clayton activity centre precinct, refers to a master plan project by the City of Monash (2020). The boundary of this precinct extends approximately one kilometre from the centre of Clayton railway station. It encompasses a mix of land uses, including retail, employment, education, community, health, and open space (refer to Figure 1.5). The project aims to establish a framework for future-oriented mixed land use in an emerging suburb, including employment opportunities, housing, transportation infrastructures, and retail and commercial services.

The Monash Technology Precinct (MTP) is the central hub within the Monash National Employment and Innovation Cluster (refer to Figure 1.6), serving as a catalytic centre. Located within the suburb of Clayton, Victoria, MTP integrates global innovation initiatives with a community of researchers, entrepreneurs, and organisations (Monash University, n.d.a). The Monash University Clayton campus is situated at the heart of MTP and serves as the focal point of the ongoing research project. The MTP has no formally defined boundary. The Clayton campus is the focus of this research project; in the following chapters, the terms "Clayton Precinct" and "Clayton Campus" refer specifically to the Monash University Clayton campus.

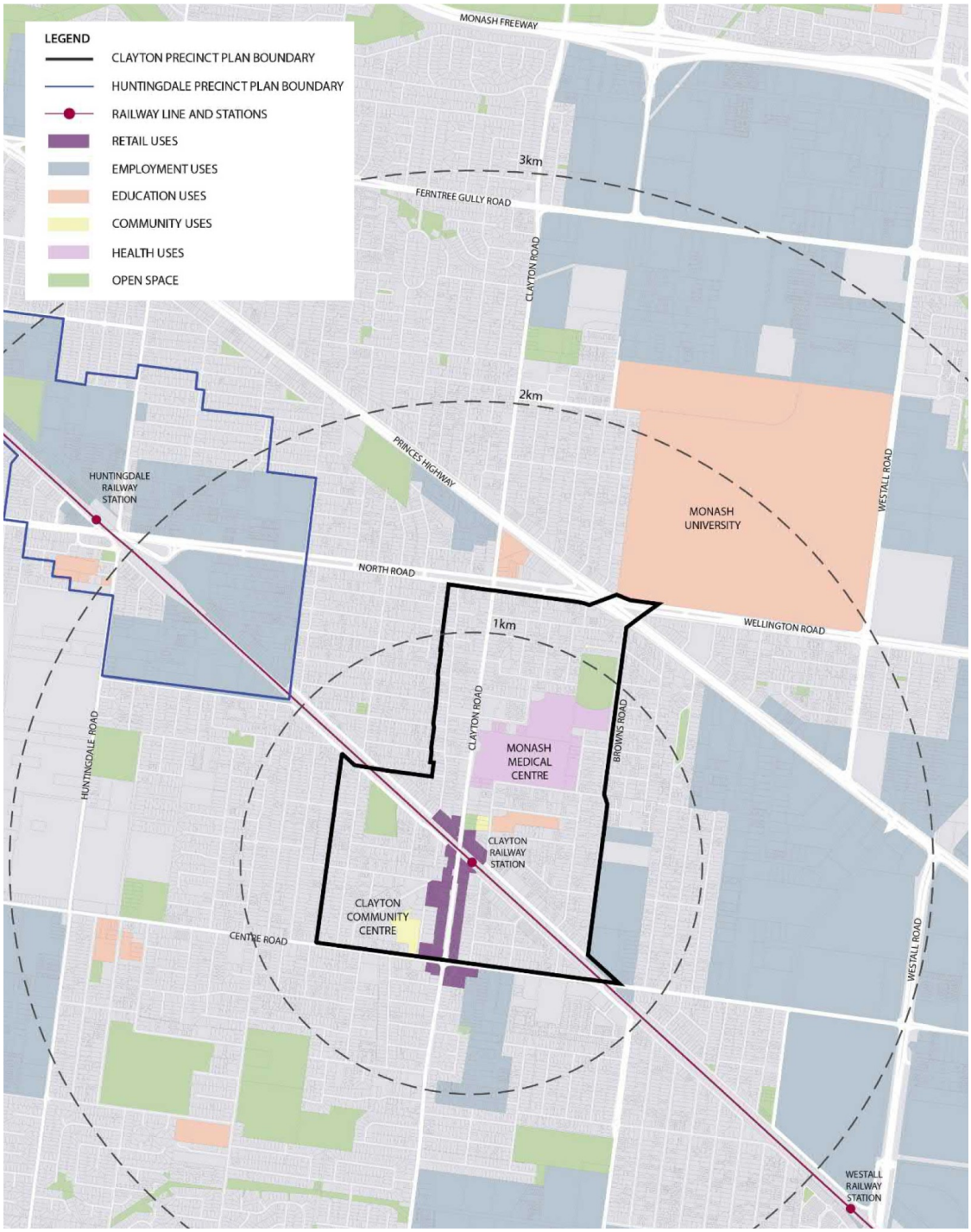


Figure 1.8. The Clayton Activity Centre Local Context (City of Monash. 2020. P.17)

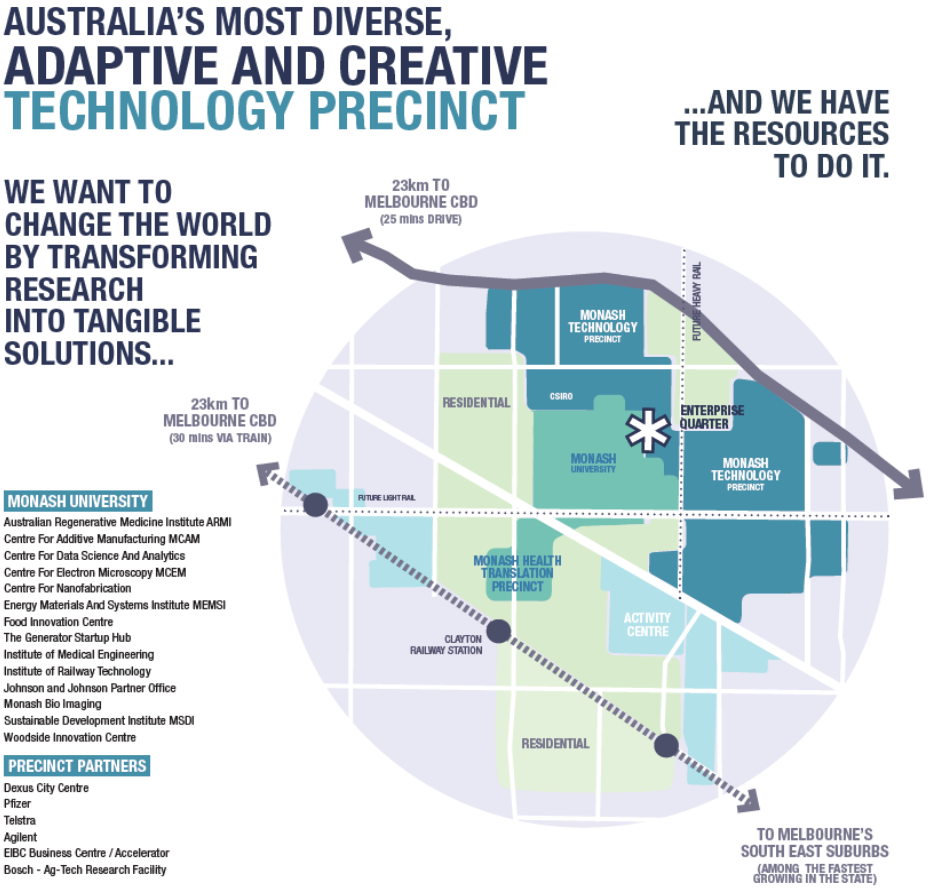


Figure 1.9. Map of Monash Technology Precinct (Monash University, n.d.a)

1.3.1.2. Opportunities for sustainable mobility transition at the Clayton Precinct

The Clayton Precinct, as an education precinct centred by the Monash Clayton campus, is located in the suburban region of Melbourne, Australia. The Clayton Precinct faces challenges regarding inadequate and unreliable public transport services and a lack of well-established infrastructure to support active modes of campus access (Sharp et al., 2023). These are highlighted barriers to adopting sustainable transportation modes for Clayton commuters. Unlike metropolitan campuses, which typically benefit from better public transport services and infrastructure that support active commuters (Rybarczyk & Gallagher, 2014), suburban campuses face significant challenges in achieving sustainability transitions. Examples include the Autonomous University of Barcelona (UAB) in the metropolitan region of Barcelona (& Domene, 2010); Najran University in the eastern outskirts of Najran city, Saudi Arabia (AlOuhtani, 2022); Özyegin University in Istanbul, Turkey (Göcer Ö & Göcer K, 2019); and the Democritus University of Thrace in Xanthi, Greece (Kotoula et al., 2018).

The university campus is a hub for various human activities and employment opportunities, resulting in significant journeys to and from the area (Nelson et al., 2023). This has a profound socio-environmental impact on both the universities and the surrounding regions, characterised by a substantial reliance on

automobiles (Geller, 2003) and the consequent challenges of traffic congestion, noise pollution, and GHG emissions (Dell'Olio et al., 2014). The university campus assumes a pivotal and pioneering role in a geographical location with clearly defined boundaries for the experimentation and assessment of sustainable mobility solutions, as well as the prospective dissemination of cutting-edge knowledge and technologies to an expanded range of urban areas (Tolley, 1996; Pitsiava-Latinopoulou et al., 2013; Tormo-Lancero et al., 2022). In recent years, many sustainable transition research projects and experiments have been conducted in the context of university campuses. Such studies have addressed Travel Demand Management (TDM) (Wang et al., 2012; al., 2020), travel behaviour change and mode choice (Balsas, 2003; Kotoula et al., 2018; Pedreira Junior et al., 2022), and travelling attitudes (Susilo et al., 2010; Shafi et al., 2020). Evidence from these scholars shows that sustainable transportation applied in the context of university campuses requires a systematic roadmap or framework that integrates measures of policy-making, infrastructure design, promotion, and long-term monitoring and evaluation (Pitsiava-Latinopoulou et al., 2013; Papantoniou et al., 2019; Tormo-Lancero et al., 2022).

As discussed in the section on the car-dependent context in Australia (Cui et al., 2017; Porter et al., 2018; also refer to Figure 1.7), driving has been an established and enduring practice at the Clayton campus, tracing its origins to the opening of Monash University in 1961 (refer to Figure 1.8 & Figure 1.9). Nowadays, driving is still the most popular travelling option for students and staff to access the Clayton campus. Based on the transport survey conducted by the Monash BPD database in 2022, it was found that approximately 36 percent of students and staff opted for private vehicle usage to commute to the Clayton campus. Additionally, a significant proportion of vehicles used for transportation to campus are single-occupancy automobiles, leading to a notable increase in average per-person carbon emissions for the journey to the university.

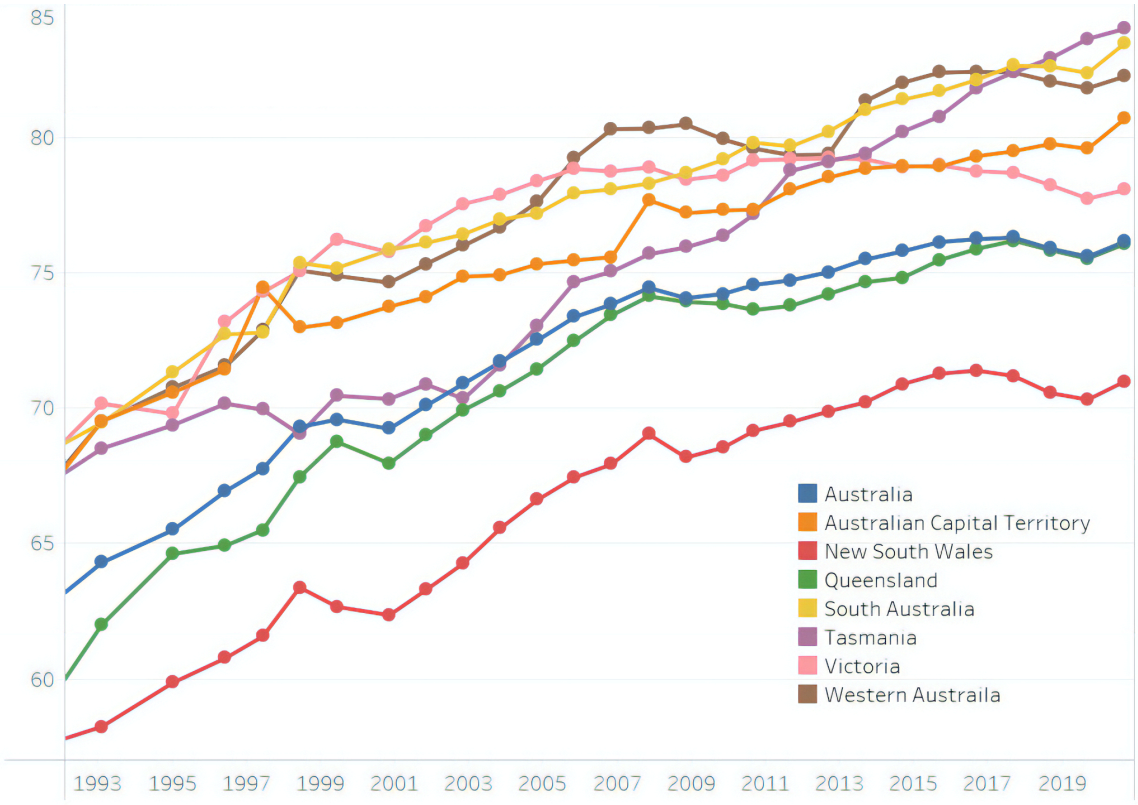


Figure 1.10. Passenger cars per 100 residents aged 18-84 (Chart made by Charting Transport, n.d.; Data source: Australian Bureau of Statistics, 2021b). The chart shows the growing trend of passenger car ownership from 1993 to 2019 in all states of Australia.



Figure 1.11. Menzies building from the south car park, with Law building at left (Monash University Archives, IN7077)



Figure 1.12. Arts car park (Monash University Archives, IN9232)

The reframing and redesign of mobility is one of the most notable components of the process of the zero-emission transition in the Clayton Precinct. Driving, which remains the option most commonly chosen by students and staff to access the Clayton campus (refer to Chapter 2.8), is the largest carbon dioxide contributor in the transport sector, accounting for 18% of national carbon dioxide emissions in Australia (Building and Property Division of Monash University, 2022; Commonwealth of Australia, 2022; National Transport Commission, 2021). Over-reliance on car driving is a noticeable barrier to sustainable transition, represented on the Clayton campus. In 2022, around 7000 staff and students parked at the Clayton campus (Sharp et al., 2023). Evidence from the campus access survey shows increased private car use and decreased use of sustainable transport modes from the group of staff and students in 2022 (Monash University, 2022).

To achieve the target of zero-emission campuses in Australia by 2030, Monash University established a net-zero transport strategy by the end of 2021, which aims to encourage over 80 percent of staff and students to access the Monash campuses through sustainable transport modes. The objectives of Monash's net zero transport strategy are to eliminate, reduce, and offset greenhouse gas emissions from transport. This is achieved by integrating organisational policy, behaviour change incentives, infrastructure developments, and fleet electrification (Monash University, 2022). Monash University integrated a campus access strategy to reduce GHG emissions. This strategy focuses on encouraging the switch from single-occupancy vehicles, influenced by personal choices, to sustainable alternatives, for instance, public transport, campus shuttle buses, walking, or cycling (Monash University, 2021).

As previously mentioned, the precinct serves multiple functional purposes, including commercial services, retail, public transportation, hospitals, entertainment, and education. Compared with the conventional neighbourhood design, the planning or regeneration of a precinct needs to consider two or more dimensions of the identified areas with different detailed purposes (refer to Figure 1.10). For example, the precinct design needs to address urban structure, the public realm, zoning, and land use, the transportation network, and built form (State of Western Australia, 2020). Hence, the reconfiguration or enhancement of the transport infrastructure system within an activity centre precinct, in conjunction with collaboration across various domains such as urban planning, policy advocacy, energy management, and building renovation, has the potential to facilitate the progression of the precinct towards achieving a net zero emissions future.

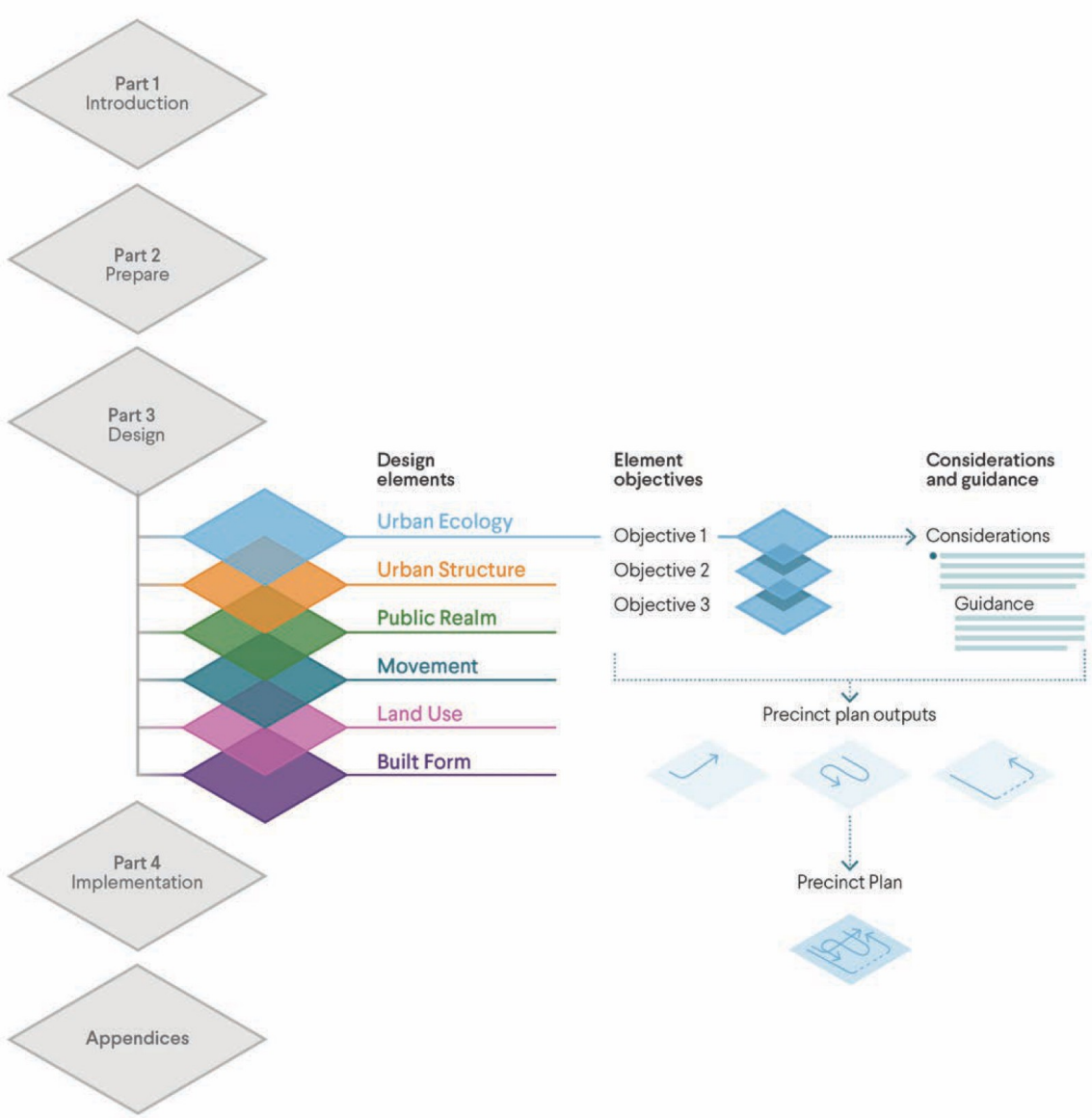


Figure 1.13. The structure of precinct planning (State of Western Australia. 2020)

The systematic transition towards a zero-emission paradigm for the Clayton precinct appears complex but attainable. As mentioned above, Monash University has set the net zero goal by 2030, coupled with a holistic and multifaceted approach to future-oriented precinct planning. The experiment of sustainable transition at the Clayton precinct could provide a potential roadmap for other institutions or precincts in similar geographical and environmental conditions worldwide. By promoting and shifting people's daily mobility behaviours and fostering cross-disciplinary collaborations, the Clayton precinct might demonstrate a forward-thinking approach to mitigate climate change challenges at a micro-scale level, specifically within an educational precinct.

1.3.2. Mobility as a Service (MaaS) and international students

Mobility-as-a-Service (MaaS) has emerged as an integrated mobility service concept which combines public transport, active modes, micro-mobility, shared vehicles, and real-time information through a single digital interface

(Heikkilä, 2014). It integrates planning, booking, and navigation into a cohesive service ecosystem, diminishing the fragmentation that characterises contemporary transportation systems. MaaS is increasingly acknowledged as a user-centric solution that simplifies multimodal travel, reduces cognitive load, and facilitates sustainable travel behavioural change (Jittrapirom, Caiati, Feneri, Ebrahimigharehbaghi, Alonso-González, et al., 2017; Sochor et al., 2018). The emphasis of MaaS on personalisation, adaptability, and ease of access may therefore make it a well-suited model for university communities, where mobility demands are varied, time-sensitive, and significantly influenced by dynamics of academic schedules. The implementation of MaaS or similar concepts in university communities is seen as an emerging opportunity to promote sustainable mobility transition, reduce reliance on private cars, and improve accessibility for all commuters. By providing a one-stop shop for mobility service, MaaS might encourage a modal shift towards public transport and shared mobility options, and contribute to lower road carbon emissions, reduced congestion, and enhanced campus-related journey efficiency (C.-F. Chen & He, 2023a; Coppola et al., 2025a; Hao et al., 2025). However, the efficacy of MaaS implementation in these university contexts relies on specific user-centred design, comprehension of user preferences, and the capacity to tailor service offerings to the distinct requirements of the academic environments (Coppola et al., 2025b; Qiuchen et al., 2022; Silvestri et al., 2025a; H. Tang & Feng, 2026).

International students hold a distinctive role within this evolving context. Their transportation decisions are shaped by unfamiliarity with local transit systems, pre-arrival cultural expectations, and practical considerations regarding reliability, safety, and independence. Initial adaptation to local transportation systems frequently entails ambiguity and a lack of confidence in navigating multimodal alternatives, a trend extensively documented in mobility adaptation studies (T.-J. Cheng & Fong, 2024; Simonn et al., 2025b). These challenges are exacerbated in suburban university settings like Monash University's Clayton campus, where fragmented land use, inconsistent first-mile and last-mile connectivity, and restricted evening or off-peak services perpetuate a reliance on private cars (Shafi et al., 2020a). For many young adult international students, driving is a symbolic and practical means of achieving control, independence, and predictability in an unfamiliar environment (Hopkins, 2016).

MaaS provides a framework to reduce these obstacles by presenting international students with a cohesive and comprehensible mobility ecosystem. MaaS diminishes informational complexity and enhances user confidence through route comparison tools, real-time updates, personalised suggestions, and integrated navigation. Research on digital mobility platforms highlights that these attributes can facilitate behavioural changes by enhancing perceived reliability, reducing uncertainty, and simplifying the assessment of multimodal commuting options. For international

student car drivers, MaaS might also provide an opportunity to renegotiate the meaning of independence by offering alternative modes of transportation that preserve a sense of convenience and personal control while reducing reliance on private cars when they navigate in a new or unfamiliar environment.

In the context of Australian universities, the implementation or trials of MaaS remains limited and exploratory (refer to Appendix C. Review on ten selected Australian universities). The University of Sydney piloted a MaaS initiative in 2019, and the University of Queensland has since launched its own MaaS application for students and staff (refer to Chapter 2.4.2). These initiatives reflect an increasing interest in integrating mobility service providers within Australian higher education institutions. Both campuses are nonetheless located in urban or metropolitan areas with dense transport network connections. There remains a notable absence of research on MaaS in suburban university environments, where spatial dispersion, inadequate public transport infrastructure, and heightened car dependency result in distinctly different mobility conditions. Moreover, current research seldom addresses MaaS adoption from the end-user perspective, especially that of international students who are acclimatising to the country's mobility systems and may encounter supplementary cultural, language, informational, and behavioural obstacles.

Overall, MaaS provides a promising framework for facilitating the potential mode shift of everyday commuting behaviours or mobility behavioural change with supporting evidence from urban areas in EU and Australian cities or local communities. However, there is limited investigation on MaaS implementation in the suburban areas of educational precincts in Australia, which feature a car-centric commuting culture.

1.4. Research objectives and scope

This research aims to investigate how a design-led approach might facilitate the adoption of sustainable mobility behaviours among international student car drivers at Monash University's Clayton campus. The initiative addresses a series of mobility challenges influenced by the suburban context of the precinct, the unique cultural and behavioural experiences of international students, and the isolated structure of current transit information and services. The purpose arises from the recognition that daily mobility choices are substantially shaped by infrastructure and transport availability and reliability, as well as personal aspirations, social norms, cultural adaptation, and the emotional aspects of everyday travel. These variables necessitate a methodology that integrates practice-based design, qualitative research, and iterative design prototyping to investigate how a MaaS platform may be made meaningful and usable for a specific population, in this case international student car drivers.

The research project focuses on developing design insights from the commuting experiences of international students. Participatory design workshops, semi-structured interviews, and iterative

prototyping support an understanding of how student participants perceive their mobility environment, negotiate convenience and safety, and evaluate the merits of driving in comparison to choosing public transport or active modes. The focus is on drivers who frequently travel to the Clayton campus and depend on private cars due to perceived or actual deficiencies in the existing suburban transportation systems. Their experiences constitute the basis for design interventions addressing behavioural challenges, social identities, and expectations related to independence and reliability.

The research is located at Monash University's Clayton campus and its adjacent suburban areas as a bounded mobility ecosystem in Melbourne. This enables the investigation to focus on, but not be limited to, unique first-mile and last-mile obstacles, safety issues, micro-mobility connections, and the distribution of housing in relation to the university campus. It situates Monash University's Net Zero Precinct initiative as the central institutional context, emphasising the need to reduce private-car use among student communities as part of the university's broader sustainability commitments (refer to Chapter 1.3.1.2). The temporal scope follows the Double Diamond design process (refer to Chapter 3.3), moving from early discovery work into the development of a high-fidelity MaaS digital prototype. Each iteration stage integrates insights from thematic analysis and the participatory input of international student car drivers, creating an ongoing dialogue between empirical findings and design refinement.

The research objective is to establish which informational, motivational, and social mechanisms within a digital mobility service platform are warranted by the commuting conditions that international student drivers encounter. Instead of specifying features in advance, the research treats the candidate mechanisms identified in the literature, including journey-planning support, reward structures, and social features, as propositions to be tested, retained, or set aside on the evidence of the participatory investigation (refer to Chapters 2.6.5 and 8.3). These design features are not analysed in isolation but are regarded as elements of a broader service ecosystem that connects mobile interfaces with physical travel conditions and campus transportation infrastructures. The focus does not include the development of a commercial and ready-to-use MaaS product; instead, it emphasises the conceptual and experiential attributes of a platform designed and iteratively refined throughout the participatory investigation practice.

As a practice-based design research project, the boundaries of the project are defined by its methodological framework and concentration on a particular campus demographic. One boundary concerns the sense in which the research is participatory. Participants held authority over problem framing and over the acceptance or rejection of design directions within the design sessions, while the research questions, the choice of MaaS as the object of design, the analysis and the final design decisions remained with the researcher. The project

therefore claims participation in the sense of shared authority over design judgement, and not in the stronger democratic sense of distributed control over the research programme or its implementation. The basis for that distinction is set out in Section 3.2.4. This research does not attempt to represent all international student travellers in Melbourne, nor does it generalise across all university environments. This project provides a comprehensive and contextual understanding of a unique user group of MaaS, in this project, international student car drivers from Chinese cultural backgrounds, whose experiences illuminate the obstacles and the design opportunities for sustainable mobility transitions in a suburban university setting in Melbourne.

Critically, the decision of this research to focus exclusively on international student car drivers requires justification, since car dependency at Clayton is shared by the whole campus population. This focus is supported by three considerations, each developed in further detail in the following chapters. The first concerns the formation of travel habits and not demographic identity. Travel habits emerge through repeated behaviour in stable contexts and are most susceptible to change when those contexts are disrupted (Cui et al., 2017; Dashtestaninejad et al., 2023; Soltani et al., 2019b). Relocation to another country represents such a disruption, creating a well-defined period during which established mobility practices are reconfigured (refer to Chapter 9.3.1). The second concerns the epistemic requirements of participatory design. Meaningful participation depends on participants having direct experience of the behaviour the design seeks to influence, together with sufficiently recent experience of establishing that behaviour to enable critical reflection and co-design (refer to Chapter 4.3.1). The final concerns a gap in the existing literature. MaaS research has predominantly relied on general population samples, pilot participants, or early adopters, while international students and newly arrived residents have rarely been treated as a distinct unit of analysis despite facing mobility challenges that differ from those of the broader local commuting population (refer to Chapter 2.5.3).

Two alternative research designs were considered at an early stage of this project but not adopted, because they were inconsistent with the epistemic requirements of the study. The first, a comparative design involving both international and domestic students, would have strengthened claims about differences between the two major population groups at Clayton campus. However, such comparisons were not the primary objective of this research. More essentially, dividing a relatively small participatory sample across two cohorts would have reduced the sustained engagement necessary for collaborative design, thereby weakening the depth of the empirical material from which the design proposition emerged. The resulting gain in comparative breadth would therefore have come at the expense of methodological depth.

Another alternative was a whole-of-campus study, which could have increased the diversity of participants and produced

findings potentially more representative of the broader campus population. Yet this broader scope would also have required treating commuting practices as an aggregate phenomenon, masking the contextual conditions through which travel decisions are formed and negotiated by particular groups. Such an approach would have generated a more general account of campus mobility, but a less precise design brief that might reduce the capacity of the research to develop an intervention responsive to the specific circumstances of international student drivers.

These alternatives were not rejected because they represented inferior research designs. On the contrary, each would have produced valuable knowledge. They were set aside because they prioritise different epistemic goals. A comparative design privileges explanation through difference, while a whole-of-campus study privileges breadth and representativeness. By contrast, this research adopts a practice-based and participatory design approach in which knowledge is generated through sustained engagement with a clearly bounded user group. Since the research question asks what a MaaS platform would need to do to support international student car drivers during a period of disrupted travel habit formation, methodological depth, contextual specificity, and iterative co-design provide a more appropriate basis for enquiry than broader and less situated forms of evidence.

A narrower boundary follows from the recruitment undertaken for this research. All ten participants came from Chinese cultural backgrounds, which reflects both the composition of the international cohort at Clayton and the reach of the recruitment channels described in Chapter 4.3.1. This narrowing is reported as a property of the evidence and not as a further design decision, and Chapter 9.5 sets out what it means for the transfer of the findings. Taken together, these boundaries define a study that seeks a detailed and situated account of one group in one precinct, and that offers its findings to adjacent populations as propositions for testing and not as established results.

2. From theories to campus realities through a review of literature, cases, and the precinct

CHAPTER OVERVIEW

This chapter explores essential concepts and research on sustainable mobility, behavioural change theories, participatory design methodology, and digital platform development within the Mobility-as-a-Service framing, contextualising these topics within the mobility landscape of the Clayton area. The review draws on literature and relevant practical cases in user-centred and participatory design, alongside contextual observations of campus mobility conditions, to surface tensions, restrictions, and design opportunities that are inadequately explored. This chapter elucidates how existing knowledge informs the precinct environment and how identified gaps shape the research direction and questions for the subsequent chapters.

2.1. Introduction and scope

The literature review chapter utilises a narrative method (R. Ferrari, 2015; Jahan Nusrat et al., 2016; Pautasso, 2019). The review examines the mobility conditions that give rise to car dependency at suburban university campuses, the behavioural literature that accounts for it, and the design responses that have been proposed. Mobility-as-a-Service enters the review as one candidate response among these, and its suitability for international students at Monash University's Clayton campus is treated as a question for the empirical chapters and not as a premise. This research is positioned within the broader debate on sustainable transport strategies, digital platform design approaches, and the theories of behavioural change. This chapter critically analyses the current scholarly literature, identifies gaps, and emphasises the unique mobility challenges faced by international students from suburban university environments, thereby providing a solid rationale and theoretical basis for the research.

The literature review functions as a form of enquiry, since it both establishes the terms in which the research questions are posed and supplies part of the evidence on which the answers rest. The overarching research question is derived from the literature through three structured themes (see Figure 2.1), namely sustainable transition design, Mobility-as-a-Service, and international student mobility behaviours.

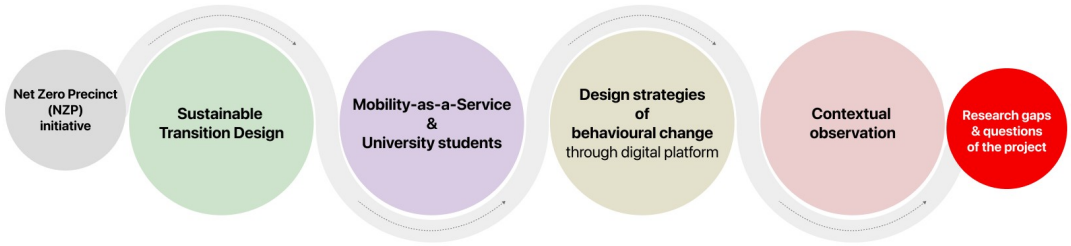


Figure 2.1. Thematic scoping view of the literature review

Several scoping searches were conducted to identify scholarship on MaaS, sustainable transitions, behavioural change, and international students (see Figure 2.2). The initial search occurred between October 2022 and November 2023, with updates in July 2024 and January 2025 to refine the research focus and include recent literature (refer to Table 2.1). The search strategy comprised (1) systematic searches of electronic databases, (2) manual searches of selected publications such as white papers and conference proceedings, and (3) examination of hard-copy design collections and portfolios held by Monash University Library. Electronic sources included ScienceDirect, Scopus, Google Scholar, JSTOR, Monash University Library, SAGE Publications, MIT Press, World Transit Research, the National Academies Transportation Research Board, and Informit. Research Rabbit, Scite, and Elicit supported citation chaining and the discovery of related literature.

Table 2.1. List of keywords and synonyms generated as search terms

Keywords	Synonyms	Search String Example
Sustainable Mobility	Sustainable transport, green transportation, carbon-neutral mobility, eco-friendly transport, green travel, low-carbon transport, green mobility	(“Mobility-as-a-Service” OR “Transportation-as-a-Service” OR “Integrated Mobility Solutions”) AND sustainability
Mobility-as-a-Service	MaaS, smart mobility, sustainable mobility solutions, urban mobility, digital mobility service, transportation-as-a-service, intelligent transportation systems, multimodal transport services, digital mobility platforms, mobility service applications	(“Mobility-as-a-Service” OR “MaaS” OR “Transportation-as-a-Service” OR “Integrated Mobility Solutions” OR “Shared Mobility Services” OR “Digital Mobility Platform”) AND (“sustainable mobility” OR “low-carbon transport” OR “green transportation” OR “sustainable transportation systems”) AND (“international students” OR “foreign students” OR “overseas students” OR “global learners” OR “transnational students” OR “student mobility”)
International students	Foreign students, overseas students, international scholars, global students, study abroad participants, international university students, international postgraduate students, undergraduate international students	
Digital platform	Mobile applications, smartphone apps, online services, digital ecosystems	

Keywords	Synonyms	Search String Example
Participatory design	User-centred design, co-design, collaborative design, human-centred design, design workshops, design sprints, participatory design methods	((“Speculative Design” OR “Design Fiction” OR “Critical Design”) AND ((“Mobility-as-a-Service” OR “MaaS”) AND (“digital platforms” OR “mobile applications”)) AND ((“international students” OR “foreign students”) AND (“university campuses” OR “student mobility”)) AND ((“sustainable transport” OR “carbon-neutral mobility”) AND (“scenario planning” OR “design workshops” OR “future-oriented design”)))
Speculative design	Design fiction, design futures, critical design, future-oriented design, scenario planning, future thinking,	

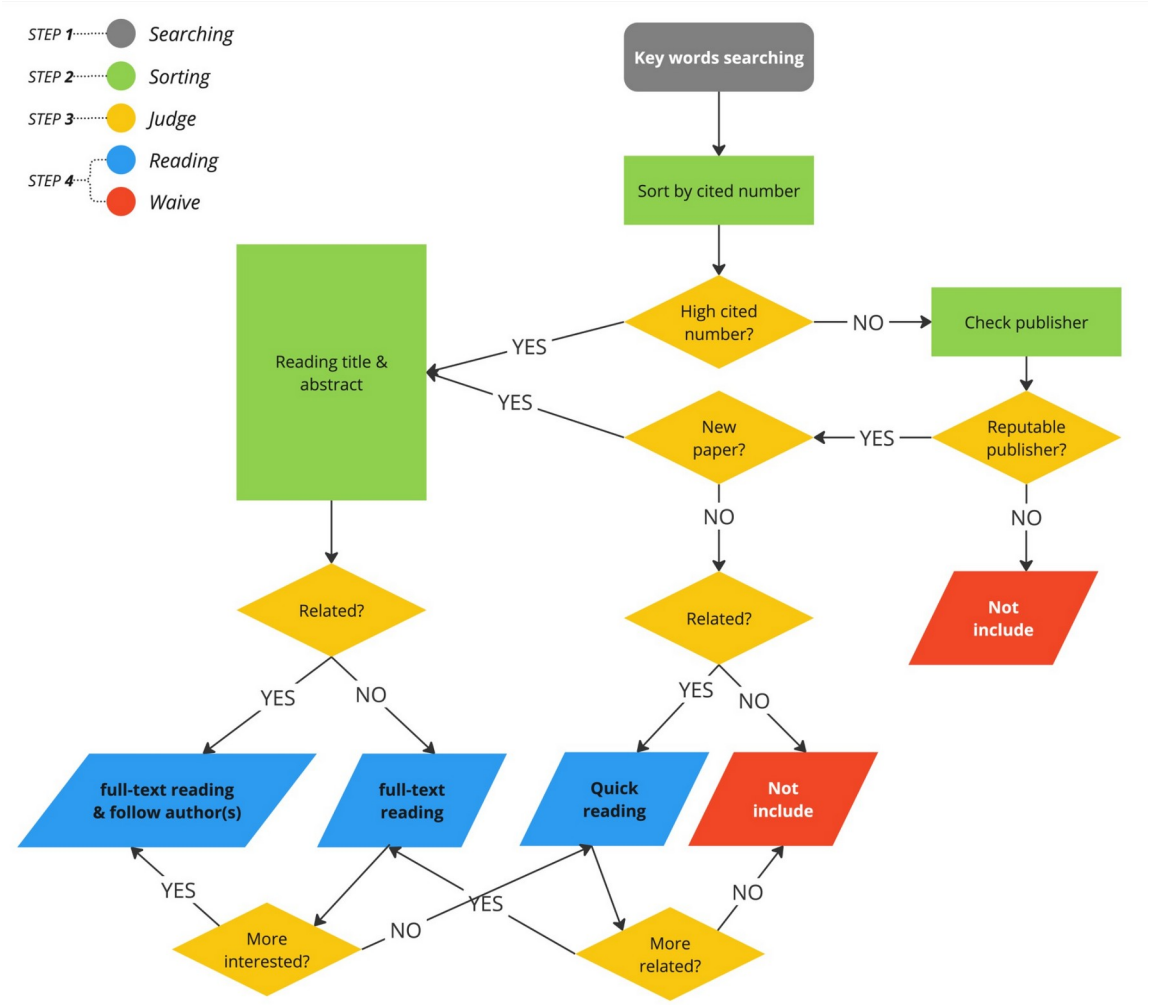


Figure 2.2. A designed strategy of paper searching, screening and reviewing (author’s own graph)

The chapter provides an exploratory review of the existing literature relevant to the design of sustainable MaaS platforms for international students, focusing on reducing car dependency and promoting sustainable transport behaviours. The chapter is organised into four thematic layers, which together structure the research problem and articulate the complexity of the research undertaken.

This chapter adopts a multi-layered structure to examine sustainable mobility design through the lens of MaaS platforms for international student populations. At the foundation level, sustainable transition design principles provide the theoretical guidance for transformative socio-technical interventions within the Avoid-Shift-Improve (ASI) framework (F. W. Geels, 2018). The second section explores MaaS as a pioneering sustainable mobility solution, analysing its historical evolution and assessing its effectiveness in reducing private car use through a review of cases from selected urban and university campus contexts, thereby establishing it as a vital facilitator for attaining sustainability objectives through integrating mobility service systems (Jittrapirom, Caiati, Feneri, Ebrahimigharehbaghi, Alonso-González, et al., 2017; Sochor et al., 2018). The third section, by examining university students' mobility behaviours, identifies the barriers international students face in adopting sustainable transport, and examines the claim made in that literature that they act as 'agents of change' within suburban mobility ecosystems (Shields, 2019; Zhou, 2012). Section 9.3.1 returns to this claim and specifies the sense in which this exegesis advances it. The final section investigates the crucial role of user-centred digital platforms and behavioural interventions in encouraging sustainable or multimodal travel.

The findings section synthesises the insights drawn from the review, identifies critical knowledge gaps, and provides the foundation for the research questions addressed in the subsequent chapters. Finally, the discussion and summary section contextualises the literature within the broader scope of the study, underscoring the importance of designing effective, inclusive, and sustainable MaaS platforms tailored to international student drivers in suburban university settings.

This layered analysis offers a framework for examining how digital mobility service platforms may support sustainable transition among international student populations, contributing to locally focused low-carbon emission transportation objectives.

2.2. Theoretical foundations for framing the transition

2.2.1. Sustainable transition

Sustainable transition theory presents essential frameworks for understanding the fundamental transformations of socio-technical systems towards more ecologically sustainable configurations.

The multi-level perspective (MLP) (F. W. Geels, 2011) provides analytical tools to examine transitions through interactions between niche innovations, established regimes, and broader landscape pressures (refer to Figure 2.3). Niche development serves as a vital protected environment for experimenting with radical ideas, articulating expectations, and establishing social networks. The trajectory of niche development is characteristically non-linear and substantially shaped by the interaction of internal learning mechanisms, actor networks, and evolving expectations (F. Geels and Raven, 2006). Innovative mobility initiatives within the framework signify potentially disruptive niche developments that challenge the dominant automobility system.

This theoretical perspective is especially relevant when examining the potential of MaaS platforms as transformational forces in suburban university settings. (Köhler et al., 2019) contend that a successful shift to sustainable transportation systems requires technological innovation together with a fundamental reconsideration of user behaviours, institutional frameworks, and

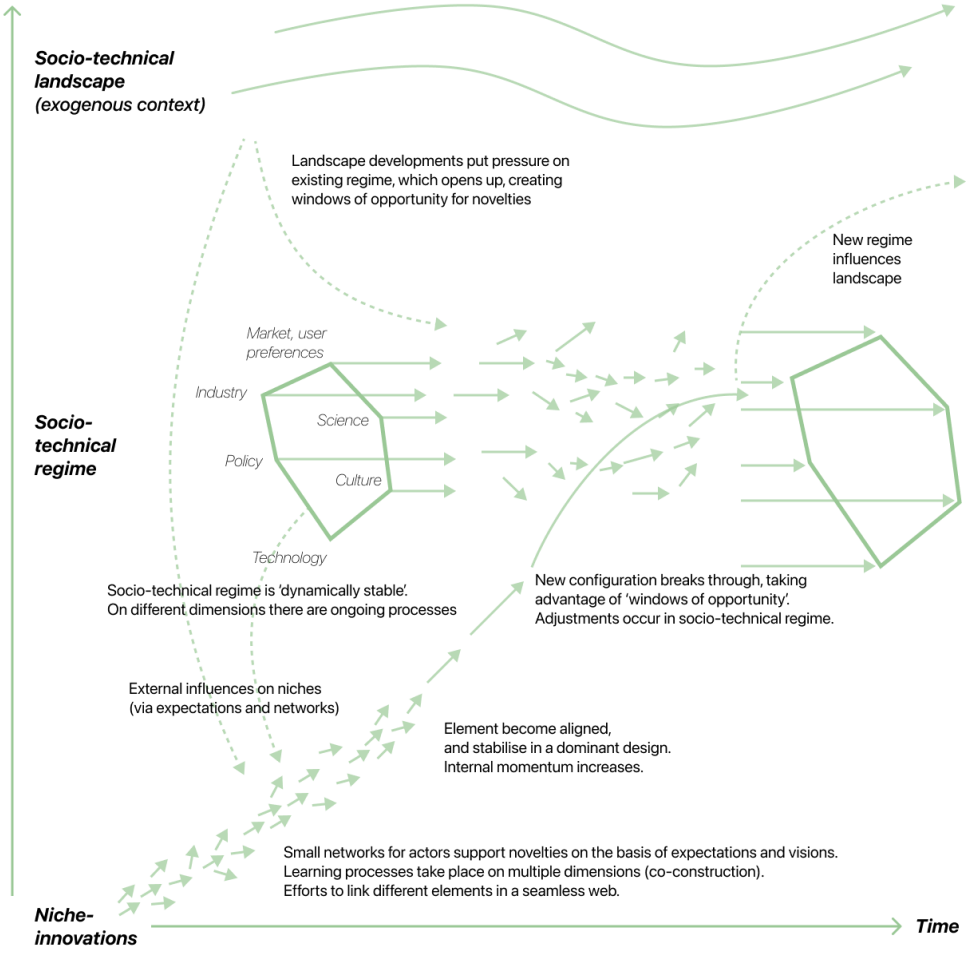


Figure 2.3. Dynamics of socio-technical transitions according to Multi-Level Perspectives, redrawn from (F. W. Geels & Schot, 2007)

supporting infrastructure. The MLP framework elucidates how MaaS interventions may function as protected environments or "incubation rooms" (F. W. Geels & Schot, 2007) where novel concepts might evolve insulated from the selection pressures of the mainstream market, which tend to sustain the prevailing automobility paradigm.

Urry (2004) describes the existing automobility regime, characterised by private vehicle ownership and infrastructure that prioritises single occupancy cars, as a system of interlocking sociotechnical practices that has resisted transformation. Drawing on transition studies, Temenos et al. (2017) indicate that regime stability is sustained by several lock in mechanisms, including irreversible investment in road infrastructure, entrenched user habits, institutional obligations, and influential interests in the automotive and fossil fuel sectors.

The MLP is not without critics, and the criticisms bear directly on a design study. Scholars of everyday practice have argued that the framework describes systems more convincingly than it describes people, since it accounts for niches, regimes and landscapes as structures while leaving the ordinary conduct of daily life largely outside the analysis (Shove & Walker, 2010). A related criticism is that the framework treats the boundaries between its three levels as given instead of as something to be established empirically (Genus & Coles, 2008). Both points matter here, because this study claims that a particular group of people can act within a niche and not merely occupy one. The MLP is therefore used as a framing device instead of as an explanatory model. It supplies the vocabulary for describing the Clayton precinct as a protected setting, while the account of what people do inside that setting comes from the participatory work reported in Chapters 4, 5 and 8.

Read through this theoretical framework, the case of international student mobility at Monash University's Clayton campus indicates how landscape pressures, including climate change imperatives, urbanisation challenges, and evolving sustainability discourse, generate opportunities for specialised innovations such as customised MaaS platforms. These platforms may help to address the "governance void" in sustainable mobility transitions (Schwanen et al., 2012), where conventional policy tools have proved inadequate in instigating systemic change.

Read alongside the preceding paragraphs, the value of the MLP for this study lies less in explaining how a transition unfolds than in specifying the conditions a setting must meet to host one, namely protection from mainstream selection pressure, room for expectations to be articulated, and a network of actors able to learn from what is tried. Suburban university campuses appear to meet all three conditions (Cuesta-Claros et al., 2024; Deleye et al., 2019), and may therefore act as protected niches (F. Geels & Raven, 2006; Schot & Geels, 2011) for developing sustainable mobility innovations before broader geographic implementation (Keller et al., 2022). This theoretical framework emphasises the

necessity of addressing emerging technological solutions and the social, institutional, and individual behavioural dimensions of sustainable mobility transition (F. W. Geels, 2018; Hopkins, 2017; Ruhrort, 2020; Whittle et al., 2019), such as MaaS (Mladenović, 2021; G. Smith & Hensher, 2020).

2.2.2. Transition design approach

Transition design was proposed by Carnegie Mellon University's School of Design as a response to complex or wicked societal challenges requiring systemic interventions. Drawing on systems thinking, social practice theory, and transition management, Irwin (2015) elucidated a continuum of design approaches (see Figure 2.4), which situates Design for Service and Design for Social Innovation along a horizontal axis of time and depth of engagement.

This framework characterises transition design as a broad and temporally extended methodology that tackles the essential prerequisites for transitions to more sustainable futures. The approach acknowledges that contemporary concerns such as climate change, resource depletion, and social inequity require responses extending beyond conventional design boundaries (Tonkinwise, 2015a). As Irwin et al. (2020) stated, transition design recognises the interrelatedness of social, economic, political, and ecological systems, suggesting that sustainable solutions must function across many scales and temporal dimensions.

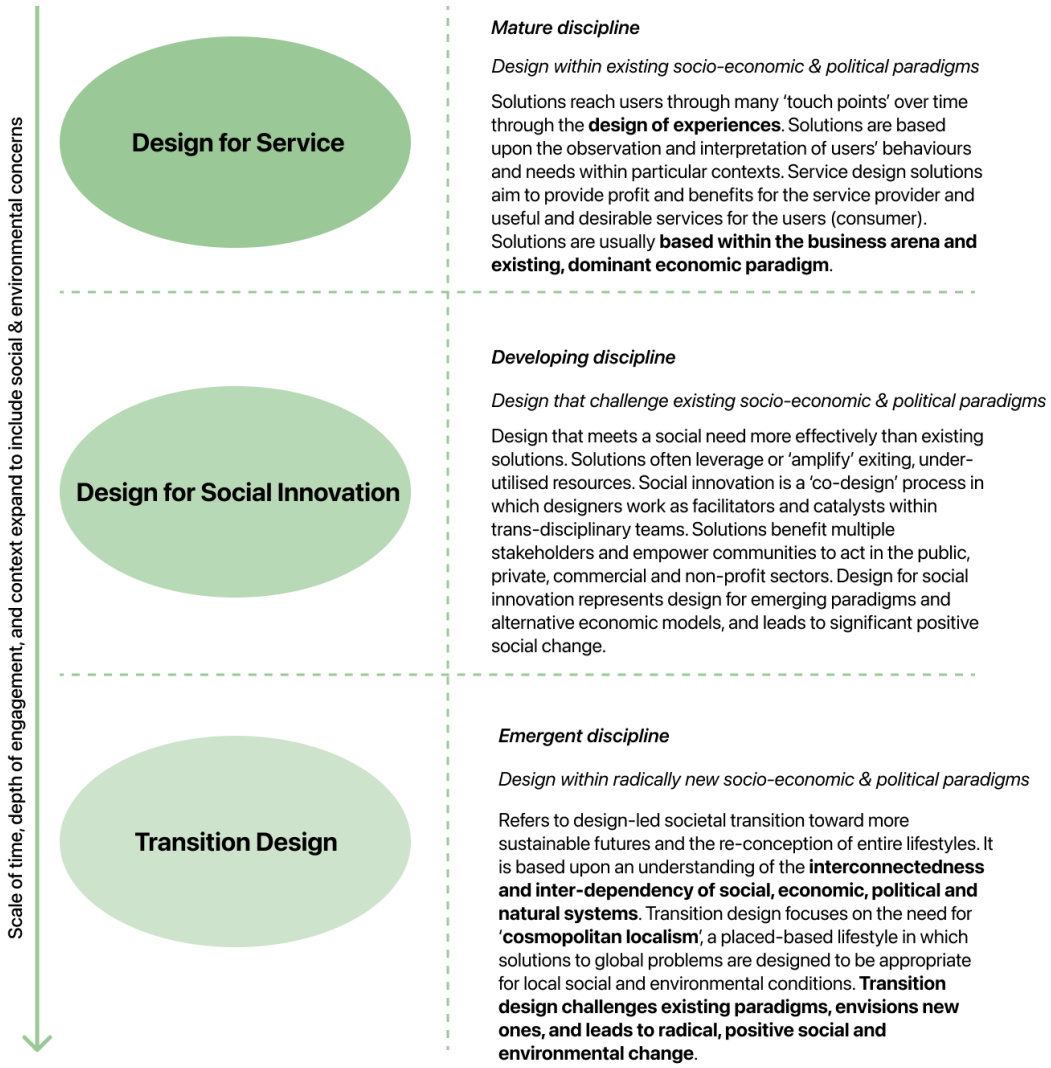


Figure 2.4. A continuum of Design Approaches, redrawn from Irwin (2015)

The conceptual foundation of this approach draws on systems thinking, social practice theory, and transition management. In particular, the study leverages the notion that everyday practices, such as the choice of commuting mode, are shaped by and in turn shape socio-technical systems. Consequently, small-scale, user-centred design interventions might reveal hidden obstacles to sustainable transportation and highlight locally relevant solutions. This research investigates how design-oriented involvement with participants' lived experiences and envisioned futures might promote behavioural change and contribute to cultural and infrastructural transformation over the nearer term.

In research concerned with MaaS, the transition design approach provides a methodological framework to investigate how digital platforms might facilitate behavioural and cultural shifts among specific demographic groups, such as international students (Irwin, 2015; Loorbach, 2022). The adoption of transition design in this project reflects a deliberate shift from conventional artefact-based solutions towards user-centred or stakeholder-driven transformations in mobility design

practice. The MaaS platform may be understood as a boundary object that supports cross-sectoral dialogue and co-creation of knowledge between students and future policy actors. This is also supported by transition design's focus on "seeding change" through interactive, user-driven interventions (Manzini, 2015; Tonkinwise, 2015b).

In summary, this project contributes to a growing body of work that highlights the role of design in facilitating bottom-up, experiential pathways to change by embedding transition design principles into practice-based design research. This research emphasises the agency of individual users in the sustainability transition and examines how small-scale design innovations might aggregate to influence broader practices, behaviours, regulations, and expectations related to sustainable mobility.

2.2.3. Sustainable mobility transition

Transportation is seen as a pivotal sector in the global sustainability transition, owing to its substantial contribution to greenhouse gas emissions, urban congestion, and resource consumption. Consequently, it is crucial in establishing sustainable patterns for the movement of people and commodities (Banister, 2008a; Creutzig et al., 2018; F. W. Geels, 2012). Academics contend that the transformation of transportation networks necessitates tackling systemic difficulties across technical, behavioural, and institutional dimensions, in accordance with overarching objectives of low-carbon and equitable futures (Chapman, 2007; Schwanen et al., 2011b).

The concept of 'sustainable transport' was first proposed in the 1980s as an area of action developed within the broader context of an agenda for sustainability set out in the Brundtland Report (Secretary-General & Development, 1987). In recent years, studies have investigated sustainable transport interventions across various domains, including policy, transport management, business, information, and communications technology (ICT), and social research.

To overcome the issue of 'automobile dependence' (Newman, 1999) and the automobile-oriented structuring 'system' of modern society (Waerden & Timmermans, 2013), planners and policymakers are redesigning and reorganising traffic infrastructures and shaping laws, norms, and policies from a top-down perspective (Jensen, 2013a; Panko & Sharma, 2017). (Bakker, 2018) elucidates the relationship among three elements, including transport, development, and climate (see Figure 2.5). The three dominant policy paradigms describe the functional relationships between transport-development, transport-climate and development-climate. This research project focuses on the relationship between transport and climate, from which the Avoid-Shift-Improve (ASI) framework is drawn.

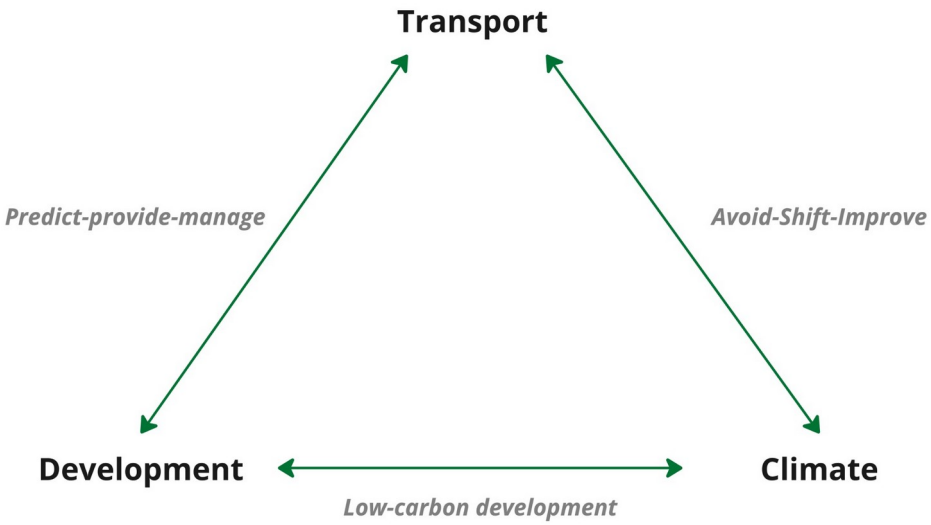


Figure 2.5. Schematic representation of the current situation featuring the three dominant policy paradigms, adapted from (Bakker, 2018)

2.2.3.1. Cases of sustainable mobility strategies

Regarding the framework of ASI, emerging models of urban sustainable mobility transition prioritise a shift from car-owning to shared- or people-oriented transportation ecosystems, emphasising active mobility through enhanced walking and cycling infrastructure (Nieuwenhuijsen, 2021). This includes some notable cases which were conducted in European cities, such as the 15-minute city in Paris, low-traffic neighbourhoods in London, and the Superblocks model in Barcelona.

i) 15-minute city

The 15-minute city (FMC or 15mC) is an urban planning concept that encourages sustainable mobility choices by enabling residents to reach essential local services such as work, shopping, education, healthcare, and leisure within a short distance of walking or cycling (see Figure 2.6 and Figure 2.7) (Pozoukidou & Angelidou, 2022; Moreno et al., 2021; Allam et al., 2022a; Allam et al., 2022b, Maximilian, 2022). The primary objective of FMC is to reform transport infrastructure and urban ecosystems to encourage healthier and more sustainable lifestyles within the neighbourhood boundaries (Jäger, 2022; Khavarian-Garmsir et al., 2023; Patterson & Barrie, 2023).

The 15-minute city concept was introduced in Paris on the principle that everyday destinations, including work, study, entertainment, culture, and leisure, should lie within a 15-minute walk or cycle. Realising the concept requires substantial decentralisation, reform or replanning, and urban transition. The approach may reduce private vehicle ownership, carbon emissions, and noise levels (Nieuwenhuijsen, 2021).

On the other hand, the 15mC can also be interpreted as a "20-minute neighbourhood" (Department of Transport and Planning, 2023; C40 Knowledge, 2020) or similar "chrono-urbanism" concepts (Gower & Grodach, 2022, p.36)

in other cities or neighbourhoods, depending on the travel-time and distance targets set by the relevant local government or council.

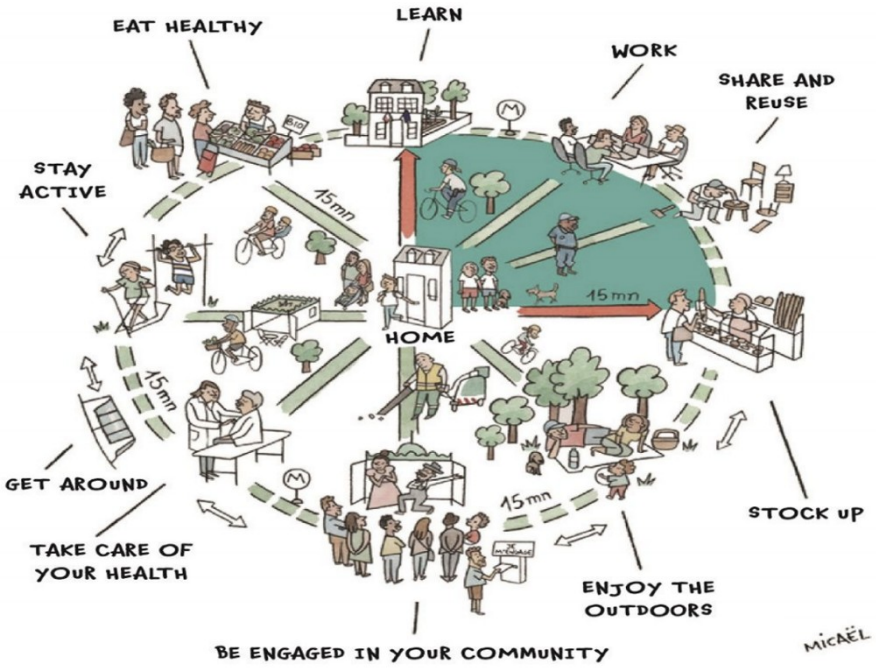


Figure 2.6. The surprising stickiness of the 15-minute city (Chamberlain[1], 2022)



Figure 2.7. The 15-minute City Transition Pathway (Jäger, 2022)

ii) Low-traffic neighbourhoods

The Low Traffic Neighbourhood (LTN) is a measure implemented in London since the 1970s, with a marked increase in new schemes during the spring of 2020 (TfL community, 2020). LTN (see Figure 2.8) aims to restrict motor vehicles from accessing neighbourhood streets by using bollards, planters, and cameras, which could encourage residents to use active mobility, for instance, walking, cycling, or

1 Chamberlain, Lisa.(2022). The surprising stickiness of the '15-minute city'. World economic forum. https://www.weforum.org/agenda/2022/03/15-minute-city-stickiness/ (Accessed 29 Mar 2023)

scootering. Low-traffic neighbourhoods can reduce car dependency, street crime (Goodman & Aldred, 2021) and injuries, making the residential streets safer for socialising and exercising (Aldred & Goodman, 2020).

iii) Superblocks

The Superblocks concept, as with the LTN, entails restricting motor vehicle entry into central sections of the public space while permitting active modes of transportation such as walking, cycling, and other personal vehicles exclusively within the designated "blocks". The concept was developed in Barcelona, Spain, by the city council of Barcelona in



Figure 2.8. Low Traffic Neighbourhood (TfL community, 2020)

2014 (see Figure 2.9), to design a coverage area of around 400 x 400 metres, consisting of residential buildings measuring 150 x 150 metres (City Council of Barcelona, 2014; Love & Stevenson, 2019). The primary goals of this concept are to mitigate motorised traffic on certain routes and establish designated areas free from cars, promoting active mobility through walking and cycling. The fundamental objective of superblocks is to promote active mobility as the predominant form of transportation and offer citizens green public spaces for commuting, networking, and recreational pursuits (Nieuwenhuijsen, 2021).

The design of sustainable mobility services is closely linked to the design of artefacts that facilitate, promote, and enhance ecologically responsible transportation practices. In the realm of mobility services, artefacts encompass tangible products or infrastructure and digital platforms, interfaces, and service systems that affect user interactions and decision-making processes. This review examines selected artefacts in the design of sustainable mobility services, with a focus on Mobility as a Service applications, shared mobility tools, and digital interfaces that aim to reduce car dependency. Through critically analysing existing design projects, this sub-section seeks to clarify the essential functionalities and behavioural dimensions of artefacts that contribute to or inhibit the adoption of sustainable transportation practices (Donovan, 2016; Selvefors et al., 2016; Tilvawala et al., 2023). The insights derived from this review inform the design interventions reported later in this research, particularly in the context of international student drivers navigating the Clayton precinct.

Additionally, the report of *A Framework for an Australian Clean Transport Strategy (FACTS)* (Whitehead et al., 2022) elucidates a comprehensive approach to achieve sustainable transport

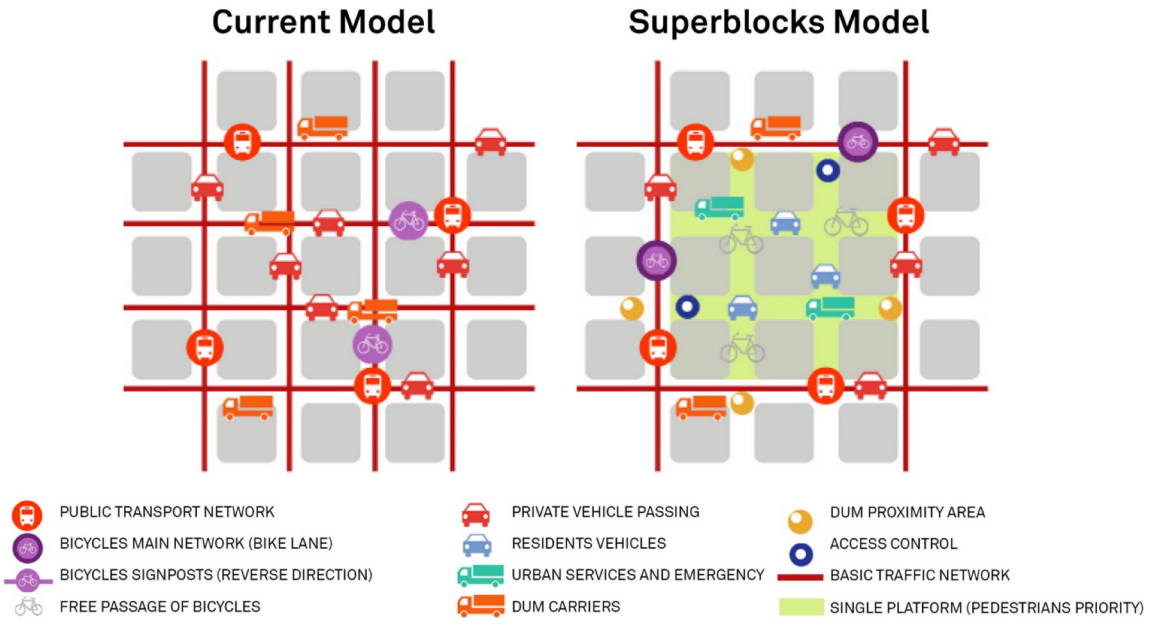


Figure 2.9. Superblocks model (City Council of Barcelona, 2014, p.10)

goals under the ASI framework (refer to Figure 2.10) for multilevel governments and related industries. The FACTS includes the following elements.

(1) ***AVOID*** strategy on reducing travel demand, such as encouraging remote work and introducing anti-idling initiatives.

(2) ***SHIFT*** strategy on mode shifts from private car use to public, shared, and

seamless multimodal travel solutions. Examples include implementing MaaS and investing in active mobility networks and electric micromobility.

(3) ***IMPROVE*** strategy on accelerating the adoption of zero-emission vehicles (ZEVs) through supporting new energy active transportation, integrating with Mobility-as-a-Service (MaaS) to provide solutions such as electricity and hydrogen-powered transport systems.

The strategy of shift within the ASI framework is essential for a design research project that addresses behavioural change, transitioning individuals from private car dependency towards more sustainable multimodal travel alternatives (Banister, 2008b; Creutzig et al., 2018). Previous research indicates that substantial decreases in transport emissions may be attained by encouraging behavioural changes towards public transport, cycling, and walking, and not by depending exclusively on technological innovations or infrastructure enhancements (Hickman & Banister, 2014b; Sovacool et al., 2018).

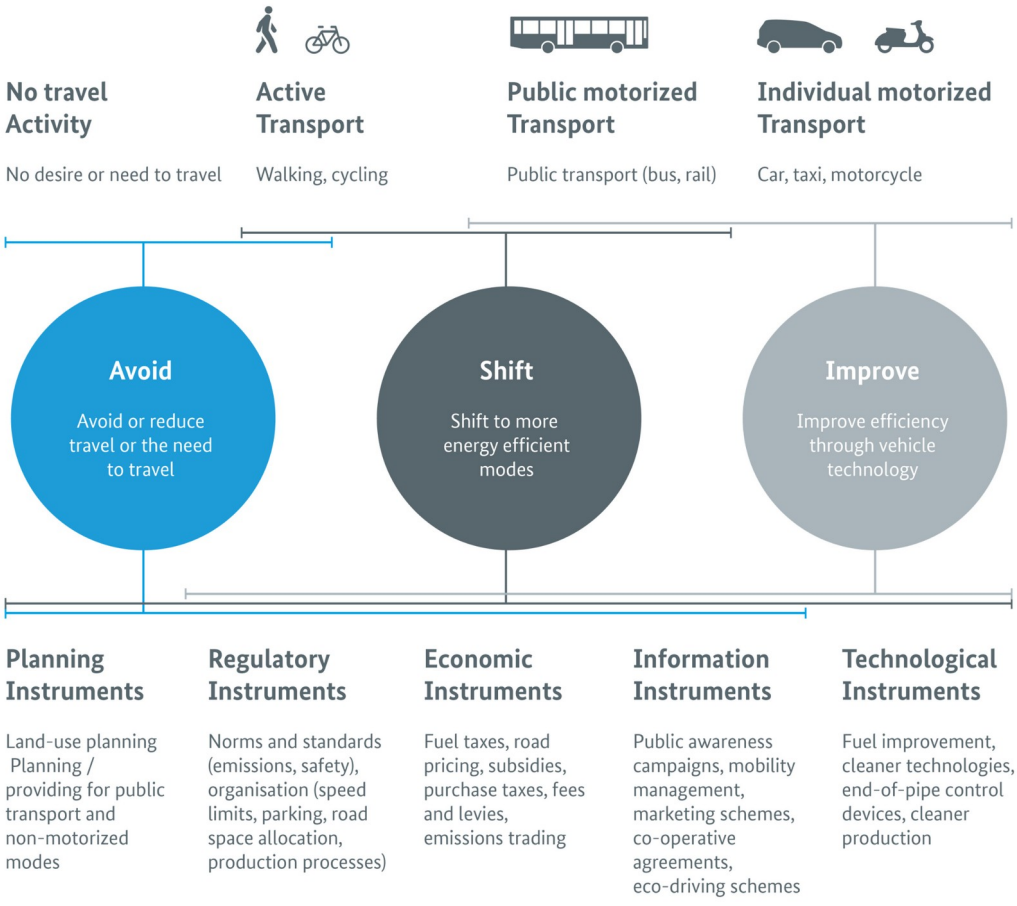


Figure 2.10. Instruments of the "Avoid Shift Improve" strategy (Bongardt et al., 2019)

Consequently, this study concentrates on the "shift" strategy within the ASI framework, examining potential interventions through the design of the MaaS platform. The following section discusses the concept of MaaS in depth, exploring its role in influencing travel behaviours and contributing to sustainable mobility practices.

2.2.4. Transition at the precinct scale

2.2.4.1. What is a precinct

i) Definition of Precinct

The precinct is generally defined as the area within a particular building or place's tangible or intangible (pre-) walls or perceived boundaries (-cinct). Additionally, a precinct can also be defined as 1) an area in a town designated for specific or restricted use, especially one that is closed to traffic (in the United Kingdom); 2) one of the parts into which a town or city is divided to organise elections (in North America); 3) a part of a city that has its own police station, or the police station serving this area; 4) the area around a place or a building, sometimes surrounded by a wall.

(Cambridge Dictionary)

The definition of a precinct might vary in different practical research projects. In urban planning and design, a precinct is defined as an urban area of distinctive character with its own enclosure and internal movement, for instance a recreation, residential, education, or entertainment precinct (Cullen, 1995). Precincts are the centres of knowledge generation and the place for commercial, cultural, and educational activities (Battle, 2007). Similarly, Sharp and Raven (2021) also point out that a precinct can represent a confined area with particular or combined functions of social or economic activity and its associated infrastructure, for example a university, retail, technology, or residential precinct with transport, energy supply, and building infrastructure. In addition, Yigitcanlar et al. (2008) describe the term "knowledge precinct", which refers to clusters located in distinct parts of a city, each with a recognisable character and a degree of cultural diversity. At the same time, Lynch (1960) expounds on an urban "district" related to the precinct, a medium-to-large section of the city with a recognisable internal homogeneity of character and a distinct identity.

Moreover, precincts can also be defined as scaled urban typologies for different purposes or functions in selected areas of a city or town. For example, Sydney Water (2020), a company providing water supply, wastewater, recycled water and stormwater services, conducted a research project on stormwater retention in two selected areas within the South Creek boundary. The project categorises the two selected areas as an employment precinct and a residential precinct, according to the functionalities of these areas. In 2020, the state of Western Australia (2020) revised its guidelines on precinct design to establish definitions and offer planning and design suggestions for precincts categorised into four primary types according to their respective functions. The four primary categories of precincts include activity-centred precincts, station precincts, urban corridor precincts, and residential/mixed-use precincts (see Figure 2.11).

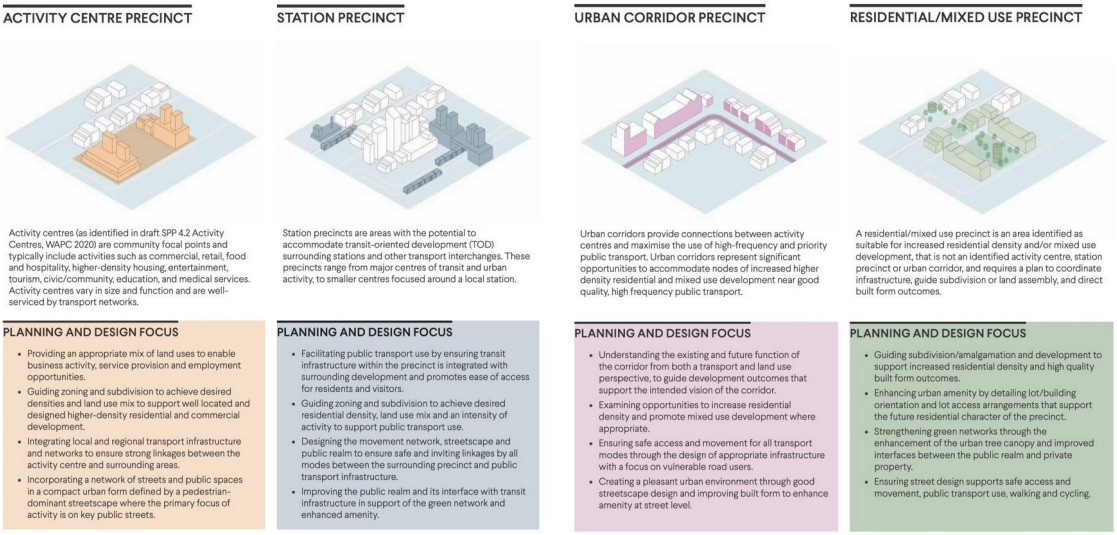


Figure 2.11. Four types of precincts (State of Western Australia, 2020)

ii) Components of a precinct

A precinct generally contains six primary layers (see Figure 2.12), namely building forms (purple), ecological planning (blue), structures/buildings (orange), public space (green), movement/transportation (dark green), and land uses (pink) (State of Western Australia, 2020). A modern precinct also combines several energy-supply systems (Huang et al., 2017) of water (Oliveira et al., 2022), gas (Chu et al., 2022), and electricity (Percy, 2019).

In a designated precinct, clusters of multifunctional buildings play a pivotal role in organising the spatial configuration and connectivity. These clusters are interconnected through road networks and through public transport services (Denholm et al., 2019). Residents might live, work, and socialise in the precinct that provides livelihood services, entertainment, and job opportunities. Precinct design and urban transition processes therefore require analysis of the precinct in its physical, community, and governance contexts, the last covering legislation and policy (State of Western Australia, 2020). Meanwhile, the Growth Areas Authority (2013) revised guidance for precinct structure and planning, indicating that a precinct contains seven elements, namely image and character, housing, employment and town centres, community facilities, open space and natural systems, transport and movement, utilities and energy.

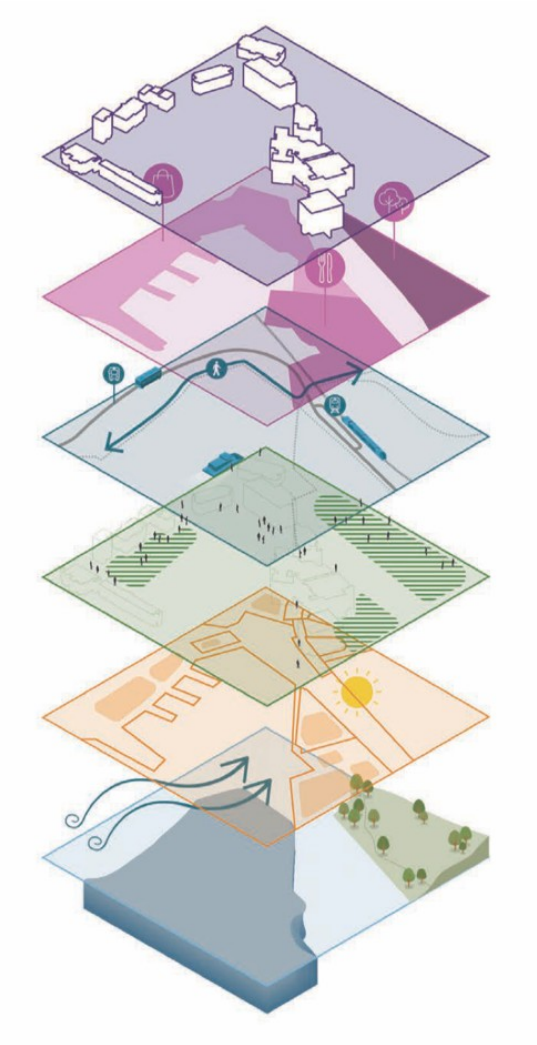


Figure 2.12. Multi-layers of a precinct (State of Western Australia, 2020)

2.2.4.2. Decarbonisation at a precinct scale

Cities are responsible for 70 percent of the world's energy-related greenhouse gas emissions, with over half of the world's population living in urban areas, a share expected to reach two-thirds by 2030 (United Nations, 2019). Mitigating the issues requires efficient decarbonisation actions in cities to reduce the carbon footprint through energy reduction, recycling, and self-supply in public infrastructure, buildings, transportation, circular economy, and energy management. At the beginning of the century, 'sustainable cities' as the emerging agenda for urban development and replanning aims to reduce the carbon footprint while maintaining and improving the liveability of the residents (Bunning et al., 2013).

The optimal intervention points for sustainable transition experiments are typically at the neighbourhood or precinct scale (Bunning et al., 2013; Hajer et al., 2020). Neighbourhoods and precincts are crucial components of cities, commonly defined as a given density of interconnected buildings with associated infrastructure, including service points and transport systems, within a relatively restricted geographical range. At that scale, selected functions of a city can be tested for their performance against

objectives of liveability and sustainability (see Figure 2.13 and Figure 2.14).

In recent decades, a growing number of initiatives have investigated and implemented sustainable experiments in neighbourhoods or micro-scale regions all over the world, encompassing several domains such as urban planning (Kameni Nematchoua et al., 2020; Sharifi, 2016; Raven et al., 2018), renewable energy (Rey, 2006; Liu & Ledwich, 2021; Butera, 2018), buildings (Reith & Orova, 2015; Vilela et al., 2020), transportation (Kennedy et al., 2005; Kesselring et al., 2023), waste management (Guirguis & Moussa, 2019; Budihardjo et al., 2022), and healthy lifestyles (Cloutier et al., 2014; Pfeiffer & Cloutier, 2016; Barton et al., 2021). Scholars across several disciplines have identified a range of feasible strategies for developing sustainable neighbourhood concepts. The notion of Sustainable Neighbourhoods (SN) encompasses interdisciplinary studies and practices (Harris et al., 2014) that strive to reduce greenhouse gas emissions, foster local activity, and establish a circular economy within a specific geographic region, generally a small segment of urban areas (Vilela et al., 2020).

A Zero Emission Neighbourhood (ZEN) is a cluster of buildings with associated infrastructure within a confined emission boundary (Huang et al., 2017). ZEN aims to reduce direct and indirect GHG emissions to zero through a decarbonised transition within the geographical area (Wiik et al., 2019; Wiik et al., 2021). ZEN is a research project for urban decarbonisation with some pilot research locations in Norway (see Figure 2.15), which defines a neighbourhood as a group of adjoining buildings within a confined area, together with its related infrastructure, for instance, transportation services, technologies for generating and storing electricity, and ICT (Brozovsky et al., 2021). A sustainable precinct typically combines medium-density development, a coherent mix of retail, services, and employment that reduces daily travel requirements, reduced dependence on private vehicles, and environmentally responsible planning that supports quality of life (Thomson et al., 2019).

Similar to the concept of ZEN, Bunning et al. (2013) proposed a framework for ZEP (Zero Emission Precinct) or precinct-scale land development (see Figure 2.16), which includes six factors, namely materials, buildings, energy, and production management, water management, waste management, and transportation. The framework of six key emission sources provides a guideline for the future practice of Net Zero Precinct (NZP), which requires interdisciplinary cooperation and contribution. It also presents the current approach of ZEP, which focuses on the aspects of the energy system, transition to a Climate Friendly Neighbourhood (CFN), ICT, and project organisation and stakeholder engagement (Brozovsky et al., 2021).

However, future NZP faces challenges and financial barriers. These include a lack of connection between financial investment, technology developers, and the benefits accruing to residents (UNEP, 2014); the storage of electricity and its lifecycle (Thomson et al., 2013); and the high cost

of decarbonisation transition within cities or towns compared to conventional designs (Australian Capital Territory Climate Change Council, 2018).

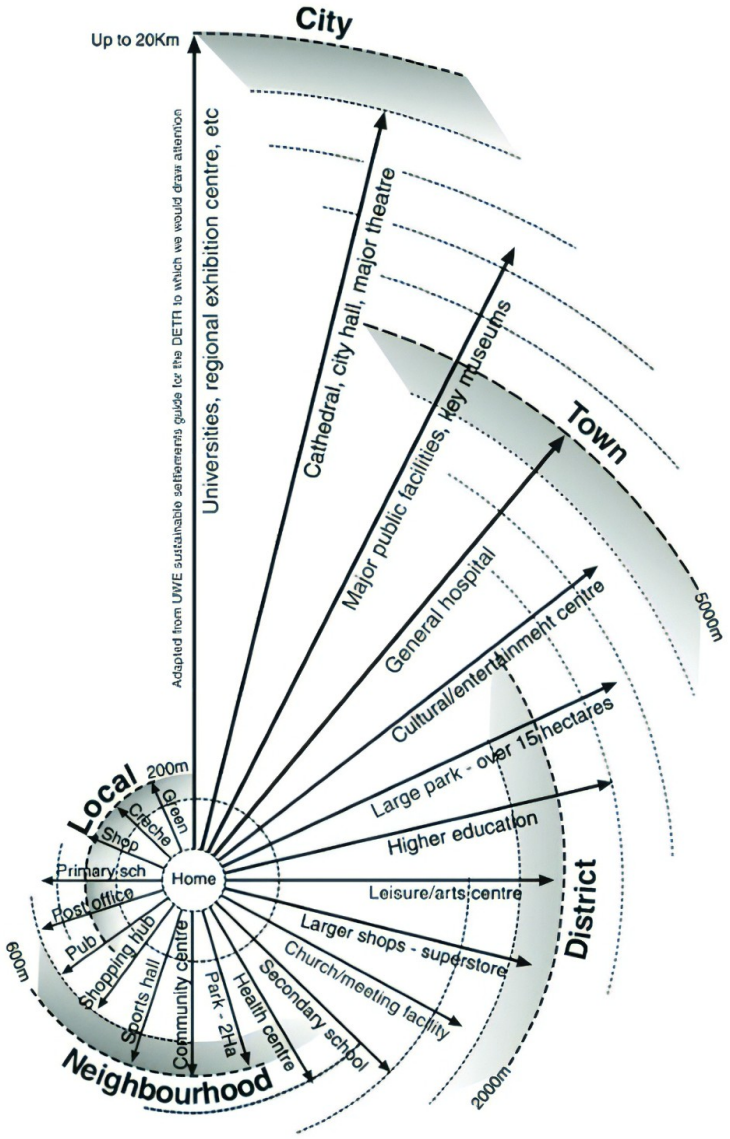


Figure 2.13. The scale levels of the city with the geographical size (Barton, 1995)

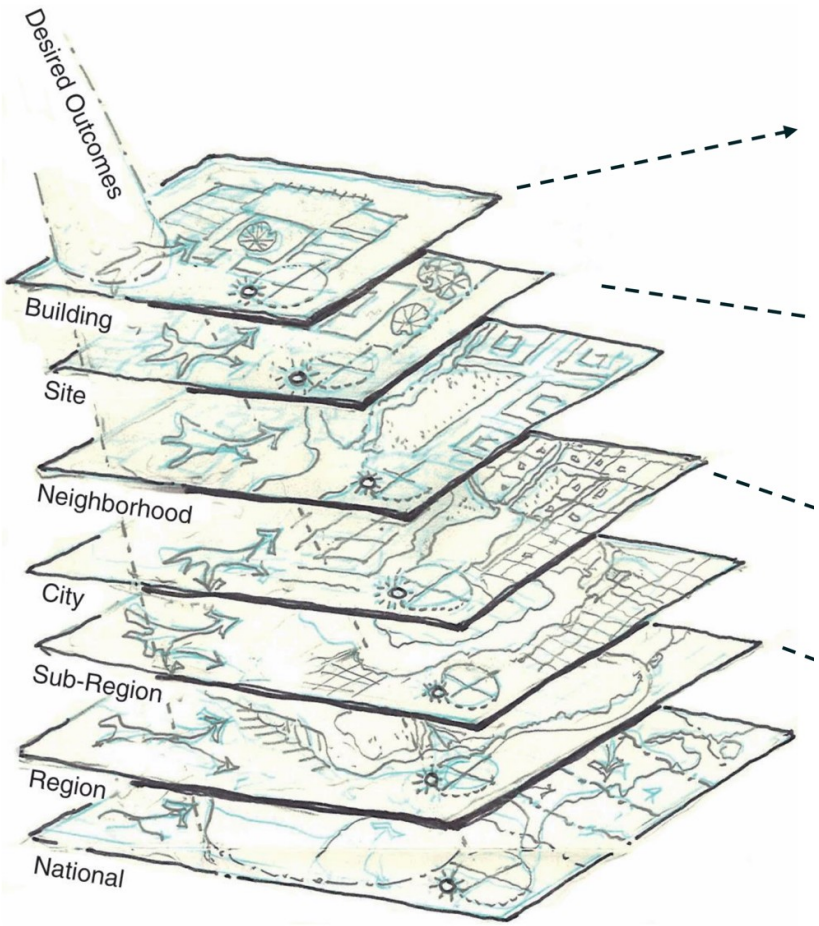


Figure 2.14. Level map of spatial scales relevant to urban planning and urban design for climate change mitigation and adaptation (Raven et al., 2018, P.144)



Figure 2.15. Pilot projects of the Research Centre on Zero Emission Neighbourhoods and Smart Cities in Norway (FME ZEN, n.d.)



Figure 2.16. Key emission sources within precinct developments (Bunning et al., 2013, p. 2310)

2.3. The concept and evolution of Mobility as a Service (MaaS)

In 1933, the International Council of Modern Architecture (CIAM) formulated a programmatic document on urban planning at the Athens Conference, titled the Outline of Urban Planning, also known as the Athens Charter (Le Corbusier, 1973). The Athens Charter initially emphasised that the objective of urban planning is to address and facilitate the standard functioning of four primary activities, namely dwelling, work, recreation, and transportation (Curtis, 1996).

As one of the four primary purposes of a city, transportation is central to connecting residences, workplaces, and recreational areas (refer to Figure 2.17). The evolution of urban transportation can be categorised into three phases, specifically (1) "Automobile-Oriented" development (Newman, 1999, 2015), characterised by a swift increase in urban motor vehicles, significant traffic congestion, and diminished travel efficiency (B. Wang et al., 2022; X. Wang et al., 2015; L. Yang et al., 2018), (2) "public transport priority" development, wherein public transportation directs urban growth and enhances traffic planning and travel efficiency (He, 2013), (3) the "higher development stage", which employs rational traffic demand management based on public transportation-led urban development and advances in a "people-oriented" sustainable manner (Wibowo, 2023).

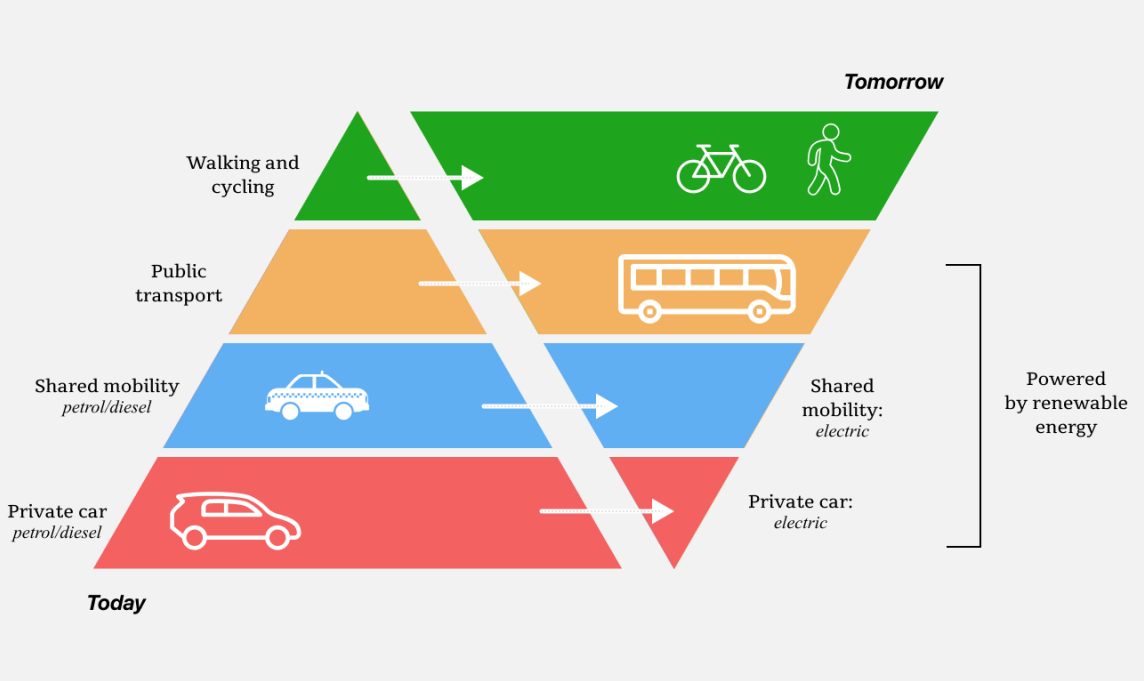


Figure 2.17. Proposal to create a connected, healthy and efficient transport system that is good for people, space, and our climate, redrawn from Climate Council (2022)

A sustainable transportation system encompasses all transportation modalities that minimally affect the environment, including public transit, walking, cycling, Transit-Oriented Development (TOD), eco-friendly vehicles, shared mobility options, and systems designed for energy efficiency, spatial conservation, and health enhancement.

2.3.1. Conceptual foundations of MaaS

2.3.1.1. What is MaaS?

The concept of MaaS (Mobility as a Service) originated in Europe. Although the public sector and mainstream organisations are interested in the concept, there is not yet consensus on its definition (Arias-Molinares & García-Palomares, 2020a). In 2017, the MaaS white paper released by the MaaS Alliance (2017) proposed the first consensus definition between the public sector and freight organisations, "For the user, MaaS offers added value through the use of a single application to provide access to mobility, with a single payment channel instead of multiple ticketing and payment operations. To meet a customer's request, a MaaS operator facilitates a diverse menu of transport options, be they public transport, ride-, car- or bike-sharing, taxi, car rental or lease, or a combination thereof". In 2019, the (European Metropolitan Transport Authorities, 2019) described MaaS as "... a solution for citizens to source and manage their total mobility and travel demands through one unified service. Customers are enabled to choose their transport option based on their respective general preferences but also under consideration of needs that may be specific to a certain journey". In addition, UITP (International Association of Public Transport, 2019) defines MaaS as "the integration of, and access to, different transport services (such as public transport, ride-sharing, car-sharing, bike-sharing, scooter-sharing, taxi, car rental, ride-hailing and so on) in one single

digital mobility offer (see Figure 2.18), with active mobility and an efficient public transport system as its basis. This tailor-made service suggests the most suitable solutions based on the user's travel needs. MaaS is available anytime and offers integrated planning, booking and payment, as well as route information to provide easy mobility and enable life without having to own a car". The MaaSLab of University College London proposed a definition of MaaS as "a user-centric, intelligent mobility management and distribution system, in which an integrator brings together offerings of multiple mobility service providers and provides end-users access to them through a digital interface, allowing them to seamlessly plan and pay for mobility" (Kamargianni et al., 2018).

These four definitions agree on more than they dispute. Each treats MaaS as the integration of separately operated transport services, each requires a single digital point of access, and each assumes that planning, booking, and payment are handled in one place. Where they differ is on what the integration is for. The MaaS Alliance and EMTA definitions are framed around user convenience and demand management, the UITP definition adds a normative commitment by placing public transport and active modes at the base of the offer, and the MaaSLab definition is framed around the market role of the integrator instead of around any transport outcome. That difference matters for a study concerned with sustainability, because only the UITP definition makes the hierarchy of modes explicit, and a platform built on any of the other three could integrate ride-hailing and car rental while leaving car dependency untouched. This exegesis therefore adopts the UITP definition as its working definition and treats integration as a means towards mode shift and not as an end.

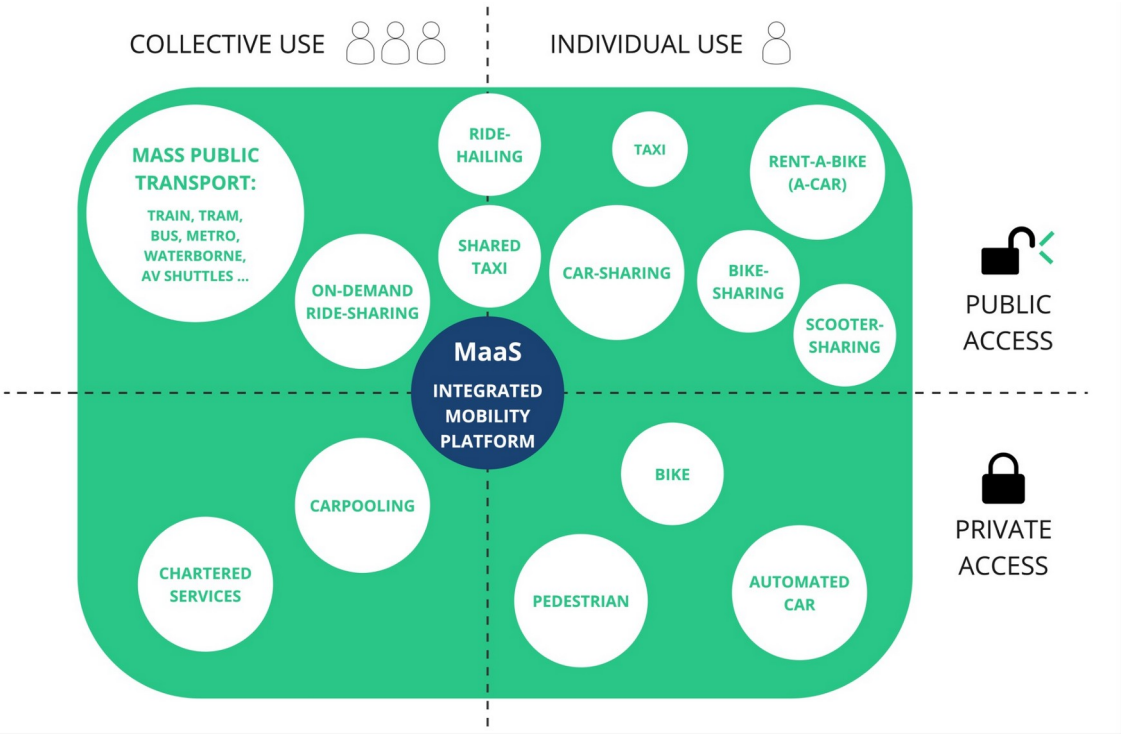


Figure 2.18. Urban mobility services, redrawn from (UITP, International Association of Public Transport, 2019)

The concept of MaaS has gained considerable attention in academic and industry discourse as a transformative strategy for urban transportation systems, with the goals of a net-zero future and smart cities. The concept involves integrating multiple modes of transport service into a single, accessible, and seamless platform (Jittrapirom, Caiati, Feneri, Ebrahimigharehbaghi, Alonso-González, et al., 2017). The development of MaaS comprises three main phases (see Figure 2.19), including MaaS 1.0 (I-MaaS), MaaS 2.0 (T-MaaS), and MaaS 3.0 (S-MaaS), which describe a staged progression towards those targets (Vitetta, 2022). MaaS 1.0 establishes the foundational ICT (Information and Communications Technology) infrastructure for information, booking and payment functions, while MaaS 2.0 introduces decision support systems that integrate transport service providers, and MaaS 3.0 represents the most advanced level centred on sustainable objectives or broader societal values (Lyons et al., 2020a; Sochor et al., 2018). Furthermore, although the framework encompasses system components and information flows, it inadequately reflects user behaviours and acceptance factors identified by Hensher et al. (2020) as essential for the success of MaaS. This suggests that subsequent research might investigate the mechanisms facilitating transition between integration levels, while exploring design opportunities or strategies through methodologically rigorous user-centred research to inform empirically based behavioural adoption of future MaaS platforms.

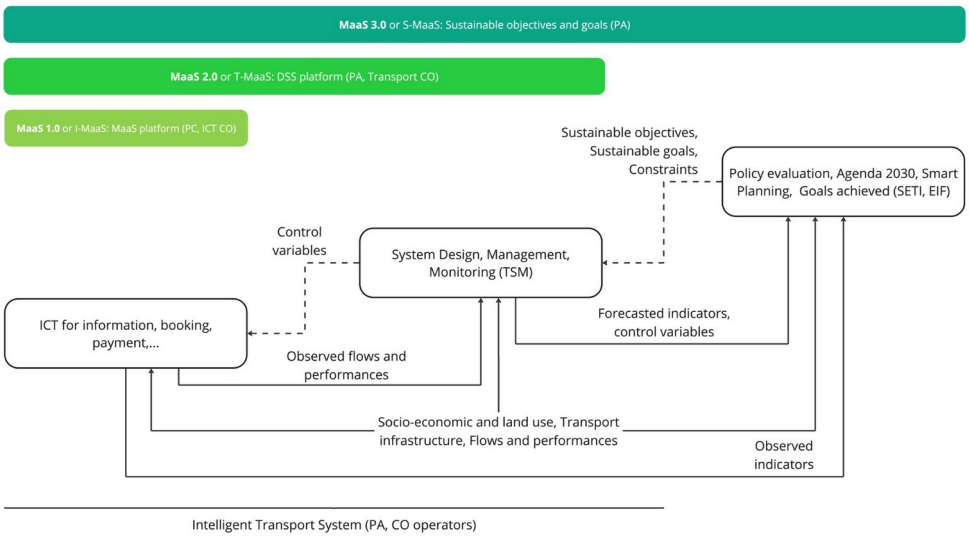


Figure 2.19. Classifies the levels of integration on which this review draws, adapted from (Vitetta, 2022)

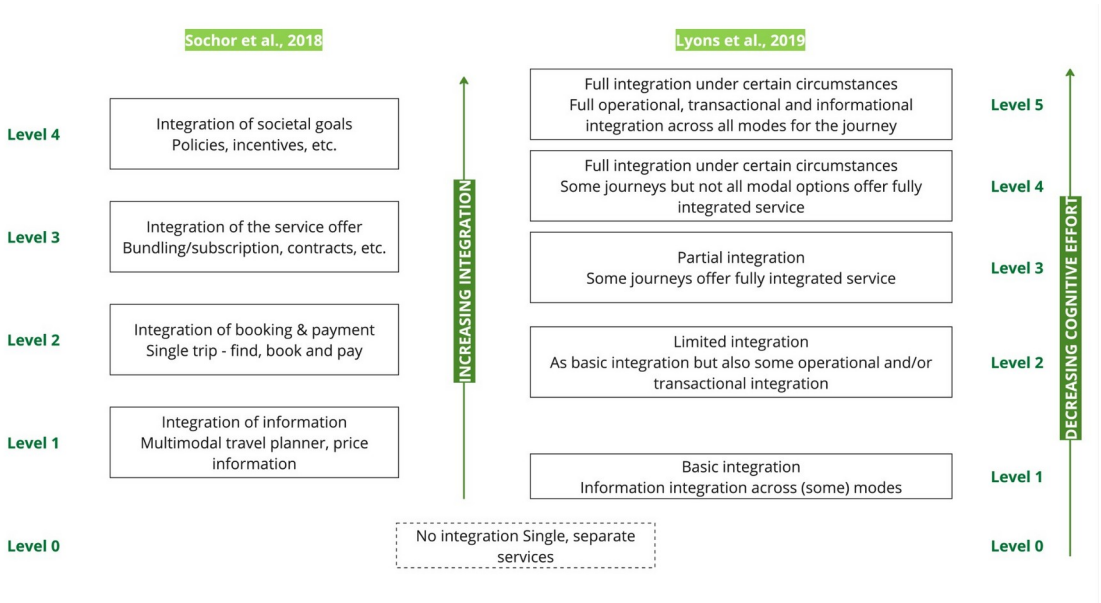


Figure 2.20. A classification of MaaS integration, adapted from (Hensher et al., 2020)

2.3.1.2. Benefits of MaaS

The concept of MaaS has emerged as a transformative approach to urban transportation planning, providing a paradigm shift from conventional car-centred mobility services towards an integrated and sharing ecosystem (Jittrapirom, Caiati, Feneri, Ebrahimigharehbaghi, Alonso-González, et al., 2017). When planning, booking, and payment functionalities are consolidated into a single interface, commuters gain a more comprehensive understanding of available transportation options and can coordinate multimodal trips with substantially reduced effort. As Hensher et al. (2020) demonstrated, this form of integration diminishes the cognitive burden associated with navigating multiple operators, which frequently hinders the utilisation of public and shared mobility services. The research further indicates that commuters are more amenable to transitioning from private cars when digital coordination alleviates ambiguity regarding routes, costs, and timing.

The implementation of MaaS may support a broader transition from mobility based on ownership to mobility based on access. By integrating public transport, ride sharing, and micromobility within a unified interface, MaaS may reduce dependence on private automobiles. This integration may improve convenience and support more efficient use of existing infrastructure. It may consequently alleviate traffic congestion, reduce carbon emissions, and release urban space allocated to parking while supporting more resilient and sustainable communities. Evidence from early MaaS trials, including UbiGo in Sweden, suggests that integrated digital platforms may encourage more sustainable travel choices and help normalise multimodal travel as an everyday practice (refer to Section 2.3.2.2).

Furthermore, research from Europe and Australia indicates emotional and psychological benefits that accompany these practical improvements of the MaaS platforms. Users experience reduced stress when traversing intricate systems,

as MaaS applications consolidate fares, itineraries, carbon emission data, and service disruptions in a single platform. Ho et al., (2021) discovered that subscription bundles enhance predictability, thereby reinforcing users' confidence in non-automotive modes of transportation. This perception of consistency is especially crucial for populations unfamiliar with local transportation systems. G. Smith et al. (2022) elucidate how MaaS fosters "mobility confidence," enabling travellers to undertake journeys they previously deemed challenging.

Moreover, institutions might also gain benefits through implementing MaaS-related mobility services. Transport authorities and precinct-scale companies utilise MaaS-generated data to monitor real-time traffic patterns, regulate demand, and implement sustainability initiatives. Audenhove et and Hensher et al. (2020) highlight that this analytical capability enables public entities to transition from mode-specific to system-wide planning.

These should be read as claims the literature makes for MaaS and not as outcomes it has demonstrated. Most derive from pilot studies with small and self-selected samples, from stated-preference surveys, or from trials running for months, and few report what happened to travel behaviour after the trial ended. The UbiGo trial is the most frequently cited evidence of normalised multimodality, yet its participants volunteered for an integrated mobility service and were therefore already disposed towards using one. Reviews of the field observe that the sustainability case for MaaS rests more on plausible reasoning about mode substitution than on measured reductions in car use, and that a platform integrating ride-hailing alongside public transport may raise vehicle kilometres instead of lowering them. The present study accordingly treats the benefits summarised in Figure 2.21 as design intentions to be tested with users, not as established effects.

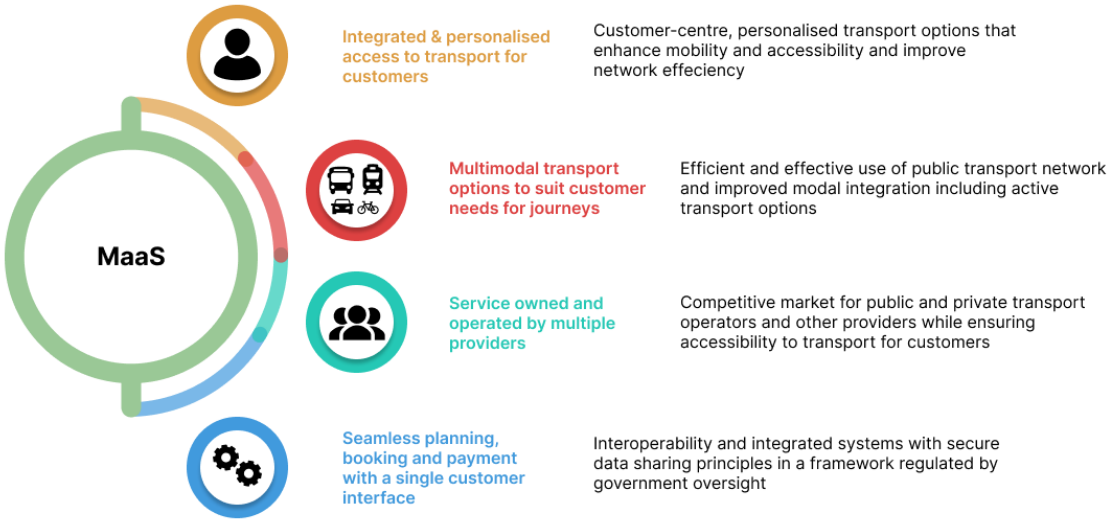


Figure 2.21. Summarises the benefits of MaaS across users, operators and institutions (author's own summarised infographic)

2.3.1.3. User perspectives in the evolution of MaaS

The scholarly exploration of MaaS has proliferated across various fields, encompassing economics (Chi & Mazzer, 2022; Nemoto et al., 2024), transportation planning (Mitropoulos et al., 2023), urban architecture, data sciences, and behavioural sciences. This interdisciplinary focus underscores the intricacy of effectively executing MaaS systems in practical environments. The implementation of MaaS necessitates cooperation among multiple actors, including end-users (PE), Public Authorities (PA), and Companies (CO) (see Figure 2.23). The MaaS operator functions as an intermediary between users and Mobility Service Providers (MSPs) (see Figure 2.22), organisations that supply various transportation modes (Kamargianni et al., 2016).

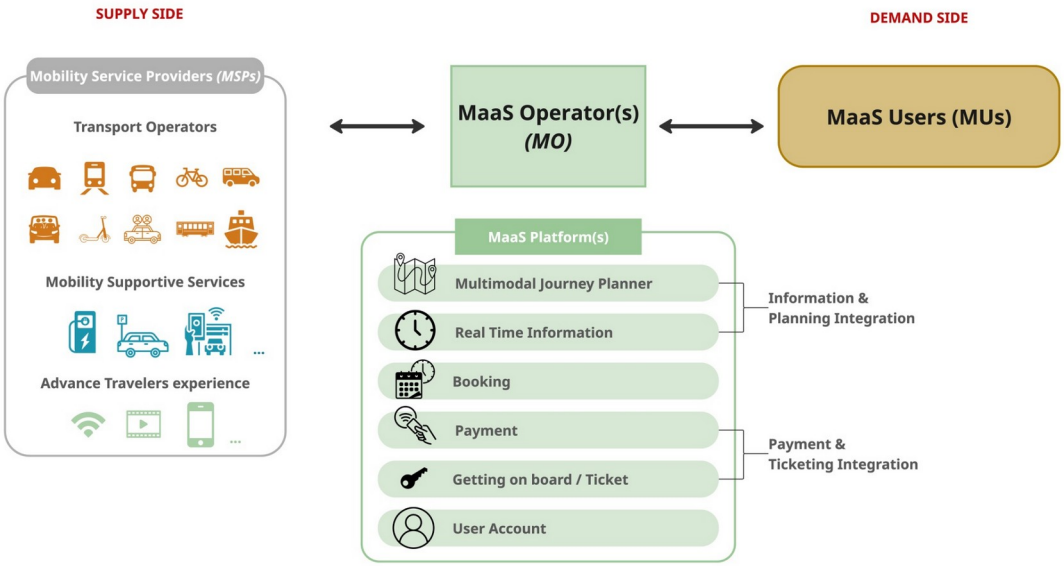


Figure 2.22. The suppliers of the MaaS Concept, recaptured from (Kamargianni et al., 2016)

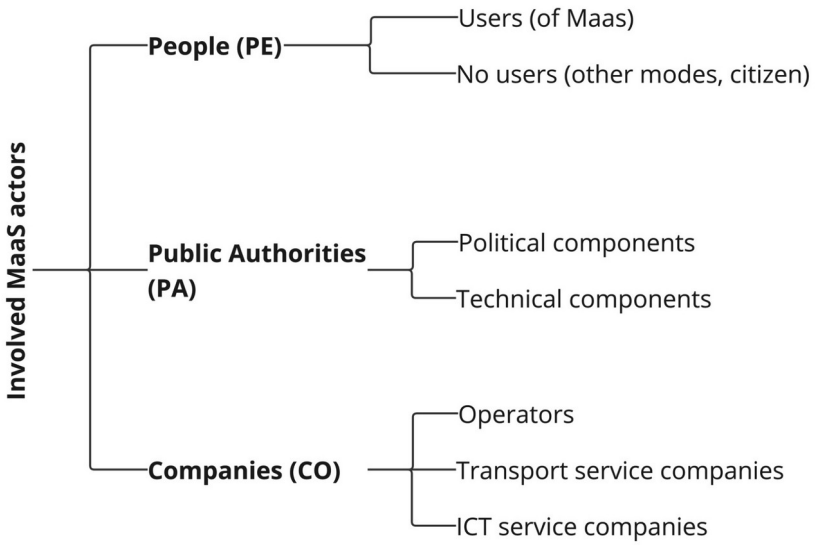


Figure 2.23. Involved MaaS actors, adapted from (Vitetta, 2022)

2.3.2. Environmental and social implications of MaaS

2.3.2.1. The reduction of carbon emission through MaaS

Urban transportation systems substantially contribute to greenhouse gas emissions, primarily owing to a reliance on private automobiles. Recently, MaaS has been proposed as a solution to mitigate these emissions by promoting alternative or multimodal modes of transport. Integrating various transportation options into a single accessible platform, typically designed as a mobile application, could encourage a broader range of commuters to choose public transit, cycling, or walking instead of driving private cars. Recent studies have reported that promoting MaaS might help cities or communities achieve sustainability objectives, including reducing carbon emissions and road traffic congestion (C.-F. Chen & He, 2023b; Gan & Li, 2025; Zhao et al., 2020), as well as decreasing private car use (Chang et al., 2025; C.-F. Chen & He, 2023b; El Mustapha et al., 2024; Gan & Li, 2025; J. Liu et al., 2023; T. Tang et al., 2025; Zhao et al., 2020). Additionally, it has the potential to promote healthier lifestyles among residents (El Mustapha et al., 2024; T. Tang et al., 2025; Zhao et al., 2020).

Since the introduction of MaaS, several European cities have integrated the concept into their local transportation networks and promoted it among residents. For instance, in the Helsinki metropolitan area, the first commercial smartphone-based MaaS (Whim, a pioneering app) has been implemented at a relatively advanced level. Several studies indicated that through promoting the Whim app around Helsinki, total car trips fell markedly (Weinreich & Riihelä, 2019) and the number of public transport-trips increased (Hammond, 2023).

2.3.2.2. Cases review

The emergence of MaaS has brought new opportunities and challenges to the development of transportation systems in various countries. At present, many countries and regions are also actively working on the implementation and application of MaaS, and numerous MaaS mobile-applications and services have been launched around the world (refer to Appendix A. Summary of MaaS products and services with their implementation status under review).

However, implemented or trial systems that effectively fulfil the essential objectives of MaaS remain exceptionally rare. Moreover, a comprehensive MaaS system that unifies all accessible mobility services within an urban setting has not yet been achieved. As a result, the efficacy of a fully functional MaaS system remains mostly uncertain. The following analysis of six examples aims to synthesise and evaluate the operational performance of various experimental systems and prototype implementations produced in recent years, emphasising the reduction of dependence on private automobiles.

1. UbiGo

From the perspective of time, UbiGo can be considered one of the earliest MaaS trial projects. In 2012, Sweden launched a smart mobility project (Go: smart)[2]with the objective of promoting better sustainable mobility alternatives by demonstrating new business models to investigate the possibility of providing new mobility services to reduce the need for people to own cars. As part of the two-year project, UbiGo developed and tested an innovative mobility broker service to promote and reward sustainable travel within cities. The "broker of everyday travel" could provide customised travelling services to each traveller for every trip (Karlsson et al., 2016).

During the UbiGo pilot in Gothenburg, researchers tracked the effectiveness of the app through questionnaires, interviews, and travel logs, and compared it with travellers who did not participate in the experiment (Sochor et al., 2015b). The findings indicated that users of this MaaS service are primarily motivated by curiosity, and for continued use, they must be enticed by elements such as ease of use and cost-effectiveness. At the same time, by comparing the change rates of travel modes of participants before and during the experiment (see Table 2.2), it can be found that the MaaS service model may reduce dependence on private cars and increase the frequency of choosing public transport and active mobility alternatives.

The UbiGo experiment in 2014 found that the expectations of MaaS matched the results, in that travellers accepted the concept of "travel service buffet", reducing the number of private cars, and increasing pre-travel planning. However, there are also aspects where the expectations did not match the results of field practice, such as the reduction in car use exceeding expectations, the business model of travel agents and service

2 https://closer.lindholmen.se/en/closer-together-sustainable-transport-solutions (accessed Feb 2025)

providers, back-end management and smartphone-based platforms (Linton & Bary, 2019; Sochor et al., 2015a).

Table 2.2. The change rate of each travel mode of the experimental participants, adapted from (UITP, International Association of Public Transport, 2019)

Modes	**"Before" travel diary** from UbiGo participants (n=40) (%)	**"During" travel diary** from UbiGo participants (n=36) (%)
Walk/run	25	-5
Bicycle	10	+35
Private car	25	-50
Car sharing	2	+200
Tram	15	+5
Bus (local)	15	+35
Bus (express)	3	+100
Train	2	+20

2. SMILE

SMILE was a pilot project in Vienna from 2013 to 2015, during which 1,000 participants evaluated an integrated mobility application prototype from 2014 to 2015. The application (see Figure 2.24) facilitates the booking and purchasing of various mobility services, including public transit, shared bikes and taxis (Linton & Bary, 2019). The user interfaces of the SMILE mobile platform exemplify operational simplicity and functionality. Users could use the platform to manage multimodal trips including several modes of transport while obtaining information on pricing, duration, and CO_2emissions (Winkelhake, 2022).

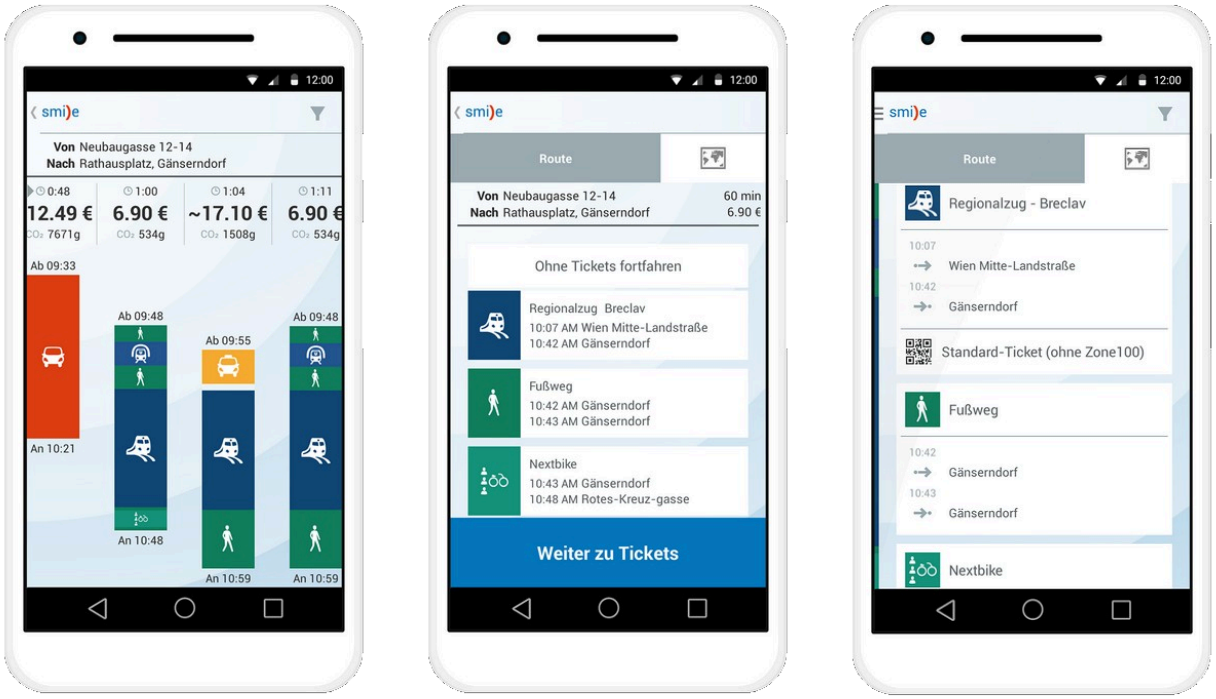


Figure 2.24. SMILE application interfaces of routine details (left), multimodal guide (middle), tickets information (right) (source: SMILE mobility)

The implementation of SMILE altered travellers' mode of transportation selection (Linton & Bary, 2019). Forty-eight per cent of respondents increased their use of public transport comprising 26% for urban public transport and 22% for railways, while 15% and 10% increased their use of car sharing and bicycle sharing, respectively. A further 7% and 6% increased their use of taxis and bicycles respectively, and 4% increased their use of electric car sharing and electric bicycles. 22% of respondents reduced their reliance on taxis, 21% curtailed the usage of private vehicles, and an additional 6% decreased their use

of bicycles. SMILE has decreased the overall volume of automobile travel.

3. Whim

Whim, known as the pioneer of commercialising the MaaS model, is a collaboration between MaaS Global (a Finnish startup company) and transportation service providers. By 2020, Whim had integrated the services of 11 transport service providers in Helsinki, including Helsinki Region Transport (HRT) and Hertz, and had also launched a WeChat applet, "Helsinki City Travelling Bag" (see Figure 2.25), for Chinese tourists. Whim analyses users' travel patterns based on their travel preferences and recommended the best travel options and routes for users, including public transportation, taxis, car rentals, shared bikes, shared cars and other local transportation services. The specific user interfaces are shown in Figure 2.26. As of 2022[3], Whim has been applied in cities in many countries, including Helsinki, Birmingham, Antwerp, Vienna, Singapore and the greater Tokyo area.

The discontinuation of Whim's services following MaaS Global's bankruptcy in 2024 represents a significant setback in the MaaS ecosystem. The early Whim studies remain informative, but the collapse of the operator should temper how they are read. Those evaluations measured subscriber behaviour during a period of venture-funded growth, and the subsequent bankruptcy suggests that the pricing which produced those results was not commercially sustainable. What Whim demonstrates most clearly is that technical integration alone does not make a MaaS operator viable, and that the commercial model carrying a platform is as much a design condition as the interface itself.

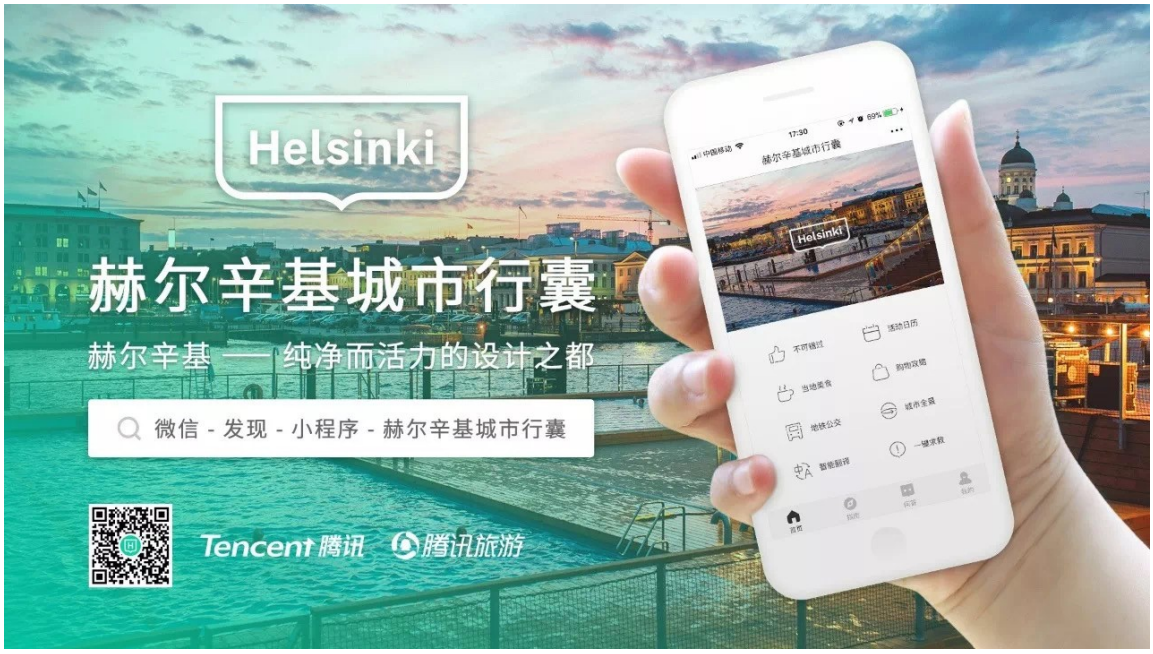


Figure 2.25. Promotion page of "Helsinki City Travelling Package" for Chinese tourists in Helsinki (source: Helsinki Airport official WeChat account)

3 https://whimapp.com (Accessed in December 2022)

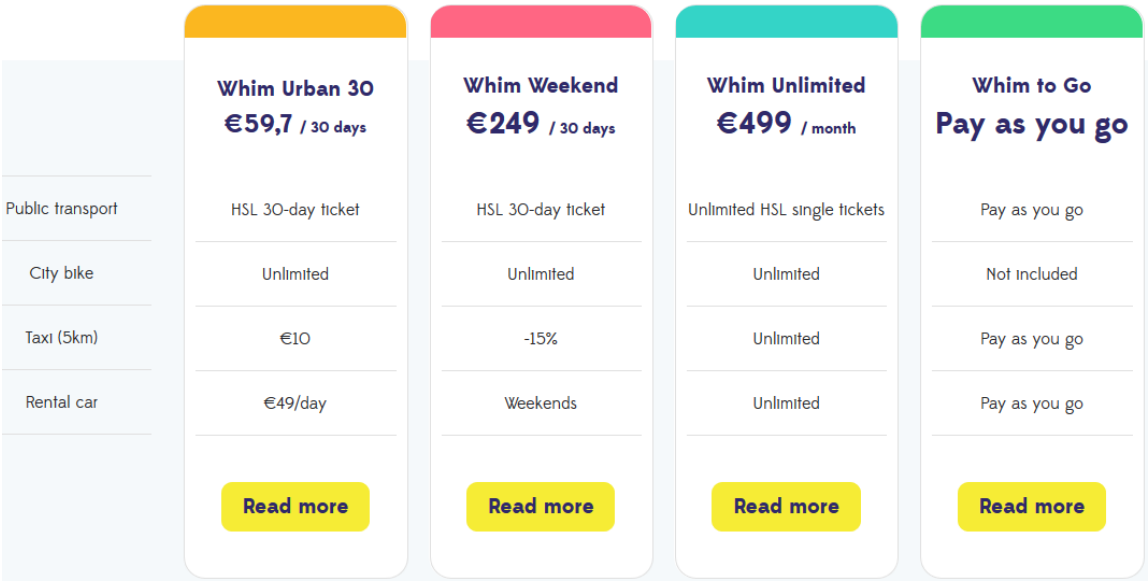


Figure 2.26. Subscription pricing tiers for Whim, illustrating how a commercial MaaS operator bundles multimodal access into monthly packages instead of selling individual trips (source: VentureBeat)

4. Other experiments

Besides the previous implementations of the MaaS concept, the successful implementation of MaaS with local users requires the seamless integration of multimodal transport alternatives, which cover each stage of journey, including customised journey planning before travelling, seamless or real-time transportation data suggestion on the way, and rewards or incentives at the end of each journey for continuing usage. The following cases are pilot projects which implemented MaaS-ready or similar concepts in real-life local settings, to investigate the barriers of MaaS to enhance sustainable travel.

a. Cambridge

Bridging the gap between first and last mile of travelling is one of the principal factors in enhancing public transport and promotion of MaaS to communities. In 2016, Atkins executed a proof-of-concept MaaS experiment in Cambridge (called Zume) for a duration of two weeks (Bakshi & Heathcote-Márcz, 2018), including ten participants, primarily assessing the first and last mile (Alfaris et al., 2024; Mohiuddin, 2021) shuttle service (parking and public transit shuttle). Atkins collaborated with a local taxi company to offer a carpooling service (up to three passengers) from a nearby location in the morning to transport travellers to the parking and public transportation station and provide a return service from the station to their homes in the evening (the last mile). The trial was free and mainly took place at a location 12 miles away from the centre of Cambridge.

The trial offered a total of 119 services, and at least three individuals had never used the park-and-ride service for their daily commuting prior to this. Service satisfaction was rated at four out of five, and 75% of those owning more than two automobiles said they would contemplate relinquishing the second car. This demonstrates the capacity of MaaS to diminish automobile ownership and usage. The Zume experiment shows that if effective last-mile services are

available, travellers remain inclined to transition from driving private cars to public transportation. However, the issues of MaaS still remain in its inflexibility, necessitating ongoing enhancements in the public transportation network (Butler et al., 2021; Lesh, 2013).

b. Manchester

In 2018, Atkins and Transport for Greater Manchester (TfGM) partnered to execute a MaaS experiment (called MaaS Evolution) in the Manchester region, providing MaaS services to 39 participants, enabling them to access a multi-modal personalised transport solution. The experiment aimed to understand user behaviours and perceptions of MaaS (Wray, 2019). The MaaS project in Manchester incorporates transportation services, including public transit (buses and rail), demand-responsive taxis, car-sharing clubs, bicycle-sharing systems, and demand-responsive minibuses. The trial encompassed trip planning, real-time information updates, and integrated ticketing services. It aimed primarily to ascertain whether MaaS enhances traveller satisfaction, while also evaluating its potential advantages and

A total of 39 participants were involved, and each was eligible to receive a complimentary one-month travel card (Linton & Bary, 2019).

c. Belgium

In mid-2017, a MaaS pilot project was initiated in Ghent, Belgium, with a test duration of two and a half months (Storme et al., 2020). The study recruited 100 car drivers as participants, primarily employees of Ghent University, to investigate how monthly MaaS packages might facilitate the reduction of private vehicle usage. The experimental findings indicated that participants were inclined to use MaaS services (refer to Figure 2.27), especially public transport and shared-car services. Nevertheless, a substantial reduction in private car use remained challenging. Although participants had strong desires to diminish their automobile reliance and were offered incentives, the shift from private cars faced considerable barriers. These challenges were particularly evident in leisure travel, as alternative mobility options were inadequate to satisfy participants' diverse requirements.

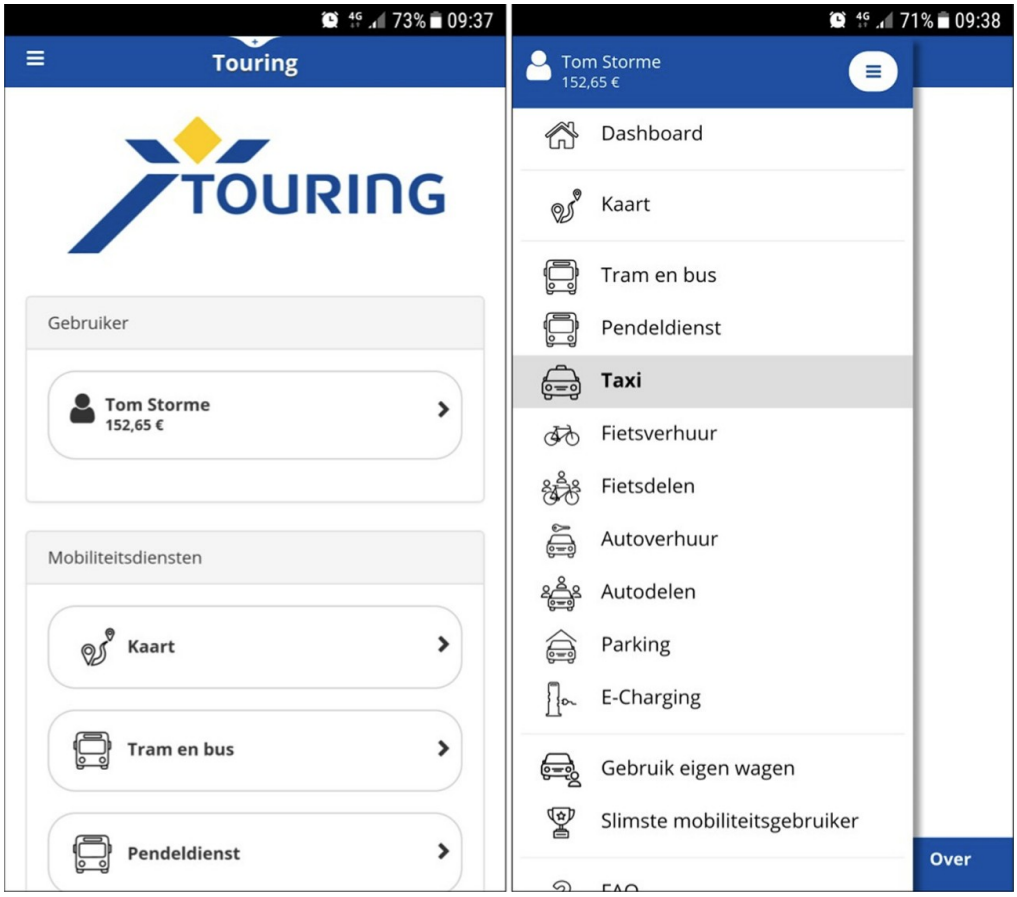


Figure 2.27. Smartphone application interfaces in the Belgian MaaS study (Storme et al., 2020)

These studies provided empirical evidence of the challenges of shifting entrenched commuting habits, even under optimised experimental conditions with motivated research participants (Schwanen et al., 2012; Verplanken & Roy, 2016). This finding emphasises the persistence of routine travel patterns despite intentional interventions for behavioural adaptation, such as customised travel plans or incentive-based MaaS platforms (Walker et al., 2015). The challenge of affecting deeply rooted travel habits, particularly driving private cars, indicates that initiatives aimed at shifting routine travel behaviour may necessitate more extensive and varied design strategies that consider deliberate decision-making and automatic responses formed through repetition.

2.3.2.3. Summary

The six cases (refer to Table 2.3) support a narrower conclusion than their individual reports suggest. Their combined evidence base is in the order of two hundred participants across trials running from two weeks to two years, and in every case those participants volunteered for a mobility service they were already curious about. The three trials that measured mode change, including UbiGo, SMILE and Ghent, report reductions in the frequency of private car use, yet the Ghent study, which had the largest sample and focused specifically on existing car drivers, found that a substantial reduction in private car use remained difficult even where incentives were offered. These MaaS projects showcase how digital integration of diverse mobility options, including public

transportation, shared micro-mobility, ride-hailing, and car-sharing services, makes multimodal journeys easier to access, plan and pay for, which is a necessary condition for an alternative to private car ownership and not a demonstration that one has been achieved.

The evidence indicates that effectively implemented MaaS systems address several critical factors that typically reinforce car dependency by integrating multiple transportation alternatives into a single digital platform such as smartphone applications, to improve multimodal journey planning, booking and unified payment process (Hensher et al., 2020; Jittrapirom, Caiati, Feneri, Ebrahimigharehbaghi, Alonso-González, et al., 2017).

Despite the sustainability challenges faced by pioneering MaaS implementations, the evidence from Whim indicates that while the conceptual foundation holds promise for urban mobility transformation, the business models and operational framework require further refinement to ensure long-term viability. Moreover, the prospect of diminishing automobile reliance through extensive mobility integration remains substantial, even as the sector persistently adapts its strategies for implementing the MaaS concept across various urban and suburban environments, including university campuses. Table 2.3 sets the six trials against a common frame, so that scale, integration, measured outcome and evidence limit can be read across cases instead of case by case, and records the lesson each one contributes to the design developed in Chapters 6 and 7.

Table 2.3. Comparative evaluation of the six MaaS trials reviewed, showing scale, integration achieved, measured outcome, the main limit on the evidence, and the lesson carried into this study.

Case (scale, duration)	Integration achieved	Measured outcome	Main evidence limit	Lesson carried into this study
UbiGo, Gothenburg (40 participants, 6 months)	Booking and payment across public transport, car share, bike share and taxi	Self-reported fall in private car use, with increases in cycling and bus use	Volunteer sample, short trial, no follow-up after the trial closed	Curiosity brings users in, but ease of use and cost keep them, so the design must serve continued use instead of first use (Section 6.3.2)
SMILE, Vienna (1,000 participants, 12 months)	Booking and payment across public transit, bike share and taxi, with CO_2 information shown per option	48% increased public transport use, 21% reduced private car use	Self-reported, no control group, no measure of persistence	Presenting emissions alongside time and cost is workable at scale, which supports the feedback design in Section 6.3.2
Whim, Helsinki (commercial service, 2016 to 2024)	Full subscription bundling across eleven providers	Reported reduction in car trips among subscribers	Results produced under venture-funded pricing, and the operator later became insolvent	The commercial model is itself a design condition, which supports institutional hosting instead of subscription bundling

Case (scale, duration)	Integration achieved	Measured outcome	Main evidence limit	Lesson carried into this study
Zume, Cambridge (10 participants, 2 weeks)	First and last mile shuttle linked to park and ride	119 trips delivered, and 75% of multi-car households would consider giving up a second car	Very small sample, free service, two-week duration	Solving the last mile changes willingness to leave the car, which supports the first-mile and last-mile staging in Section 7.1
MaaS Evolution, Manchester (39 participants, 1 month)	Planning, real-time information and integrated ticketing across five modes	No outcome reported in the published account	No results available	Comparable trials often report intent instead of outcome, which is why this study evaluates with participants over time (Chapter 8)
Ghent (100 car drivers, 10 weeks)	Monthly packages combining public transport and car share	Willingness to use the service was high, but substantial car reduction was not achieved	Short trial, and leisure travel was poorly served by the available options	Motivation alone does not shift entrenched car use, which is the finding behind the habit-focused design position in Section 6.2

2.4. MaaS at universities

"No college or university campus is an island. The degree to which the college community uses alternate modes of transportation is influenced by the availability of transportation options other than an automobile."

- Toor (2004)

Since the 1990s, universities have been urged by various scholars to adopt emerging roles in society for the creation of a sustainable future (Berchin et al., 2021; Chebrolu & Dutta, 2021; Cuesta-Claros et al., 2022; L. Li, 2019). Higher education (HE) institutions, as hubs of knowledge creation and innovation, are distinctly equipped to drive sustainability transitions by modelling and promoting sustainable practice on their campuses (Lozano et al., 2013; Tilbury, 2011). As discussed above, sustainable mobility is a crucial emphasis area owing to the substantial environmental effects associated with transportation patterns at universities (Toor & Havlick, 2013; Zhou, 2016). MaaS provides universities with a strategic opportunity to reduce transport-related emissions and encourage behavioural changes towards more sustainable travel modes through integrated multimodal transportation solutions for their students and staff (Hensher et al., 2021; Ho, Hensher, & Reck, 2021). The core of the concept is the synchronisation of transport initiatives with the United Nations Sustainable Development Goals (SDGs), especially Goal 11, which promotes inclusive, safe, and sustainable urbanisation (Chakraborty et al., 2021).

2.4.1. University campus settings

The concept of MaaS has arisen as a transformative approach to urban and suburban transportation, especially in the context of university campuses. This section examines contemporary research on the implementation and implications of MaaS in suburban and university campus environments. Section 2.4.3 then assesses what that research can and cannot establish for a dispersed suburban setting such as Clayton. The surroundings of university campuses possess distinct characteristics, encompassing geography, demographics, traffic patterns, and connections with adjacent towns. Consequently, numerous research initiatives designate university campuses as sites for assessing sustainable mobility options. Tomás et al. (2021) emphasised that university campuses can serve as essential traffic attractors and generators, thus presenting opportunities for implementing MaaS concepts that might mitigate traffic congestion and reduce environmental impacts from roads.

MaaS signifies a transformative change from conventional transportation paradigms, prioritising the accessibility of mobility services and integrating several transport modes into a unified service platform, such as mobile applications or websites. Ribeiro et al. (2021) contend that this transition encompasses a change from ownership to usage, fostering a culture of accessibility and enhanced quality of life. This is particularly relevant in suburban areas and university campuses, where the integration of diverse transport options may substantially enhance accessibility for

students and residents. Moreover, other research highlights the necessity of modern digital solutions, open data access, and interoperable payment systems for facilitating seamless mobility options (S. Wright et al., 2020a).

University campuses provide important settings for studying and implementing the MaaS concept. By integrating diverse transportation modes, such as public transport, ride-sharing, bike-sharing, carpooling, and micro-mobility options, MaaS can provide seamless, flexible, and sustainable mobility solutions tailored to the needs of these communities. A recent study explored the accessibility of a MaaS-like concept specifically tailored for university communities, identifying the prospects for integrating various transport services to enhance mobility for students and staff (Le Pira et al., 2023).

MaaS is developing as a viable means of bridging first-mile and last-mile connections in suburban and university campus environments. Diverse approaches have been suggested, encompassing autonomous vehicles (Kalda et al., 2024; S.-W. Kim et al., 2017), bike-sharing (Cho & Shin, 2022), and other shared mobility services (Shaheen & Chan, 2016). These solutions seek to expand public transport catchment areas and enhance accessibility (Kriswardhana & Esztergár-Kiss, 2024; Mohiuddin, 2021). The advancement of MaaS applications and data exchange platforms can improve the integration of diverse transport modes, thereby enhancing the accessibility and seamless connectivity of public transportation networks (Kalda et al., 2024). Introducing MaaS, which involves integrating emerging mobility services, may increase use of pedestrian and bicycle infrastructure and may align with regional emission reduction goals (Lesh, 2013; Mohiuddin, 2021).

2.4.2. Cases of MaaS in the university contexts

SMART COMMUTE at the University of Maryland, USA

The University of Maryland (UMD) has implemented the Smart Commute programme, a comprehensive initiative aimed at promoting sustainable transportation alternatives among its campus community. The programme integrates various local transportation options including public transport, carpooling through Uber and Lyft shared rides, car sharing through UMD Zipcar, bicycles, scooters, and electric vehicles, into a unified online platform accessible to students, faculty, and staff. Specifically, the programme introduced the Commute Tracker app (developed with RideAmigos) and the Smart Commute Dashboard (see Figure 2.28), enabling users to find ride matches, track their trips, and earn rewards for eco-friendly travel choices. Through offering incentives such as preferential parking, discounted permits, and rewards for trackable sustainable trips, the programme aims to reduce reliance on private cars and mitigate traffic congestion and carbon emissions from roads around the campus.

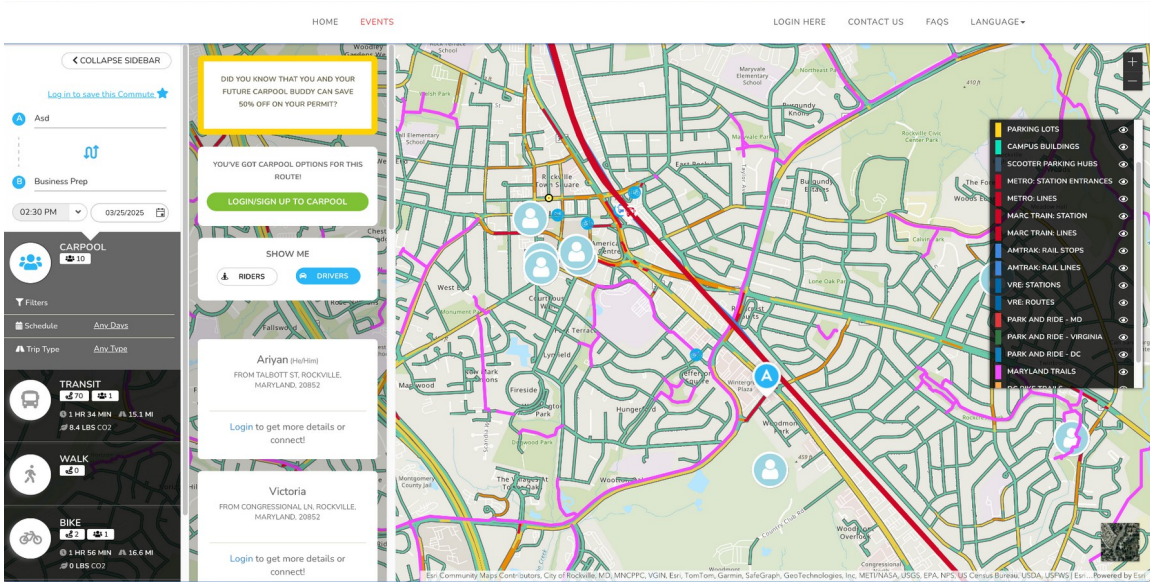


Figure 2.28. Snapshot of Smart Commute Dashboard from Transportation services, Maryland University (2024)

According to the 2022 Maryland Commuter Survey (Harvey et al., 2023), the findings indicate a potential contribution of Smart Commute to reducing vehicle miles travelled (VMT), alongside the increased adoption of remote and hybrid work schedules. The Smart Commute programme addresses these patterns by offering incentives for sustainable travel choices. The reduction in vehicle miles travelled falls in the same period as the growth of remote and hybrid schedules, so the contribution of the platform cannot be separated from the contribution of people travelling less often for reasons unrelated to it. What the case establishes securely is that a campus can operate an integrated tracking and incentive system at scale, not that such a system alters mode choice.

Tripi at the University of Sydney, Australia

Tripi is Australia's first MaaS pilot programme tailored to urban and university campus settings (see Figure 2.29). Like Whim, which integrates regional trains, buses, taxis, shared bicycles, and rental cars within one application, Tripi combines locally available modes, including public transport, ride sharing, bicycles, and campus shuttles, on a digital platform. Whim's Pay As You Go, Urban Travel, and Unlimited Travel subscription plans informed Tripi's user focused strategy, which offers adaptable options for students and staff with different travel requirements. Tripi seeks to reduce reliance on private vehicles through live scheduling, trip planning, and recommendations intended to support environmentally sustainable travel. These functions may help alleviate congestion and reduce carbon emissions near the campus.

Similar to Whim's trial data, which identified public transport as the primary mode of MaaS users' journeys (Weinreich & Riihelä, 2019), preliminary findings for Tripi indicate a shift towards multimodal commuting options among students residing in suburban areas. Furthermore, its integrated system facilitates last-mile connectivity through bike-sharing and

ridesharing, reflecting Whim's focus on first-mile and last-mile solutions. The standing of this evidence differs from the Maryland case. The Tripi findings are preliminary and drawn from a pilot instead of a completed evaluation, so they indicate a direction of travel instead of a magnitude of effect. However, akin to the difficulties faced in Whim's "Unlimited Travel" option (Lyons et al., 2020a), Tripi's subscription tiers necessitate ongoing enhancement to better correspond with shifting user mobility trends and preferences over the long term.

ODIN PASS at the University of Queensland, Australia

ODIN PASS, initiated in July 2021, is a transport app shaped by the MaaS concept, established at the University of Queensland (UQ) to enhance transportation efficiency for students and staff around urban environments. Like many MaaS trial programmes, ODIN PASS integrates several local transport modes, including buses, trains, ferries, rideshare services, and micro-mobility, into a unified digital platform (see Figure 2.30). ODIN PASS accommodates the varied commuting behaviours of the UQ community, which includes local and international students living in different areas of Brisbane, by providing tiered subscription plans and pay-as-you-go pricing (see Figure 2.31).

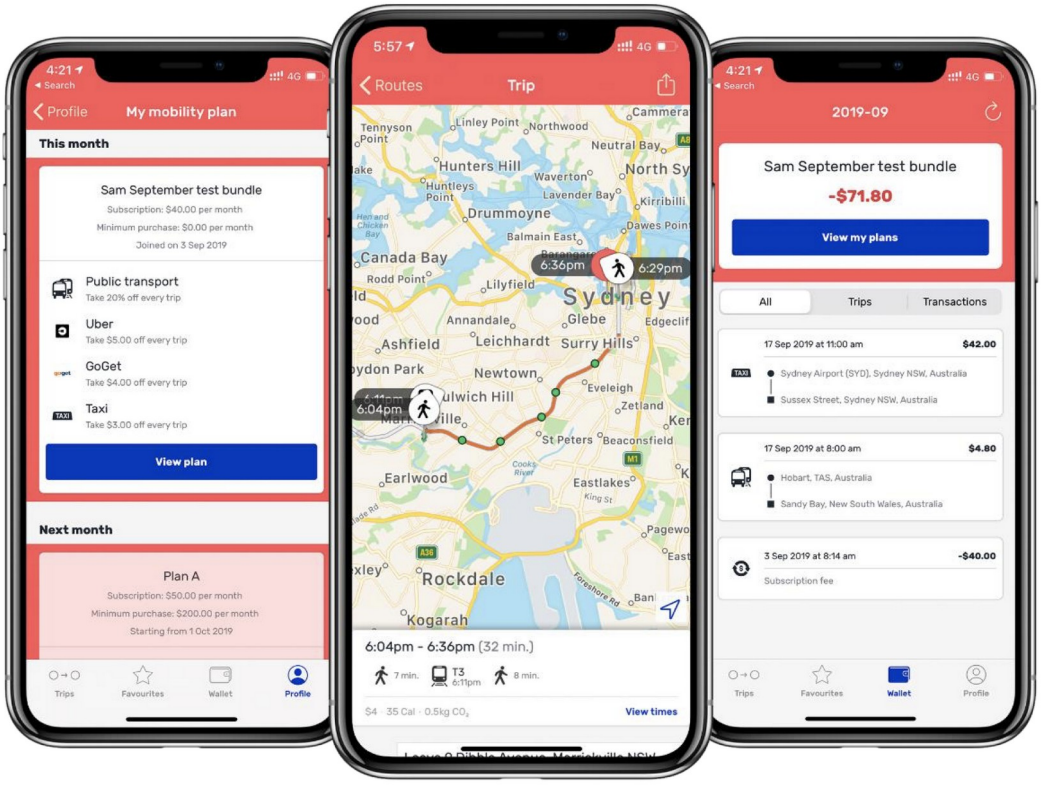


Figure 2.29. Interfaces of the Sydney MaaS app (Marlen, 2021)

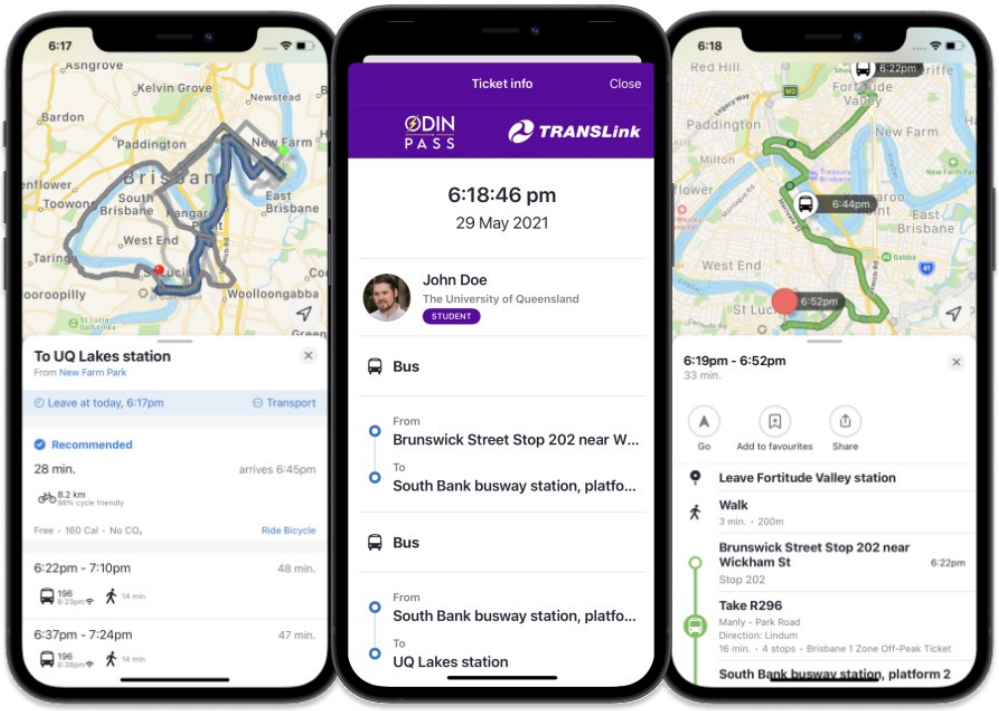


Figure 2.30. Interfaces of the ODIN PASS app (source: ODIN PASS official website)

As a research-oriented trial programme, the design of ODIN PASS relies on data processing techniques that are central to MaaS, including cloud computing, analytics, and visualisation tools, which together enhance the capacity of the system to collect and analyse substantial volumes of mobility data (Rahbar et al., 2022).

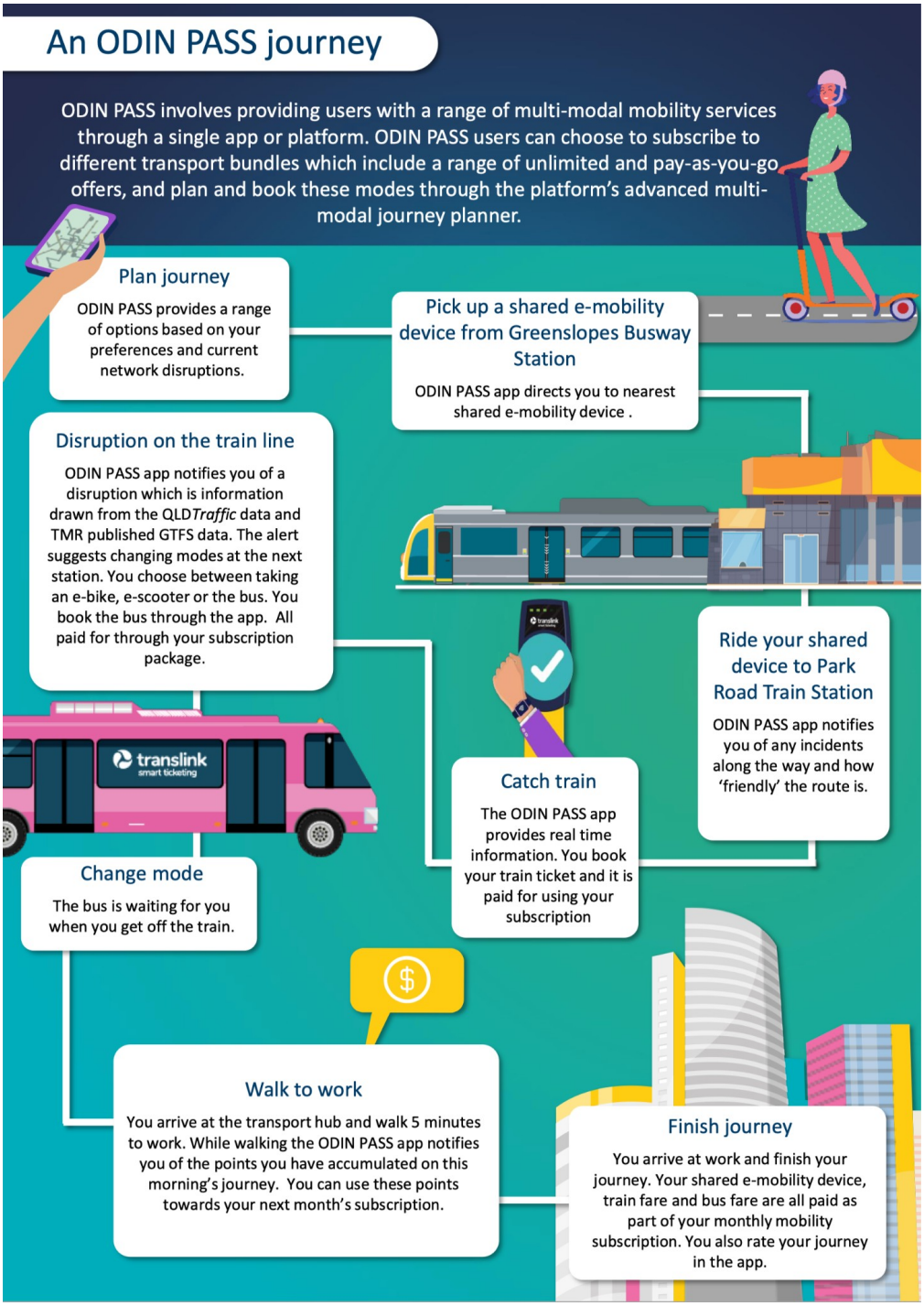


Figure 2.31. The journey map of ODIN PASS digital platform (source: ODIN PASS website, accessed Oct 2023)

IPET Platform at the University of Roma Tre, Italy

The IPET (Individual Persuasive Eco-Travel Technology) application was developed at the University of Roma Tre to promote the adoption of sustainable transportation alternatives among student populations. The study, conducted with a voluntary sample of fifty transport engineering students at Roma Tre between November and December 2017, aimed to evaluate the self-monitoring systems (B. J. Fogg, 2003) and the methodology of IPET. The application incorporated GPS data acquisition, Personalised Travel Plan (PTP), and gamification elements (Piras et al., 2018; Sottile et al., 2021a). In the domain of human-computer interaction,

the researchers (ibid.) developed a mobile application framework incorporating persuasive communication strategies (in pop-up message format) and gamified reward points (see Figure 2.32). The results indicated an 8.1% shift to sustainable transport options among students provided with personalised travel plans, accompanied by heightened awareness of carbon emissions and health-related issues, such as caloric expenditure from active mobility (Sottile et al., 2021b).

2.4.3. Challenges in implementing MaaS in suburban university contexts

Read across the four cases reviewed above, the evidence they provide is uneven, and the unevenness follows the setting. Maryland shows that a campus can run an integrated incentive and tracking system at scale, but its reported reduction in vehicle miles travelled coincides with the growth of remote and hybrid schedules, so the effect of the platform cannot be isolated from the effect of fewer trips being made at all. Tripi and ODIN PASS show technical integration across multiple operators, yet the Tripi findings remain preliminary, and ODIN PASS is reported through its data infrastructure instead of through any published account of changed mode choice. IPET is the only case reporting a measured behavioural outcome, an 8.1% shift among students given personalised travel plans, and it is also the smallest, conducted with a self-selected group already willing to change how they travelled.

Three contextual differences limit the transferability of these case studies to the present research, namely urban form, participant characteristics, and temporal scope. The studies conducted in Maryland, Sydney, Brisbane, and Rome examined mobility systems operating in relatively dense urban environments, where transport services were sufficiently frequent for multimodal integration to represent the principal design challenge. In a dispersed suburban setting such as Clayton, by contrast, the binding constraint is often the absence or poor temporal alignment of alternative transport services. The studies also differ in their treatment of participants. None of the four projects focused on international students as a distinct population, and IPET recruited volunteers already predisposed to changing their travel behaviour, thereby avoiding the recruitment challenges addressed in this research. Finally, because none of the four cases examines travel behaviour beyond the intervention period, they provide limited insight into



Figure 2.32. The indicator bar of the user's sustainability level (Piras et al., 2018)

whether any behavioural change persisted after the trial ended, leaving the question of long-term adoption unresolved.

These three conditions, namely dispersed service supply, a population still learning an unfamiliar transport system, and the question of what survives the loss of novelty, define what the present study investigates and does not assume. They are also the reason the study proceeds through participatory workshops with international students instead of through a further trial of an integrated platform.

2.5. International student mobility behaviours

2.5.1. Factors influencing mode choices of university students

University or college campuses are important in sustainable transportation, owing to their geographical location, their demographic composition, and the transport demand they generate (Tolley, 1996; Geller, 2003; Nelson et al., 2023). As students form the majority demographic group at university campuses, the travel characteristics of university students have attracted increasing research attention in recent years. Much of this research indicates that driving a private car remains one of the most common means of reaching campus for university students, particularly in suburban areas.

The geographical layout of residential accommodations, categorised as on-campus or off-campus, substantially shapes the mobility patterns and transport barriers encountered by university students (Eom et al., 2009; Khattak et al., 2011a; Shafi et al., 2020b; Zhou, 2016). Zhou (2012) analysed university students' commute and housing behaviours in Los Angeles, the U.S., a car-dependent society, and found that their choice of transport mode depends on gender, living status, age, and social influences, so that having friends living nearby increases public transport use. In addition, Khattak et al. (2011b) conducted a survey-based study and found that 42% of off-campus students at four major universities in Virginia drove alone to campus.

Psychological factors operate alongside these spatial and demographic influences, and they do not form a single category. Awareness of consequences and ascription of responsibility derive from norm-activation accounts of pro-environmental behaviour, which Section 2.6.2 examines in more detail, whereas habit belongs to a separate explanatory tradition in which repeated action in a stable context becomes automatic and largely independent of deliberation (Schwanen et al., 2011a). The distinction carries a design consequence. Interventions addressed to awareness and responsibility presuppose that a decision is being made, whereas habitual travel proceeds with little conscious evaluation, so information alone appears unlikely to disturb it (Verplanken & Roy, 2016). Habit research further indicates that automaticity weakens when the context supporting it is disrupted, which opens a period in which alternatives may be reconsidered (Cui et al., 2017; Dashtestaninejad et al., 2023; Soltani et

al., 2019b). Relocation to study in another country constitutes such a disruption, and the following section examines what is known about the travel behaviour of international students during that period. Car-use habit, awareness of consequences, and ascription of responsibility have each been found to affect the car driving behaviours of university students (Setiawan et al., 2017).

2.5.2. Sustainable mobility behaviours of international students

Universities present characteristically advantageous conditions for implementing sustainable mobility transition experimentations targeting international students. As bounded institutional contexts with significant control over their transportation infrastructure, parking policies, and community engagement, universities serve as safeguarded areas for niche experimentation (Verlinghieri & Schwanen, 2020). The claim that international students can act as change agents in this setting is asserted more often than it is tested, and the studies that do exist disagree about whether the relevant difference is cultural, structural, or a matter of unfamiliarity with the local transport system.

International students represent a distinct demographic group in hosting countries, characterised by their diverse origins, their motivations for studying overseas, and their socio-economic effects on the host country. Countries such as Australia, the United States, the United Kingdom, Canada, and New Zealand have been particularly successful in attracting international students (Khawaja & Stallman, 2011; Oduwaye et al., 2023) and have dominated the international degree student market for decades, primarily due to the valued reputation of higher education in these Anglophone nations and the prevalence of English as the global language of education (Oduwaye et al., 2023). As a leading destination for higher education around the world, Australia has experienced a steady increase in its international student population since 2005. Between January and September 2024, a total of 824,951 international students were enrolled in Australian educational institutions (Department of Education, 2023), reflecting the country's sustained attractiveness as a global academic hub. In recent years, researchers have identified issues affecting international students in Australia, such as mental health issues (Maharaj et al., 2024). Cross-cultural studies of international students' travel remain few, however, and there is limited research on sustainable mobility behaviour change or on design practice with international students at suburban university campuses.

In Australia, Shafi et al. (2020b) conducted a study at Monash University to compare the travel attitudes and mode choices of Asian students with those of Australian students. Their findings indicate that attitudes play a substantial part in shaping travel mode preferences. Specifically, Asian students generally have more positive attitudes towards car

ownership, associating it with success and an improved quality of life, whereas Australian students tend to have a more neutral perspective. These findings align with the research of Belgiawan et al. (2014), who conducted a comparative survey study among undergraduate students in Indonesia and China. Their study revealed that students from these developing countries demonstrate a stronger aspiration to purchase a car compared to their counterparts from developed countries such as the Netherlands or the United States. Placed side by side, however, the two studies offer different explanations of the same pattern. Shafi et al. (2020b) attribute the difference to attitudes carried into the host country, whereas Belgiawan et al. (2014) locate it in the economic conditions of the country of origin, where car ownership still signals achieved status. The distinction matters for design. An attitude formed elsewhere may be revised through experience of an unfamiliar transport system, whereas a status meaning attached to car ownership is unlikely to shift in response to better journey information alone. Neither study follows its participants over time, so which explanation holds after arrival remains open.

The adoption of digital mobility service platforms, such as MaaS, has been widely explored in the context of urban transportation (Hensher et al., 2020; Kriswardhana & Esztergár-Kiss, 2023a). As discussed above, MaaS offers a platform or system that integrates mobility services, such as public transportation, shared bikes, shared scooters, and carpooling, promising economic and environmental benefits (Y. Li & Voege, 2017; Schikofsky et al., 2020). Studies indicate that university students, especially international students, are receptive to MaaS and sustainable transport options (Leontev, 2023; Shafi et al., 2020).

However, most of these studies address the student population in general and do not treat international students as a distinct group. A smaller body of work does examine features specific to international students, such as understanding their unique travel patterns in host-countries (Gardiner et al., 2013; Shafi et al., 2020b; Varasteh et al., 2015; H. Wu et al., 2015), and cultural diversity (Forbes-Mewett & Nyland, 2008), environmental attitudes, their destination image[4](C.-F. Lee & King, 2016), and their potential contribution to environmental impacts in global higher education (Shields, 2019). The challenges and potential opportunities presented by international students in the context of university campuses could further inform the adoption and implementation of MaaS, with the goal of reducing car dependency among this demographic.

As discussed above, the adoption of MaaS among university students remains largely unexplored, and it faces several challenges, including car dependence (ibid.), low awareness of sustainability (Panko & Sharma, 2017), cost concerns and language barriers. The success of

4 Destination image may be defined as "the sum of beliefs, ideas, and impressions that an individual has of a destination" (Crompton, 1979).

MaaS depends on changing attitudes towards private car ownership and incentivising responsible use. International students are facing unique challenges in accessing university support services, which could extend to MaaS adoption (Guilfoyle et al., 2012). MaaS nonetheless shows promise for shifting young adults, and international university students in particular, towards sustainable travel options, although its implementation requires careful attention to user needs and preferences (Cassar, 2023).

The literature reviewed here therefore supports a weaker claim than is often made of it. It establishes that international students arrive with mobility preferences formed elsewhere, that they encounter distinctive barriers of cost, language, and unfamiliarity, and that campuses hold the policy levers capable of altering the conditions of travel. It does not establish that this group will act as agents of transition, since none of the studies reviewed follows international students through the period in which travel habits in the host city are formed. Treating them as change agents is therefore a proposition to be tested instead of a finding to be applied, and the present study treats it as such.

Despite growing research on sustainable transport solutions for university campuses, a substantial gap remains in understanding how digital platform design influences the mobility behaviour change of international students. As discussed, international students undergo a distinctive process of acculturation in host countries, including adaptation to local transport services. Table 2.4 synthesises the key factors influencing travel behaviour change and identifies the central gap motivating this research. Existing evidence mainly concerns interventions that universities can directly control, such as transport infrastructure, parking management, and incentive schemes. By contrast, factors most relevant to international students' everyday mobility, including cultural adaptation, social integration, and participatory service development, are supported by comparatively limited evidence. This uneven distribution of knowledge matters analytically, because the literature tends to privilege institutional levers for behaviour change over the situated experiences of those expected to adopt sustainable mobility practices. By engaging international students as co-designers throughout the research process, this study addresses that imbalance and generates knowledge grounded in participants' lived mobility experiences.

Table 2.4. Key Factors Influencing Travel Behaviour Change. (Author's own elaboration)

Strategy Type	Success Factors	Barriers	Actions	Resources
Infrastructure Development	Investment in public transport and cycling facilities	Limited funding, existing car-centric infrastructure	Prioritise sustainable transport infrastructure in campus development plans	(Rérat, 2021; Soltani et al., 2019a)

Strategy Type	Success Factors	Barriers	Actions	Resources
Policy Interventions	Parking restriction, promotion of sustainable modes	Resistance to change, conflicting institutional goals	Integrate sustainability into university policies, including travel grants and admissions	(Soltani et al., 2019a)
Education and Awareness	Climate change education, transparent information and/ knowledge about environmental impacts	Lack of awareness, disconnect between knowledge and action	Incorporate sustainability education into all disciplines, provide clear information on travel impacts	(Panko & Sharma, 2017)
Cultural Integration	Consideration of cultural preferences in mobility planning	Diverse cultural backgrounds, varying mobility cultures	Develop culturally responsible mobility solutions, engage international student communities in planning	(Soltani et al., 2019a; Shafi et al., 2019, 2020a, 2023)
Incentive Programmes	Financial incentives for sustainable transport options choices, disincentives for unsustainable options	Budget constraints, potential pushback from students	Implement rewards systems for sustainable travel	(S. Hu et al., 2024; Xiong et al., 2020)
Technology Adoption	Implementation of bike-sharing and carpooling systems, smart mobility solutions	Initial costs, technological barriers	Invest in user-friendly, accessible, sustainable mobility technologies	
Collaborative Approach	Partnerships between universities, local authorities, and transport service providers	Coordination challenges, differing priorities	Establish multi-stakeholder mobility working groups, involve students in system design processes	

2.5.3. International students as a potential user group of MaaS

International students constitute a substantial yet underexplored potential user group for MaaS platforms. Compared to local commuters, international students, as temporary residents in host countries, are generally in a transitional phase where daily mobility routines are continually developed, tested, and adjusted. This matters because MaaS is more than a technical or commercial proposition. It is a service commitment that depends on users altering how they plan, pay for, and combine trips across various modes through a unified digital interface (refer to discussion in Chapter 2.3.1.1). What makes a group distinct for MaaS is therefore not a demographic label but the state of its travel habits, and international students are distinctive on exactly that measure, since they arrive without established local routines and form them within their first months of residence, which is also the period in which they are most open to overarching sustainability objectives, such as reduced reliance on automobiles.

Despite the rapid expansion of MaaS research, the evidence base predominantly reflects general population

samples, pilot studies, and early adopters, leaving many specific populations underrepresented, among them suburban employees in a European setting (S. Wright et al., 2020b). Reviews indicate that user-related studies are prevalent, although practical questions about the engagement, support, and retention of diverse user groups through interface and service design remain underexplored compared to technical and market discussions. In this context, international students constitute a distinct MaaS user group in which transport access constraints, information needs, and everyday commuting decision limits intersect, yet MaaS research has rarely treated them as a primary focus of analysis.

The condition that most plausibly connects international students to MaaS adoption is their temporary relocation, together with the learning about local transport services that relocation requires of them. The formation of travel behaviour among international students during transnational relocation remains inadequately explored, despite the growing size of this population. This exegesis treats the following as propositions to be tested and not as established findings. The first is that temporary residents rely on existing mobility options, instead of buying a car, since ownership carries set-up and running costs that a stay of two to four years does not readily justify. The second is that travel habits formed before arrival, together with where a student chooses to live, shape both public transport use and satisfaction with it, while perceiving technology as beneficial for navigation can enhance the perceived ease of using the local public transport systems during the early periods of residence. These relationships indicate a substantial role for digital travel assistance, such as a MaaS platform, during the "newcomer" phase.

The proposition should also be tested against the reasons this group may be a poor fit. International students are price sensitive, and the subscription bundles trialled by UbiGo and Whim assume a willingness to commit to monthly spending that a student budget may not support. They are also temporary, so a platform relying on habit formation has a short window in which to work, and whatever behaviour it establishes leaves the city when the student does. Their influence over the transport system is limited, since they neither vote in local elections nor sit on the bodies that set service levels. Acknowledging these limits is what separates a defensible claim about this group from the assumption that a novel user group must be a promising one, and Section 9.5 returns to them as limitations of the study.

2.6. Digital platforms and behavioural change

The user perspective is an essential component of MaaS systems. Recently, numerous research studies have highlighted that user acceptance is important in the implementation of the MaaS concept in everyday commuting practice.

2.6.1. Factors influencing the adoption of MaaS platform

2.6.1.1. What is a digital platform?

The ubiquity of digital platforms in contemporary society represents a substantial change in how people engage with fundamental elements of everyday life. These technological intermediaries have evolved from their original role as basic facilitators of online interactions to become critical infrastructures supporting transportation systems, business transactions, social networks, and resource distribution mechanisms (Helmond, 2015; van Dijck, 2018). The platformisation of transportation services (Gaponenko & Hvoevskaya, 2022; Manullang et al., 2024; Stehlin et al., 2020; Toymentseva et al., 2024), as shown by companies such as Uber and Lyft, has transformed urban mobility patterns through algorithmic matching of transport service providers and users, thereby contesting conventional regulatory frameworks and labour relations (Rosenblat & Stark, 2016; Srnicek, 2017). What these platforms share is a mechanism and not a sector, namely the insertion of an intermediary that reorganises how supply and demand meet and captures the data generated by every match (Parker et al., 2016). That mechanism carries consequences beyond efficiency, since an intermediary that arranges the matches also determines what users see and on what terms their data is used, offering new opportunities for connection while also creating intricate challenges concerning privacy, information integrity, and cognitive health (Zuboff, 2019). The sharing economy applies the same mechanism to underused private assets, and MaaS is best understood as that mechanism applied to transport, where an intermediary reorganises access to vehicles and services the user does not own, raising the same questions of governance and equity (Schor & Attwood-Charles, 2017; Trebor Scholz, 2016).

Although the definitions of digital platforms vary, they can be categorised into three viewpoints, namely technical, informational, and socio-technical perspectives (Molla et al., 2022b). This study employs a design intervention within the socio-technical perspective, defining digital platforms as intricate configurations of business processes, information systems, and service architectures that enable interaction among stakeholders within the ecosystem to create and provide innovative solutions (Ruggieri et al., 2018). This integrated approach recognises that digital platforms extend beyond technological configurations and incorporate social processes, governance structures, and value-generating dynamics in business-to-business, business-to-customer, or consumer-to-consumer interactions. Adner (2017), platforms operate within broader "ecosystems [that] are defined by the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialise". This viewpoint acknowledges that digital platforms enable transactions and coordinate value generated through intricate interdependencies among diverse participants (Cennamo & Santalo, 2013; Kapoor & Agarwal, 2017; Wareham et al., 2014).

2.6.1.2. What factors influence behavioural adoption of MaaS

Current research on MaaS behavioural impacts remains limited and fragmented (Lyons et al., 2020a). Kamargianni et al. (2016) identified the need to investigate both holistic MaaS systems and their component elements regarding potential consumer adoption barriers and enablers. In addition, Giesecke et al. (2016) provided a user-centred perspective on MaaS (see Figure 2.33), which illustrates the complex mixture of internal and external factors that affect individual mobility choices or behaviours. Early behavioural evidence from the UbiGo trial, whose recruited cohort numbered close to two hundred participants, indicated diverse adoption patterns contingent upon established mobility routines (Sochor et al., 2015b).

These preliminary findings can be interpreted through established behavioural change frameworks. Fogg's Behaviour Model holds that MaaS adoption requires motivation, ability, and effective triggers (B. Fogg, 2009). Similarly, the Theory of Planned Behaviour (Ajzen, 1991, 2015) emphasises attitudes, subjective norms, and perceived behavioural control to provide insights into how the design of the MaaS platform might support adoption and intervene in everyday commuting practices. For instance, in the UbiGo study, various user profiles had differing adoption rates, supporting the idea that pre-existing attitudes and perceived control over transport choices substantially affect behavioural intentions. This research project takes up that task instead of deferring it, applying both frameworks to what participants reported in Workshops #1 and #2 and reporting in Chapter 8 where each proved insufficient for a group still learning an unfamiliar transport system, an approach consistent with calls to examine adoption across varied user groups in particular local contexts (Jittrapirom, Caiati, Feneri, Ebrahimigharehbaghi, Alonso-González, et al., 2017; Kayikci & Kabadurmus, 2022; Ye et al., 2020).

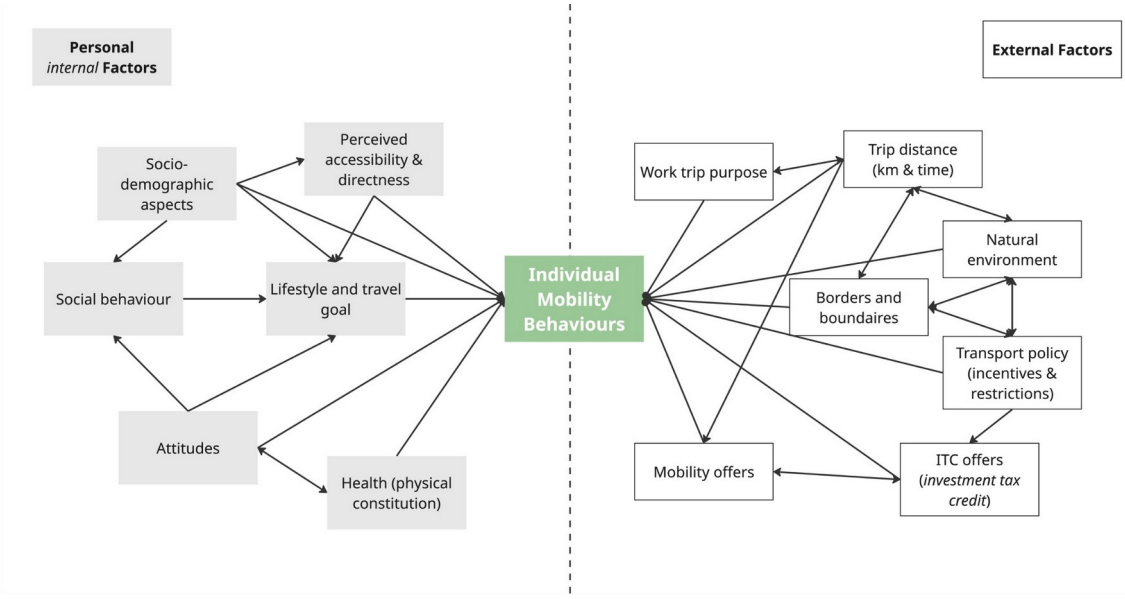


Figure 2.33. Factors influencing individual mobility behaviour, redrawn from (Giesecke et al., 2016)

2.6.2. Theories of behavioural change

Three bodies of work explain how digital systems change travel behaviour, and they locate the difficulty in different places. Persuasive technology is designed to change people's attitudes or behaviours (B. J. Fogg, 2003). Fogg (ibid.) proposed a behavioural model that identifies three elements affecting human behavioural change, namely motivation, ability, and prompts (see Figure 2.34). Fogg (2009) further explains that a target behaviour occurs only when three conditions converge, namely core motivation (for example pleasure or pain, hope or fear, and acceptance or rejection), simplicity of the process (for example time, money, physical effort, brain cycles, social deviance, and departure from routine), and a behavioural trigger (for example a spark, a facilitator, or a signal). This theoretical framework provides guidance for understanding how design interventions may support behavioural change towards sustainable travel (Anagnostopoulou et al., 2020a; V. Sunio & Schmöcker, 2017a).

Recently, (Oinas-Kukkonen, 2010, 2013) proposed the concept of behaviour change support system (BCSS), which builds on persuasive technology (B. J. Fogg, 2003). (Oinas-Kukkonen, 2010) explained the BCSS as an "information system designed to form, alter, or reinforce attitudes, behaviours or an act of complying without using deception, coercion or inducements." With the development of emerging technologies and the Internet, a web- or smartphone-

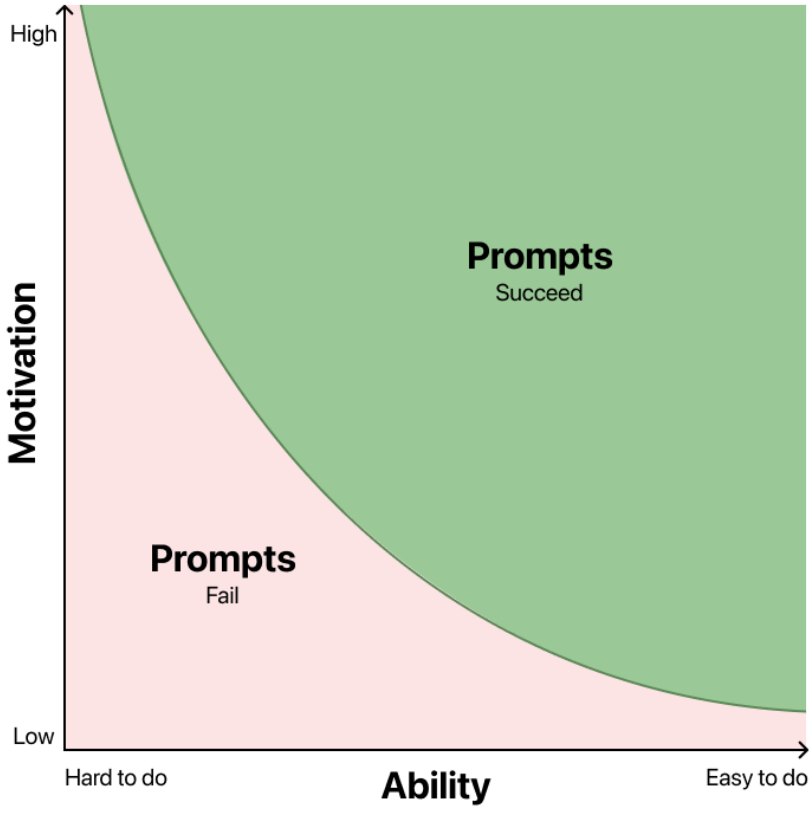


Figure 2.34. Fogg's behaviour model, redrawn from B. Fogg (2009)

based platform is often used as a BCSS (V. Sunio & Schmöcker, 2017a). Furthermore, with the widespread and pervasive use of smartphones in contemporary societies, mobile-based digital platforms can be leveraged to deliver large-scale and cost-effective behaviour change interventions (Lathia et al., 2013). BCSSs have been implemented in various domains in recent years, for instance health care and wellbeing (Hall et al., 2022; Pimsen et al., 2024; Vachon et al., 2024), energy conservation (Varela Pérez et al., 2022; C. Zhang & Chen, 2021), education, and sustainable travel (Andersson et al., 2018b; Prost et al., 2013; V. Sunio & Schmöcker, 2017b).

V. C. Sunio (2018) designed a menu-based system, named Blaze, to investigate the feasibility of mBCSS (mobility Behaviour Change Support System) for sustainable campus (home-school) commuting in his PhD thesis. Sunio adopted a persuasive systems design model into the Blaze application, which supported a positive impact of the mBCSS in reducing car use by facilitating a transition through various stages of behaviour change. These stages include pre-decision, pre-action, action, and post-action. The evaluative field study at Ateneo de Manila University in Quezon City, the Philippines, involved a small group of student participants, and it indicated that an mBCSS may support sustainable home-to-campus commuting among students.

Sunio (ibid.) evaluated these principles under the broader domain of Travel Demand Management and delivered them as a menu of ten standard interventions ranging from goal setting and travel time information to motivational messages and diagnostic reports. Read against the two accounts above, this is not simply a further example but a different position. Fogg (2009) treats behaviour as a momentary event, so the design task becomes arranging motivation, ability, and a prompt at one point in time. Sunio (2018) treats the same behaviour as a staged transition through pre-decision, pre-action, action, and post-action, so the design task becomes sustaining support across weeks instead of seconds. Andersson et al. (2018a) work at a third level again, treating the platform as a container for behaviour change techniques whose selection is itself the design decision. The staged account is the closest to the present study, yet the evidence supporting it comes from a small participant group at a single dense urban campus in Quezon City, where transport supply and trip distances differ considerably from a dispersed suburban precinct such as Clayton. What none of the three accounts settles is how the momentary and the staged views combine within one interface, or how a design sustains engagement once the novelty of an application has passed. That unresolved question is carried into the participatory workshops of this study, and it is why the evaluation reported in Chapter 8 asks participants about continued engagement instead of initial adoption.

As discussed above, to mitigate the negative effects of road transportation in terms of air pollution, congestion and climate change, MaaS has been taken up

in both scholarship and field trials across urban areas and demographic groups, with the primary objective of encouraging multimodal travel. While the concept of MaaS has potential opportunities to address the design challenges, behaviour changes have also been identified as an essential factor to achieve a modal shift from cars to multimodal commuting, such as walking, cycling or public transport (Andersson et al., 2018c). The authors proposed a conceptual framework (see Figure 2.35) that guides the implementation process of behaviour change techniques into smartphone applications to create a behaviour change support system (BCSS). Based on this statement, (V. Sunio & Schmöcker, 2017a) summarised three categories of support that facilitate sustainable travel behaviour, namely primary task support, dialogue support, and social support.

Taken as a group, this literature supplies mechanisms instead of settings. It establishes that a mobile platform can carry primary task support, dialogue support and social support, but the supporting studies were conducted largely in healthcare, energy conservation and dense urban travel contexts, with users who were not at the same time adapting to an unfamiliar transport system. The question for the present study is therefore not whether such support works, but which of these mechanisms hold when the user is new to the city, the campus is dispersed, and the alternative to driving is a longer and less legible journey.

2.6.3. Digital platform features and sustainable mobility behaviour

Mobile app-based digital platforms also are important in promoting sustainable travel behaviour. These platforms leverage emerging technologies to facilitate multimodal travel, enhance user engagement, and foster responsible travel practices. The effectiveness of these applications depends on several factors, including the availability of diverse transport modes, the accessibility

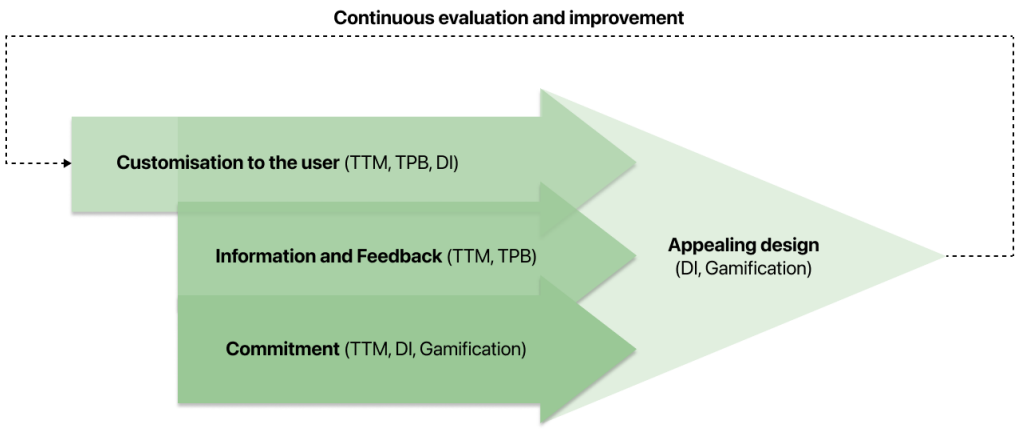


Figure 2.35. A conceptual model for combining behavioural change techniques with ICT to create a BCSS, redrawn from (Andersson et al., 2018a)

of services for broader demographic groups, and the integration of smart urban planning principles.

Accordingly, MaaS applications are gaining wider recognition as a means of promoting sustainable mobility (Feneri et al., 2022; Schubert et al., 2020), with worldwide policy makers and MaaS providers highlighting their potential to trigger a modal shift. Specifically, from this perspective, MaaS platforms can be conceptualised as mobility Behavioural Change Support Systems (BCSS), and their 'success' can be gauged by their contribution toward changing transport behaviour to be more sustainable. As V. Sunio & Schmöcker (2017c) highlighted that multimodal integration is one of the core components of mobility behavioural change (MBC), which aligns it with the foundational framework of the MaaS concept. In addition, the researchers indicated that social interaction is another critical factor that facilitates and reinforces these changes in mobility behaviours. The MaaS level-4 integration reflects this essential principle by targeting social goals aimed at facilitating substantial and durable shifts in transport mode (Sochor et al., 2018).

To effectively shape or influence user mobility behaviours, MaaS applications need to meet the principles of persuasive technology regarding the design, structure, features, and interfaces (Anagnostopoulou et al., 2018). The design of the user experience and the user interface shapes how users interact with the digital platform and how readily they shift towards more sustainable mobility choices. Casquero et al. (2022b) identify six factors that make an application attractive and that shape its role in the mobility decisions of users. These are the sociodemographic characteristics of the user, the availability of real-time information, streamlined processes for registration, planning, scheduling, and payment, options for personalisation, the presence of in-application support features, and a community or platform for peer-to-peer engagement.

2.6.4. Theory of Planned Behaviour

2.6.4.1. Understanding driving behaviours through TPB

The Theory of Planned Behaviour (TPB) originates in the Theory of Reasoned Action (TRA) (Ajzen, 1991; Fishbein & Ajzen, 1975) and followed the Reasoned Action Approach (RAA) (Fishbein & Ajzen, 2011), which posits that individuals are rational and make decisions through systematic evaluations of all available information (Moody et al., 2018). TPB posits three primary constructs, namely attitudes, subjective norms, and perceived behavioural control (PBC), which together shape behavioural intentions and in turn influence actual behaviour.

The TPB provides a framework for understanding the determinants of travel behaviour and designing interventions, such as digital mobility service platforms, to facilitate the future adoption of sustainable travel decision-making (Kerr et al., 2010). The theory posits that behavioural intention is shaped by

attitudes towards the behaviour, subjective norms, and perceived behavioural control (see Figure 2.36). In the literature, many studies treat TPB as a basis for behaviour change strategy and as a methodological framework, although Ajzen (2015) clearly stated that "...the TPB is in fact not a theory of behaviour change. Instead, it is meant to help explain and predict people's intentions and behaviours. Nevertheless, the theory can serve as a useful framework for designing effective behaviour change interventions."

In this research project, by examining attitudes, social norms, perceived control, and intentions in relation to everyday commuting, TPB supports prediction of the intention to travel without a car and informs strategies for reducing car dependence (Anagnostopoulou et al., 2020a). The following discussion explores how TPB can be adopted and extended in the context of sustainable MaaS interventions among international students at Monash Clayton campus, and addresses its predictive power, the measurement of practices, methodological challenges, integration with other theories, and insights from prior studies.

2.6.4.2. TPB for predicting and influencing MaaS adoption

The TPB posits that the behaviours of individuals are essentially driven by their behavioural intention (Conner, 2020; Kerr et al., 2010), which in turn is shaped by three psychological antecedents, namely attitude towards the behaviour, subjective norms, and perceived behavioural control (see Figure 2.36). Several studies have applied TPB to sustainable mobility contexts, providing insights and validation relevant to this research context. For instance, Bamberg (2003) utilised the framework of TPB to investigate university students' public transport usage, revealing attitudes and perceived behavioural control (PBC) as the primary determinants of behavioural intention (Haustein & Hunecke, 2007). Similarly, Abrahamse et al. (2009) found that TPB predicted intentions to reduce car use among university populations, identifying subjective norms and attitudes as the principal determinants. Furthermore, Donald et al. (2014) applied TPB to evaluate commuting patterns among university students and

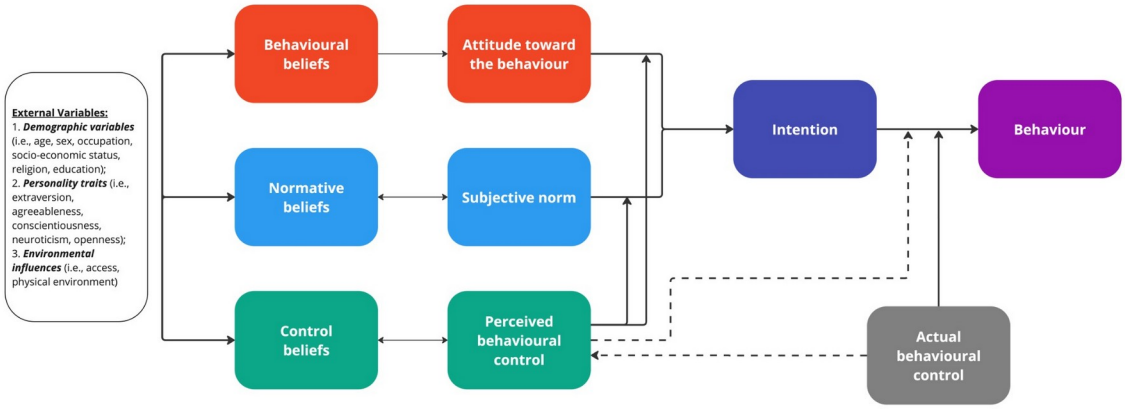


Figure 2.36. Theory of Planned Behaviour (TPB), redrawn from Ajzen (2019).

staff in the UK, emphasising the substantial influence of subjective norms, which are shaped by institutional regulations and peer practices. The study highlighted the importance of social networks and institutional contexts in shaping sustainable transport behaviours, proposing specific measures to leverage normative effects. Table 2.5 compares the strengths and limitations of the methodologies used to evaluate MaaS acceptance across these studies.

Table 2.5. SWOT analysis of MaaS acceptance evaluation methodologies, redrawn from (Costa & Delponte, 2025:8)

Methodologies	Strengths	Weaknesses	Opportunities	Threats
Stated Preferences and Intention Experiments	Allows the deepening of users' WTP and WTA, as well as users' preferences for mobility bundles	Results require to be related to actual and future mobility behaviours	Suitable for non-clustered users and high numbers of respondents	Lack of reliability of obtained results regarding innovative mobility practices, such as MaaS
In-depth and semi-structured interviews	Potential investigation of users' knowledge, perception, and acceptance towards MaaS	Results may not be representative of the whole population	Deepens understanding of motivational factors that are central to sustainable modal shift	Methodology restricted to limited number of respondents
Workshops	Allow the investigation of needs, perceived barriers and opportunities related to specific users' groups	Results may be difficult to be standardised and up-scaled	Suitable for the test of digital apps in terms of User Interface and Experience	Considering fragmented users' groups, niche needs and requirements may be overrepresented
TAM, UTAUT and UTAUT 2	Provides insights on users' mobility behaviour and consequent WTA innovative and disruptive mobility solutions through a standardised approach and pre-defined categories	Since results are related to a limited group of categories, such as perceived usefulness, or perceived ease of use, individual and motivational issues may be under-rated	Cluster analysis may be performed, thus supporting mobility bundles design	Contexts-related variable is not considered, so that demand-supply interactions are not significantly valued

2.6.5. The components of persuasive mobile application design

The preceding case reviews indicate that MaaS providers and researchers commonly offered or tested mobility services through digital platforms such as smartphone apps. This can be attributed to the proliferation of the globalised Internet and advancements in communication technologies over the past decade, which have rendered smartphones a ubiquitous necessity in modern society. The *Mobile Economy 2024* report by (GSMA, 2024) highlights that the continued development of the mobile industry, coupled with the increasing global adoption of smartphones, has the potential to significantly contribute to the advancement of the Sustainable Development Goals (SDGs) by fostering positive societal and economic impacts. Consequently, smart mobile applications have emerged as one of the most influential and widely adopted platforms or digital enablers that shape and transform people's everyday lives in various domains (Costa & Delponte, 2025; Di Martino et al., 2024; M. Lee et al., 2018). For instance, health management (Aldenaini et al., 2020; Orji & Moffatt, 2018; Stavrositu & Kim, 2018), disability support (Mukhtar, 2016), social connection, and sustainable travel

behaviour (Anagnostopoulou et al., 2020a; Cellina, Bucher, Veiga Simão, et al., 2019; dos Reis et al., 2022; Piras et al., 2018; Y. Wu et al., 2022).

Design may facilitate and incentivise the adoption of sustainable travel behaviours through comprehensive analysis of persuasive factors (Anable, 2005). Several studies found that mobile applications integrating design features can promote sustainable travel decision-making and encourage eco-friendly travelling. These studies can be categorised into three domains, specifically (1) nudging & rewarding mechanisms, (2) gamification, and (3) social networking (refer to Appendix B. Studies reviewed on mobile app-design for mobility behavioural change). The following discussion uses selected cases of mobile application design to explain how these components of persuasive mobile application design support sustainable travel decision-making. Table 6 sets out the components of persuasive mobile application design used in that discussion.

Table 2.6. Schematic diagram of the components of persuasive mobile applications design

Design strategies	***Fogg's behaviour Model***	***Theory of Planned Behaviour (TPB)***	***Evidence from the literature***
Nudging & rewarding mechanisms	With ability (simplification) and motivation (pleasure/pain) elements	Addresses perceived behavioural control through personalisation or customisation	Personalisation and customisation of incentive rewarding systems increased both perceived ability and motivation, affecting behavioural intention (Aldenaini et al., 2020; Hamari & Koivisto, 2015; Orji et al., 2017; Sundar et al., 2015)
Gamification elements	Provides triggers at opportune moments while building motivation	Reinforces attitudes through performance feedback and related information	Gamified feedback (i.e., leaderboard) develops positive attitudes (Hassan et al., 2021; Mohammed et al., 2024) and serves as effective triggers when synchronised with user ability level (Jiang et al., 2022; Johnson et al., 2016; Yue & Guo, 2023)
Mobile Social Networking (MSN)	Leverage social acceptance/rejection as powerful motivators	Strengthens subjective norms through social influence	Commitment features combined with social engagement elements increased motivation and trigger effectiveness (Aslam et al., 2018; Oinas-Kukkonen & Harjumaa, 2009)

Digital platforms, including mobile phone-based and website-based ones, can promote behavioural changes towards more sustainable transportation modes (Anagnostopoulou et al., 2020b; Andersson et al., 2018d; Casquero et al.,

2022a; Cellina, Bucher, Mangili, et al., 2019). In the areas of urban mobility, smart cities, and digital service design, three interrelated strategies have been recognised as crucial for engaging users: gamification, nudging, reward mechanisms, and mobile social networking.

As visualised in the conceptual framework (see Figure 2.37), three strategies intersect and reinforce one another in the design of effective mobility service platforms with the aims of promoting sustainable mobility. Gamification utilises components such as points, badges, challenges, and leaderboards to enhance engagement and promote appealing sustainable travel choices (S. Deterding et al., 2011; Wells et al., 2014; Yen et al., 2019). Nudging and incentive systems, grounded in behavioural economics (Thaler & Sunstein, 2021), use financial prompts and feedback to guide users towards environmentally sustainable habits while maintaining autonomy in decision-making on daily commuting. Immediate feedback on emissions reduction and financial incentives for choosing alternatives to driving may promote the utilisation of public transport, active mobility, or shared transportation modes such as car-pooling or rental cars (B. Zhu et al., 2020). The fusion of gamification and nudging provides a holistic design approach to influencing sustainable travel choices (Duarte et al., 2024).

Mobile social networking utilises digital connectivity to promote behavioural change through peer influence and social comparison. Mechanisms that facilitate the sharing of mobility routines and the comparison of social groups centred on low-carbon travel options have demonstrated the ability to promote eco-friendly norms and enhance social accountability.

The overlap among these three domains signifies a fundamental collection of evidence-based strategies, substantiated by scholarly research and the review of practical cases. These strategies elucidate significant potential to affect mobility behaviours, especially when integrated seamlessly into the user experience of a digital service platform. In contrast, strategies located at the margins of this intersection may indicate either context-specific interventions or novel approaches that necessitate additional empirical research.

To summarise, the diagram highlights areas where design strategies are undefined, indicating opportunities for the practical interventions of this research endeavour. The triadic model functions as a synthesis of existing design strategies on mobility behavioural change and a heuristic tool for directing the future evolution of digital platform design that facilitates sustainable mobility transitions among the target demographic group.

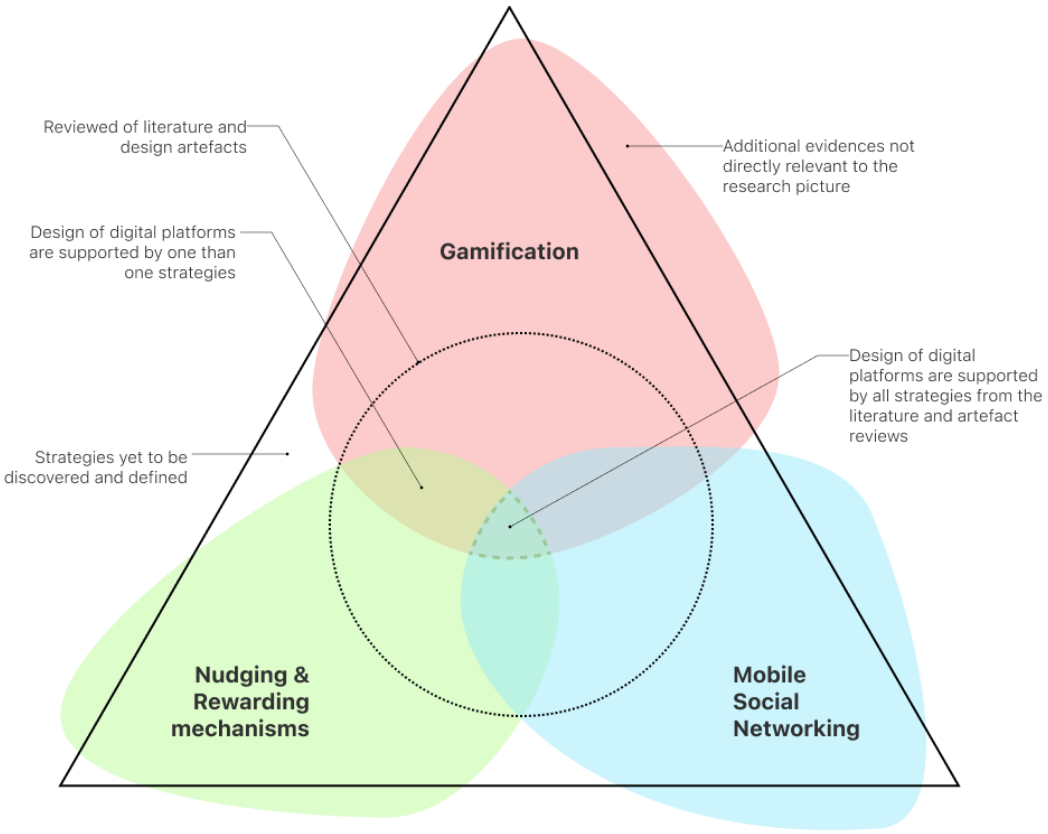


Figure 2.37. A visualised triangulation of three reviewed design strategies that enhance sustainable mobility transition from literature and artefacts (author's own summary)

2.6.5.1. Nudging and rewarding mechanisms

Nudging and reward mechanisms are among the most significant components of apps using personalised, context-aware design, and have shown positive impacts in guiding transportation choices (Christensen et al., 2022). Several studies revealed that personalised, context-aware nudging and rewards systems effectively guide users towards more sustainable transportation choices through various digital engagement strategies. The interventions included personalised route suggestions with persuasive messages, points, and rewards schemes, and challenges. For instance, (Ricci et al., 2020) conducted a group survey with 686 participants in Italy and found that 75.1% expressed their willingness to make changes to their journey patterns (to more sustainable alternatives) to receive an incentive, with discounts on their energy bills reported as the most popular reward option.

The application of monetary incentives to influence travel decisions towards sustainable and multimodal options has progressed from theoretical proposals to practical trials. One example is the incenTrip project, which uses financial incentives to encourage more sustainable travel decisions (Xiong et al., 2020). The project was funded by the U.S. Department of Energy's Advanced Research Projects Agency for Energy and developed by the University of Maryland. It has been implemented in the Washington, DC, and Baltimore area (see Figure 2.38). The incenTrip application presents several transport options,

including public transport, shared cars, designated drivers, and bicycles. Users may compare the estimated time, distance, and cost of each option with live information about traffic conditions, accidents, special events, and weather.

A central feature of incenTrip is its use of personalised green point incentives to influence and coordinate users' travel decisions (S. Hu et al., 2024; M. Yang et al., 2022). Users receive mode, departure time, and route recommendations and may earn points that can be exchanged for gas cards, public transport, electronic toll credits, bicycles, and Uber rides. The application also supports driving practices intended to reduce fuel consumption. Zhen et al. (2025) used bilevel optimisation modelling to examine the integration of carbon credits into incentive based travel demand management systems and reported substantial reductions in users' carbon emissions.

In recent years, with the emergence of blockchain technologies and the foundational principles of Web 3.0, some researchers have proposed the potential contribution of tokenised reward systems to future sustainable urban mobility transition (M. A. S. Khan et al., 2021). Barclay et al. (2021) delineated a mobility tokenisation framework (see Figure 2.39) wherein the "Travel Detection" mobile-application module functions as the primary data-acquisition interface, quantifying travel metrics and initiating token issuance protocols. These digital assets are subsequently stored within the application's secure infrastructure or cloud-based repositories linked to users' accounts. The framework culminates in a "Reward Marketplace" system where accumulated tokens can be exchanged for commodities or services through established redemption mechanisms, completing the mobility-incentivised economic cycle.

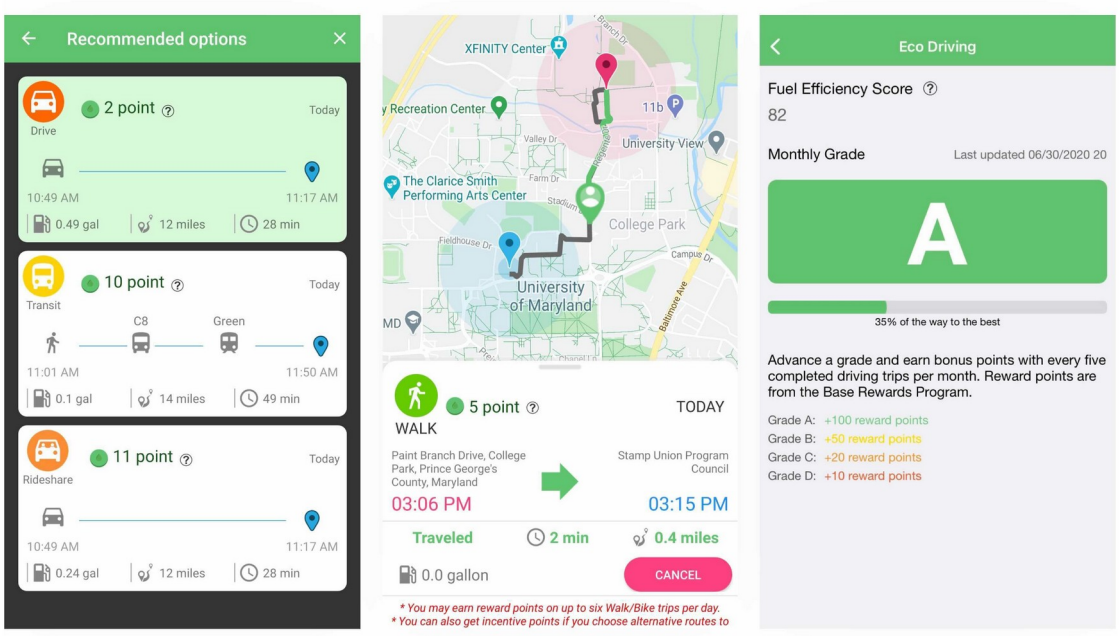


Figure 2.38. User interfaces of incenTrip app (source: incenTrip webpage)

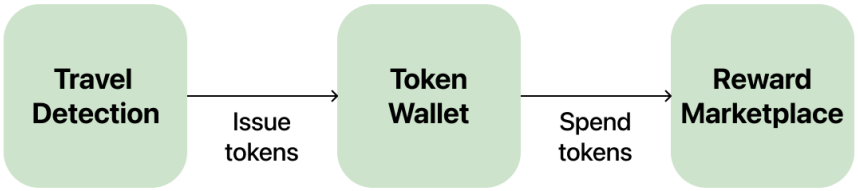


Figure 2.39. A schematic framework of mobility converting token economy, redrawn from (Barclay et al., 2021)

Additionally, Meneguzzo et al. (2024) highlighted that the tokenisation of mobility services could encourage users to make eco-friendly transportation choices through digital tokens on a blockchain featuring decentralised system design, data transparency, and immutability (Javed et al., 2022; Xie et al., 2019). Barkule et al. (2024) implemented the concept of a decentralised incentive system in a digital platform (see Figure 2.40), which is designed so that potential users can claim an incentive after every identifiable eco-friendly trip. However, blockchain technology, initially conceptualised for Bitcoin, is still a new concept that lacks clear definitions in urban sustainable transition and empirical evidence from real-world applications.

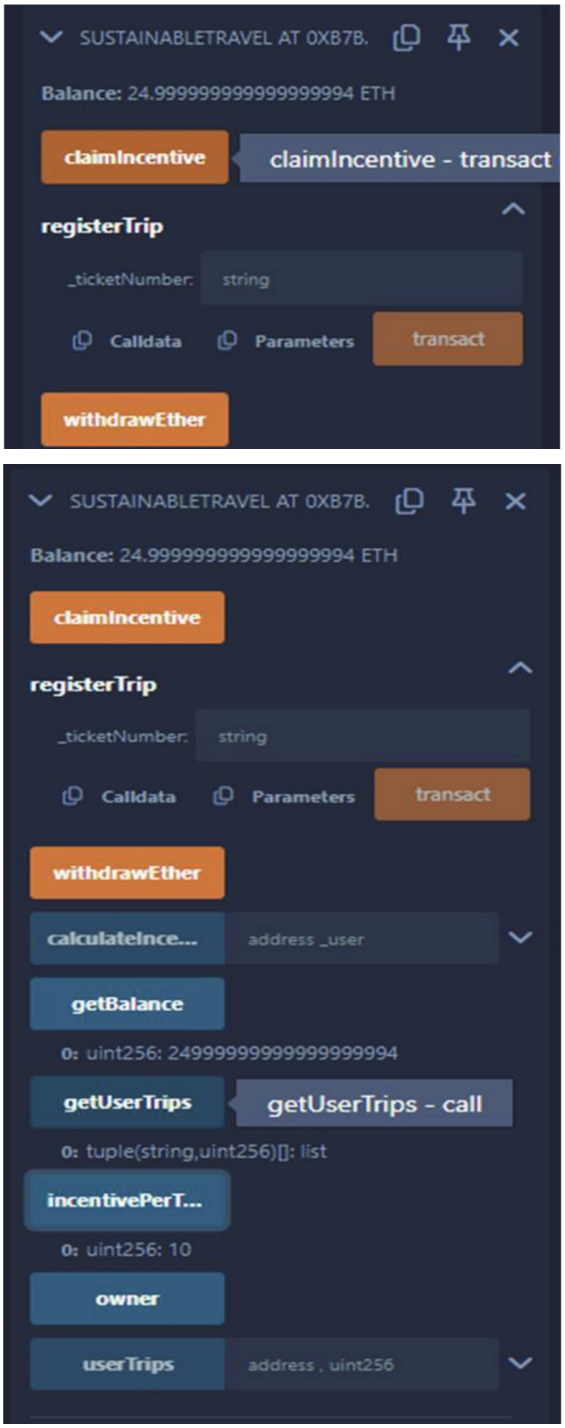


Figure 2.40. Interfaces of claim incentive dialogue box (left), and incentive withdrawal dialogue box (right), recaptured from (Barkule et al., 2024)

2.6.5.2. Gamification

Gamification can be seen as the application of game-design elements in non-game contexts to enhance user engagement and motivation (S. Deterding et al., 2011). Although gamification is still in the early stage of development (Armstrong & Landers, 2018), common gamification elements are points, scoring, leaderboards (Armstrong & Landers, 2018; Landers et al., 2015; Seaborn & Fels, 2015), process bars, ranks, or incentives (Nah et al., 2014). Specifically, the gamification design principles include goals and challenges, personalisation, rapid feedback, visible feedback, freedom of choices, freedom to fail and social

engagement (Dicheva et al., 2015; B. Wang et al., 2022). Although previous research has shown that gamification can enhance user experience, some gamification strategies may produce inconsistent results.

Some studies provided empirical evidence that the incorporation of gamification elements and feedback mechanisms within the digital interfaces can motivate users to engage in more sustainable behaviours, for example, choosing public transport over driving (Shamsuddoha et al., 2015).

Another representative of gamification elements in sustainable mobility applications design is personalised persuasive services, such as notification messages and feedback. For instance, Anagnostopoulou et al. (2018) introduced a pilot study on identifying the users' acceptance of the message and its effectiveness through designing a route planning application (see Figure 2.41) that encourages sustainable transport mode choice. This study found positive effects on users' mobility choices through gathering quantitative and qualitative data from participants, assessing their attitudes towards an approach of personalised persuasive messages.

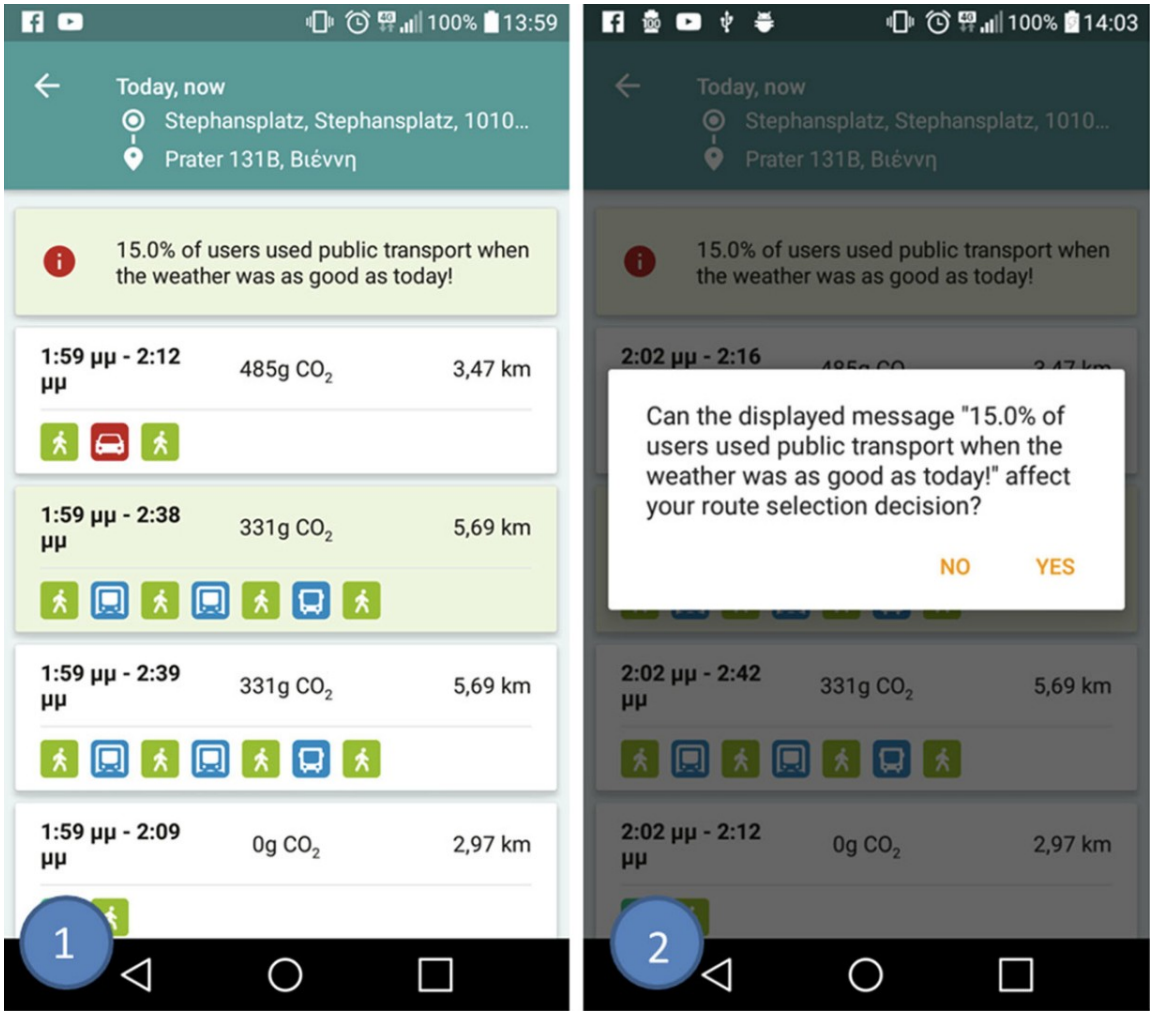


Figure 2.41. Example of route result in the route planning app (left). A pop-up information displays to ask users to provide feedback, recaptured from (Anagnostopoulou et al., 2018)

2.6.5.3. Mobile social networking

Mobile social networking (MSN) encompasses the dynamic interactions occurring between participants who share similar interests and/or objectives, facilitated through mobile devices within virtual social spaces (X. Hu et al., 2015). MSN platforms provide users with the ability to establish connections, share experiences, and participate in community activities through specialised mobile applications designed for social interactions (J. Zhang et al., 2015).

MSN plays a vital role in promoting sustainable transport behaviours. Various studies have already shown evidence that social information reflected from an individual's social network can be a potentially powerful tool to trigger sustainable travel behavioural change (Abou-Zeid & Ben-Akiva, 2011; Axsen & Kurani, 2012; Ettema et al., 2011; B. Fogg, 2009; Fujii & Taniguchi, 2005; Kormos et al., 2015; J. Zhang et al., 2015). These studies highlighted the mobility aspect that introduces distinctive opportunities for location-based social engagement, real-time communication, and contextual awareness that traditional computer-based social networking cannot fully replicate.

The design strategy of these mobile social networking elements is applied in the design of travel support platforms, for example, Pokémon GO (see below) and Waze.

Waze is a navigation platform based on mapping, functioning on mobile devices, webpages, and vehicle-mounted systems (see Figure 2.42). Unlike traditional navigation applications such as Google Maps or Apple Maps, Waze incorporates user-centred social elements that transform passive navigation into participatory cartography. The platform enables user personalisation through customisable profiles, allowing for identity expression within the navigation system. This location-sharing feature improves social interaction among nearby users, creating temporary virtual communities of car-drivers in shared geographic areas (Licoppe & Inada, 2016).

The integration of these social networking elements transforms the conventional navigation experience from isolated wayfinding to community-support mobility, potentially increasing user engagement through social validation mechanisms. However, while Waze has efficient mobile social networking capabilities, its emphasis on navigation optimisation for private car use may inadvertently hinder sustainable transportation shifts (Heiskala et al., 2016).

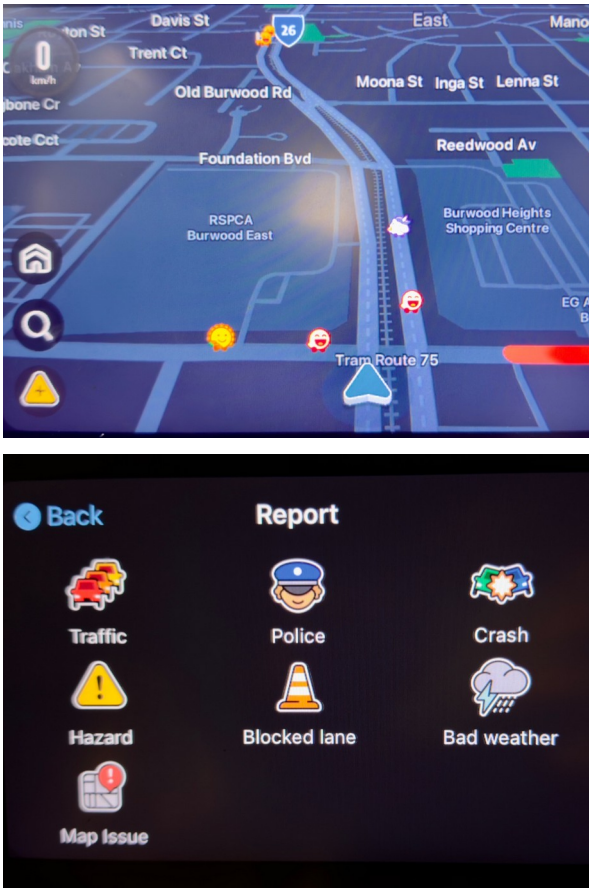


Figure 2.42. Car-play version of Waze interface, Left: mapping interface; Right: function of report on the road (author's photo)

Social connectivity within mobile platforms enables users to share experiences, establish accountability mechanisms, and access peer support, thereby creating psychological frameworks that reinforce positive behavioural modification.

2.6.5.4. Components integration

Throughout the relevant review of literature and design cases, we found that the most effective mobile applications integrated multiple components, such as nudging, rewards, gamification, and social networking, to enhance a comprehensive user experience. Based on the three design elements of mobile applications that facilitate sustainable decision making, the following discussion will examine three mobile applications that encourage eco-friendly commuting practice for their users.

Pokémon GO

Pokémon GO is a classic smartphone gaming application (see Figure 2.43) that integrates elements of gamification, social networking and reward mechanisms. Pokémon GO is a location-based augmented reality (AR) gaming app developed by Niantic, Inc., which became the most popular mobile gaming app in U.S. history, as measured by its large number of daily active users (28.5 million daily unique visitors at its peak in early July 2016 in the U.S.) after its release on July 6, 2016, in the U.S. (Allan, 2016). Pokémon GO uses the smartphone's GPS (Global Positioning System) to position the user's in-game avatar on the game map according to their real-time location. Users may engage with incentivised virtual items, both fixed and dynamic,

that are superimposed on the game map using augmented reality. Engagements with virtual objects require users to be situated within a 40-metre interaction radius, offering a range of advantages. This game application integrates emerging technology, gamification components, and social networking, therefore augmenting user engagement with external settings.

Although the app is in the gaming category, some research studies pointed out its contribution to health-related issues and active mobility choices. The ramifications of Pokémon GO transcend personal health advantages(Y.-C. Lee, 2021; Wattanapisit et al., 2018); they also include wider societal impacts. Studies suggest that the game can affect travel choices, possibly steering users towards more sustainable transportation methods by motivating them to walk or cycle to achieve in-game goals (F. Guo et al., 2022; Zach & Tussyadiah, 2017). This alteration in travel patterns can lead to less dependence on motor vehicles, therefore fostering environmental sustainability.



Figure 2.43. Pokémon GO navigation page (left), gaming process (middle), reward store (right) (source: GameUI database website)

2.7. Synthesis of literature insights

The section synthesises the prior literature and case reviews by emphasising two principal outcomes, including the recognition of enduring scholarly gaps that limit our understanding of digital mobility service design in suburban university contexts, as well as the explanation of actionable insights for the design of community-oriented, user-centred MaaS platforms for international students to mitigate the

impact of high-frequency driving in private cars to access the campus.

2.7.1. Knowledge gaps

The literature has a significant bias towards technology and system-level evaluations of MaaS, while neglecting the lived experiences and quotidian decision-making processes. A wide variety of MaaS studies and trial programs concentrate on system design, integration levels, or business models, frequently evaluated through simulations, stated-preference surveys, or pilot analyses (Jittrapirom, Caiati, Feneri, Ebrahimigharehbaghi, Alonso-González, et al., 2017; Sochor et al., 2018). These methodologies elucidate the operational dynamics of MaaS at technological and policy levels, yet they provide limited insight into how users perceive MaaS within their daily routines (Lyons et al., 2020b), particularly in contexts where private car use is already entrenched, for instance, the Clayton precinct. Figure 2.44 situates these lived practices within the wider mobility system beyond the private car.

A further gap emerges in the conceptualisation of behavioural change within MaaS scholarship. MaaS is presented as an opportunity to promote sustainable mode transition; nevertheless, numerous studies presume that access to information, pricing incentives, or seamless integration alone can produce behavioural change (Hensher et al., 2021). Research on habit and routine indicates that regular car use, particularly in low-density areas, resists modification even where alternative services exist, because the behaviour is sustained by routine instead of by a repeated comparison of options. Investigations into behavioural change highlight the significance of social influence (Hwang et al., 2023; Inan et al., 2022; Lasisi et al., 2025), habit change, and routine disruption (Eltved et al., 2021; Stoiber et al., 2019); yet the integration of these

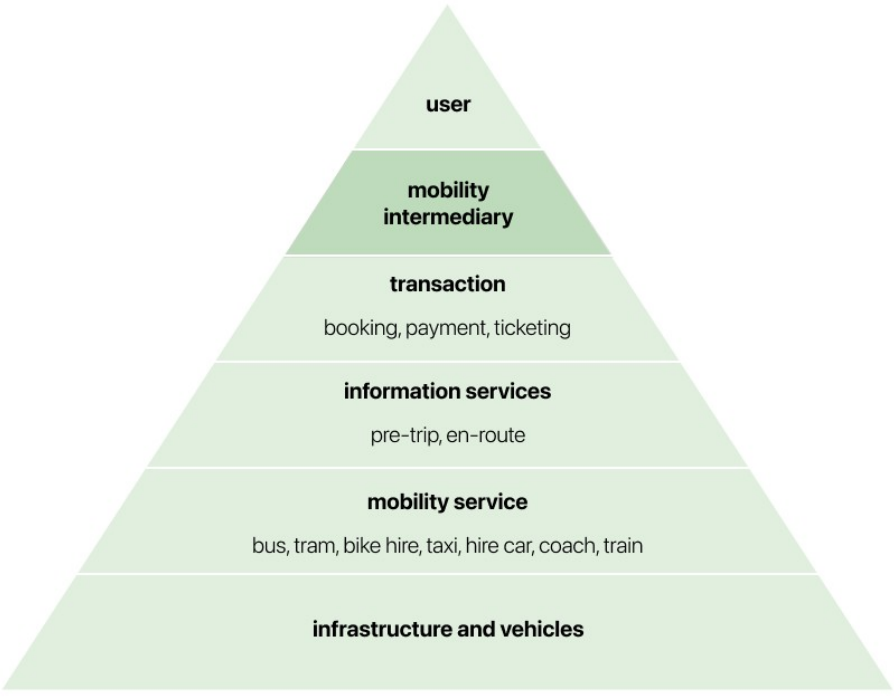


Figure 2.44. The mobility system beyond the private car, redrawn from (Lyons et al., 2020a)

behavioural drivers into MaaS design remains limited. This gap is especially relevant for international student car drivers, whose private car use may increase over time as they gain confidence, social networks, and financial stability, thereby enhancing car dependency instead of diminishing it (Shafi et al., 2020b).

Methodologically, the application of participatory and design-led approaches in MaaS research is limited in the literature. Current research frequently depends on top-down policy analysis or post-hoc evaluation of pilot programmes, with users regarded as respondents instead of co-creators (Pangbourne et al., 2020a). Although participatory design has been extensively applied to service design and digital platform development, its implementation in MaaS research remains fragmented and insufficiently theorised, particularly in transport studies that are primarily driven by engineering and economic perspectives. Notably, the existing research provides a limited understanding of the participatory aspects of MaaS. It lacks consideration of how users' active identification of problems, their predictions about the potential future commuting scenarios, and adjustments to environmental constraints could significantly influence the design of MaaS (G. Smith & Sørensen, 2023; Wacnik et al., 2025).

A fourth gap extends across the other three. The transition literature reviewed in Section 2.2 treats protected settings as places where alternative practices may be trialled before competing in the mainstream. A university campus closely fits this description because it controls its parking, roads, and information channels. However, transition and MaaS scholarship rarely intersect. Transition scholarship discusses niches at the level of policy and infrastructure without examining the interfaces through which people encounter a new mobility option. MaaS scholarship examines those interfaces without asking what makes a niche protected. The present study occupies this conceptual space by treating the Clayton precinct as a niche and the digital platform as the mechanism through which the niche may become usable to the people within it.

Therefore, these deficiencies indicate an opportunity for research that investigates MaaS in suburban university contexts, emphasises the lived experiences of international students, and incorporates participatory design methodology as a fundamental research approach. This technique can produce context-specific design insights into sustainable mobility practices, cultural norms, and real-world commuting limitations, while also guiding the iterative development of MaaS platforms that are relevant, functional, and trustworthy in low-density university campus settings.

2.7.2. Digital mobility service design insights

Digital mobility services increasingly function as critical mediators of how people perceive, plan, and enact everyday travelling. Through integrating real-time transport data, multimodal integration, and personalised guidance, these mobility service platforms facilitate daily commuting as well as expand perceived choice architecture, reduce uncertainty, and lower barriers to engaging with shared

or sustainable transport services (Goodman-Deane et al., 2021; Poon, 2021). In the MaaS ecosystem, digital interfaces function as instruments and, more significantly, as interpretive frameworks that frame mobility options for the users. By prioritising specific behaviours, these interfaces influence users' decisions among time, cost, convenience, and environmental impact of each option. Thus, interface design emerges as a critical point where abstract sustainability objectives are transformed into tangible, daily commuting choices.

Digital platforms progressively embed behavioural intervention strategies, including nudges, incentives, and goal-oriented feedback loops, to guide users towards lower-carbon mobility options. Nudges facilitate making abstract environmental effects understandable and relevant when people are making travel choices.

In addition to these nudges, gamification has emerged as a significant design strategy for sustaining user engagement. By incorporating gamified components, such as challenges, progress indicators, or badges, mobility applications can reframe routine travel as a goal-oriented daily activity (Hamari et al., 2014). Empirical studies indicated that gamified feedback, including rewards and leaderboards, enhances awareness of travel behaviour and encourages experimentation with alternate options. However, the literature highlights a "novelty effect," indicating that engagement may diminish if rewards become repetitive or disconnected from the users' lived reality. This requires a transition from static incentive structures toward adaptive, context-aware gamified systems.

Although travel behaviour is frequently regarded as a personal economic decision, it is significantly influenced by social comparison, peer influence, and shared narratives (Schwanen et al., 2012). Mobility service digital platforms that facilitate trip coordination, experience sharing, or observation of peers' sustainable decisions might establish new normative reference points. This *social embeddedness* is essential for groups like international students, who may depend on peer networks to navigate unfamiliar transportation systems. Despite this potential, social interaction remains a marginal aspect in many MaaS applications, which persist in portraying users as isolated decision-makers instead of participants within a community (Pangbourne et al., 2020a).

In summary, the four bodies of literature reviewed in this chapter converge on a single unresolved problem. Transition scholarship establishes that protected settings can host alternative mobility practices, but it does not describe how people are brought into them. MaaS scholarship establishes that technical integration is achievable, but it assumes that information and pricing will carry behaviour. Research on international student mobility establishes that this group arrives with preferences formed in their home countries, but it has not followed students through the period in which local travel habits form. Research on digital behaviour change establishes that nudges, gamification, and social features can shift attention, but it also

indicates that their effects may decay after novelty subsides. Together, these positions define the design problem addressed by the study. The problem concerns how a digital mobility platform may make sustainable options usable and support their continued selection by a population still learning an unfamiliar transport system. Effective design therefore requires usability-centred interaction and behaviourally informed engagement. Current MaaS research treats digital interfaces as active interventions that shape sustainable commuting experiences and practices, not merely as passive information channels. Within a user-centred framework, nudging, gamification, and social networking may support sustainable travel decisions, particularly in dispersed, low-density settings such as suburban university campuses.

2.8. Mapping the mobility landscape at Clayton

Mobility patterns at Monash University's Clayton campus have undergone significant transformations over the past decades, influenced by changing commuter behaviours, infrastructure advancements, and societal factors. The modal shares of commuters' journeys at the Clayton campus (students and staff) from BPD spanning 2008 to 2023 underline significant changes in transportation preferences, offering critical insights into the challenges and opportunities for enhancing a more sustainable campus mobility service ecosystem.

The Clayton campus is encompassed by regional roadways that facilitate the transportation of most trips originating from these surrounding areas. Wellington Road, located south of campus, and Blackburn Road, east of campus, are the primary roads that service the Clayton campus. The university campus is a destination for students, the university faculties, catering staff, and service providers who study or work at the Clayton campus. As the largest campus of Monash University, the Clayton campus functions as a significant destination for educational, administrative, residential, and service-based activities. Several transport modes for various purposes for different groups of people who routinely access and move around the Clayton campus were identified (see Figure 2.45).

The section categorises and evaluates both inter-campus (home-to-university) and intra-campus (on-site) travel options, including private cars, public transport services, university shuttle services, shared mobility schemes, micromobility, and planned infrastructure developments such as the Suburban Rail Loop (SRL) and Trackless Rapid Transit (TRT). In addition, the section identifies essential physical and digital navigation tools and infrastructures that enhance user experiences in wayfinding on campus.

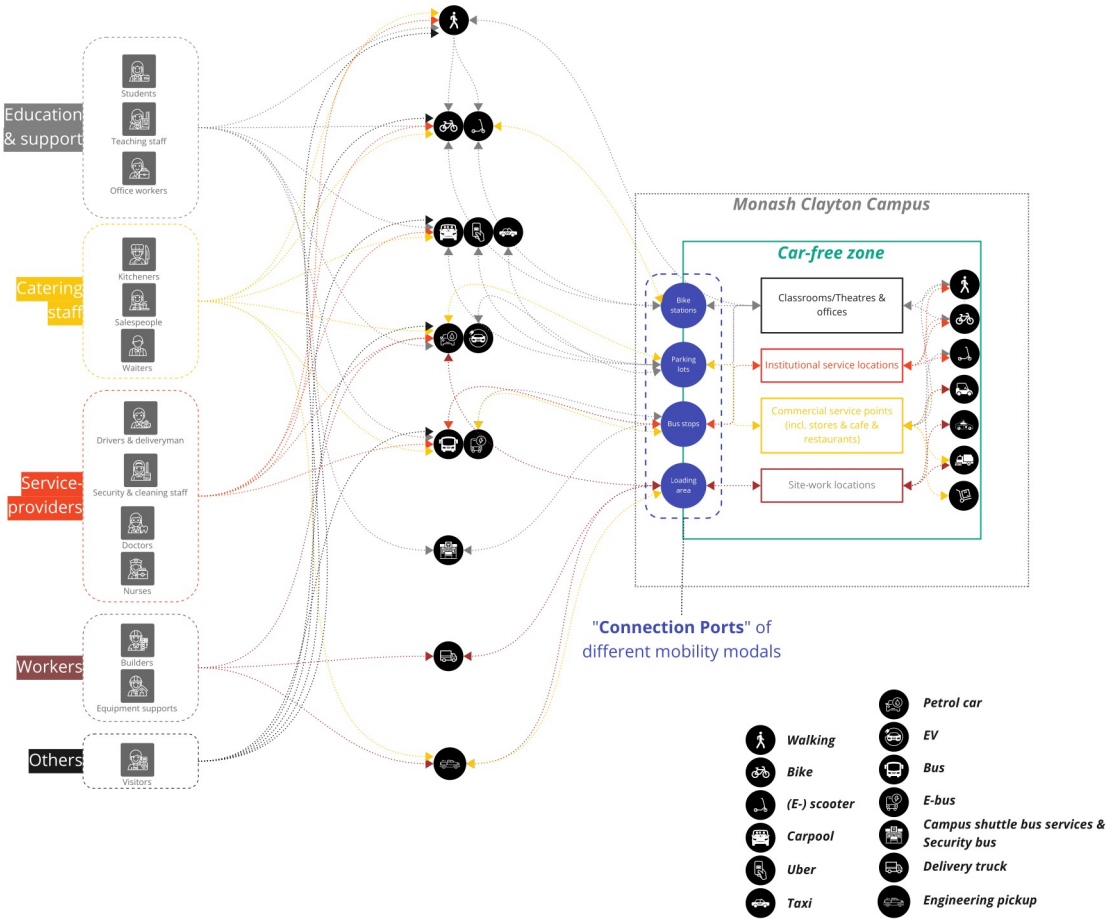


Figure 2.45. Map of Clayton Precinct transportation modes (Authors' graphic)

Critically, this section provides an evidence-based foundation within the exegesis, and extends beyond a background summary. Through unpacking how mobility services are structured, accessed, and experienced at the Clayton campus, the section highlights critical points of friction and opportunity that inform the participatory design of a more inclusive, sustainable MaaS platform for Clayton's international students. This analysis was conducted by reviewing and examining the available data from Monash University-related web pages and insights from the first-stage report of the Net Zero Precinct project (Sharp et al., 2023) and combining them with the field observations at the Clayton campus. The chapter addresses the challenges and opportunities of potential mobility design practice for the sustainable transition experiments at the Clayton precinct. Figure 2.46 unpacks the precinct into the layers on which this evidence-based audit is built, including (I) road network, (II) car parking zones, (III) mobility service infrastructure points, (IV) walking routes, (V) buildings, (VI) ecological spaces, (VII) commercial service points.

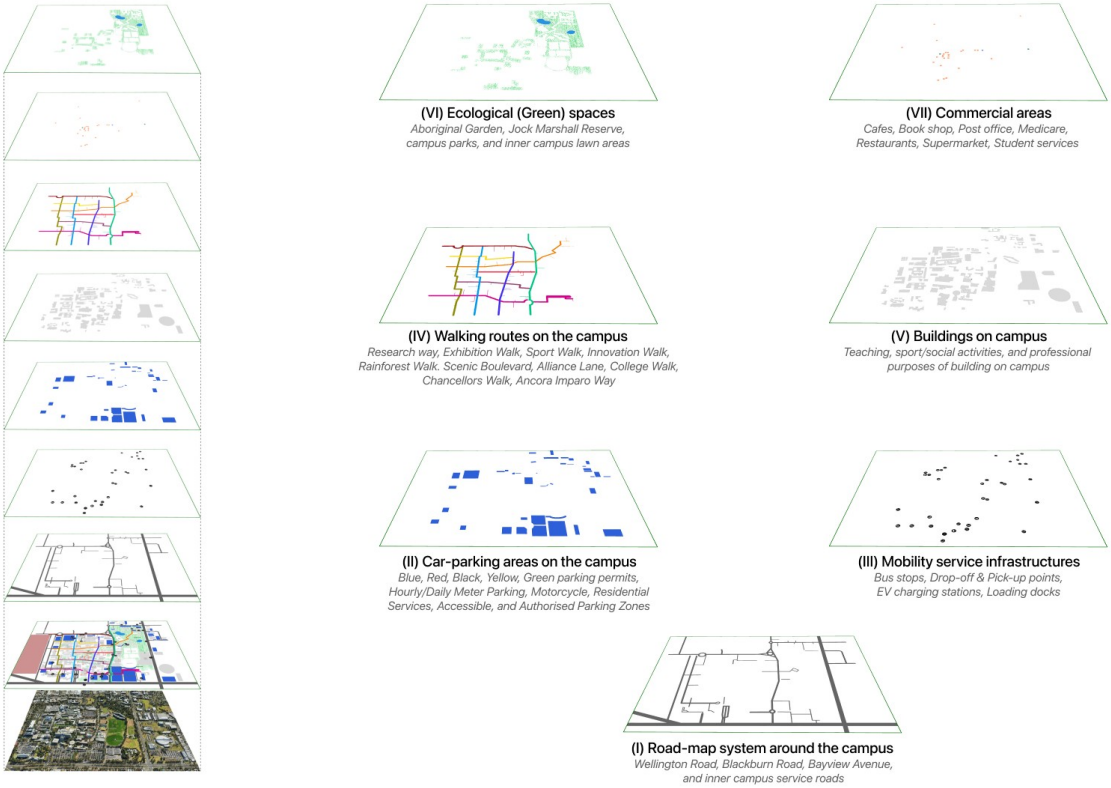


Figure 2.46. Unpacked layers of the Clayton campus, including the road map. (Redrawn from the map database: OpenStreetMap)

This study undertook a site-based mobility environment audit focused on infrastructure, service information, and spatial conditions around the Clayton campus, including paths, crossings, signage, interchange points, and publicly available service artefacts. It does not apply a comprehensive autoethnographic methodology. Selected reflexive accounts are instead integrated throughout the section to contextualise observations and findings (refer to Appendix J. Fieldnotes with reflexive accounts). These narratives drew on the researcher's experience of local transport infrastructure and mobility options around the Clayton precinct, as documented in contemporaneous fieldnotes, to support spatial and behavioural mapping. The reflexive fieldnotes (see Figure 2.47 and FN-11-MAY-2023-CLAYTON-PT-COMMUTE) provide an insider perspective on interactions among infrastructure, mobility cultures, and personal decision making. Reflexive writing operates here as a supporting perspective that strengthens the empirical and design-focused findings (Ellis et al., 2011; H. Smith & Dean, 2009). Pink (2009) frames reflexivity in ethnographic and design-oriented research as an active methodological tool that acknowledges the researcher's subjectivity and generates a more situated interpretation of context. In this study, selected reflexive narratives supported analysis of interactions among transport infrastructure, local travel cultures, and the commuting decisions of an international student driver in the Clayton precinct.

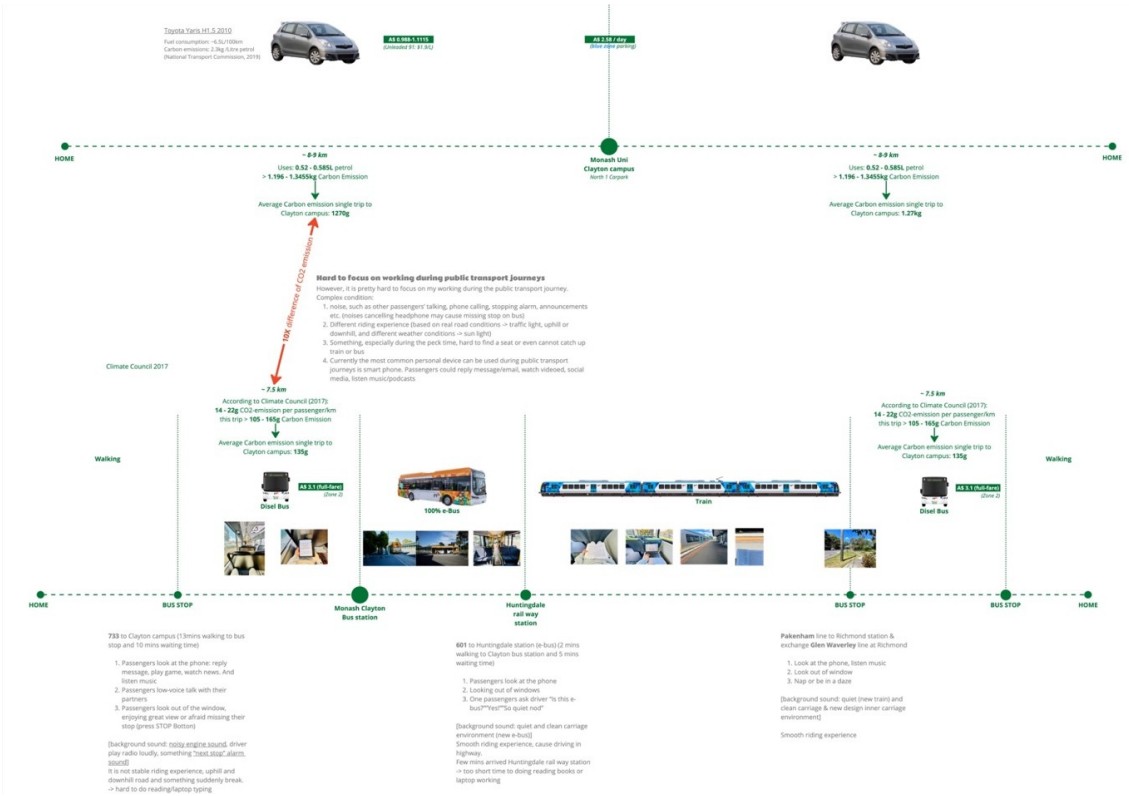


Figure 2.47. An example of reflexive notes on the comparison of the journeys of private car driving and public transportation from home to the Clayton campus. (refer to FN-11-MAY-2023-CLAYTON-PT-COMMUTE).

The following subsequent sections will review the statistical data on discovering the trend of different mode choices by commuters from the Clayton campus and the current state of these transportation options in detail, supported by visual data. The chapter aims to understand mobility behaviours and related infrastructures currently happening at the Clayton campus and reviews sustainable transport trial programmes implemented at the campus, including TravelSmart and shared-bike trials. The findings from this chapter will contribute to fostering the basic understanding of current states of mobility behaviours and mode choices at the Clayton campus and facilitating the following design practices and developing interventions.

2.8.1. Modal options and commuting trends at the Clayton campus

Transportation, as one of the most significant parts of university life, encompasses various components within an environmental boundary (Gudmundsson et al., 2016; Stokols & Novaco, 1981). This section categorises the transportation system at the Clayton campus into two parts (see Figure 2.48), including (1) the home-to-university travel chain (Sun et al., 2018) and (2) movements within the Clayton campus. Each category contains multiple modes of travel depending on individuals' habits (H. Aarts et al., 1997; H. a. G. Aarts, 1996), travel purposes, motivations, emotions, or the availability of transport services around their physical locations (Geng et al.,

2017; Göransson & Andersson, 2023; Stradling, 2011).

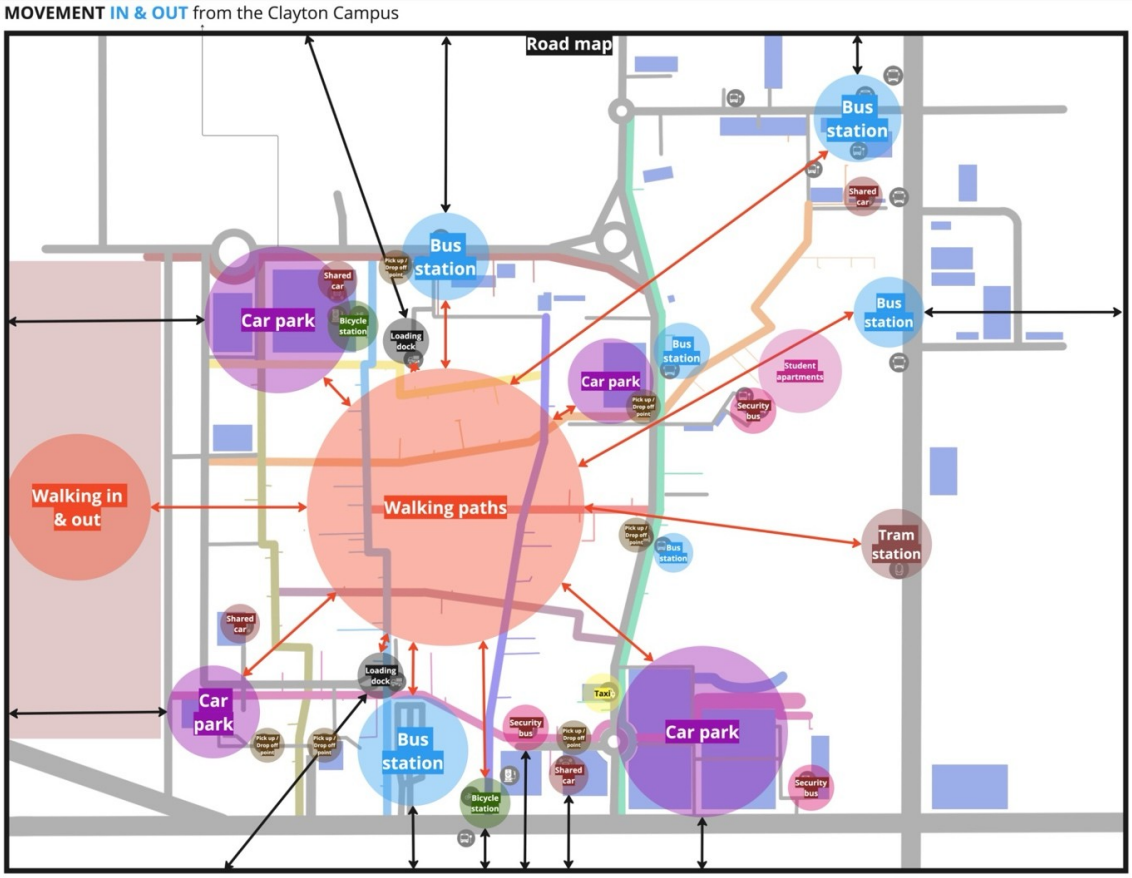


Figure 2.48. Summary of inbound and outbound movements at the Clayton campus, showing the locations of connection ports for various commuting modes (author's own infographic)

2.8.1.1. Modal share trends from 2008 to 2023

The Clayton campus is in the south-east suburban area of Melbourne, Victoria. The areas, like most suburban precincts in Australia, represent low population density and limited public transit connectivity. However, there is a significant amount of foot traffic and vehicular traffic commuting to the campus on weekdays, especially during the two formal teaching semesters of the university. The Building and Property Division of Monash University has investigated how people commute (from home) to the Clayton campus through random sampling questionnaire surveys with students and staff since 2008. The line graph (see Figure 2.49) presents longitudinal trends of transportation mode choices by everyday commuters, such as students and staff at the Clayton campus over a 15-year period (2008 to 2023).

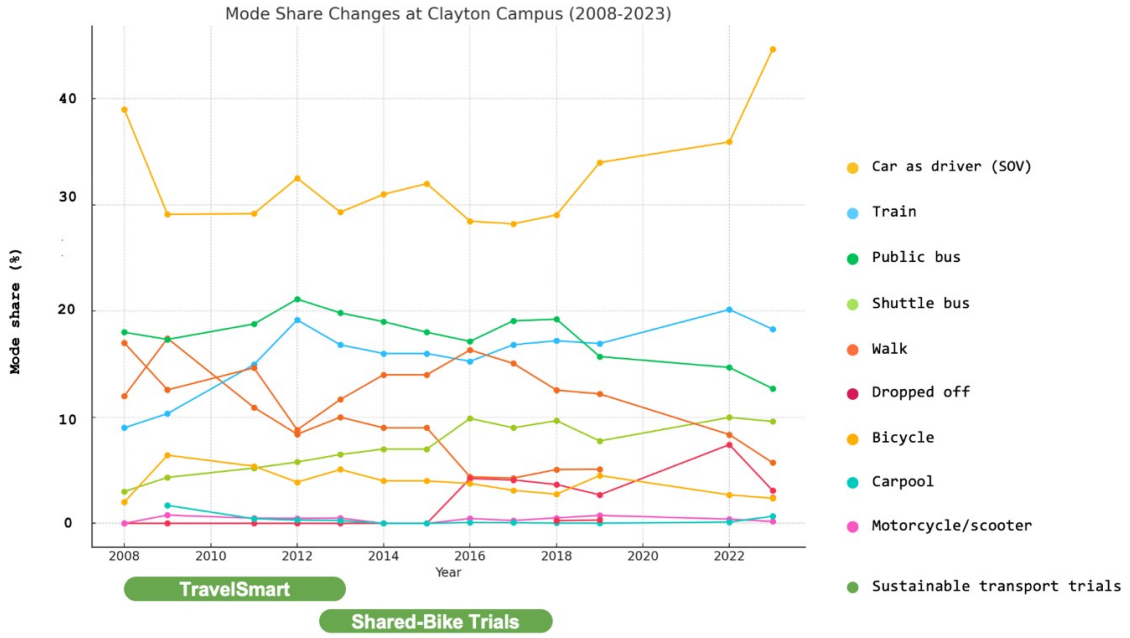
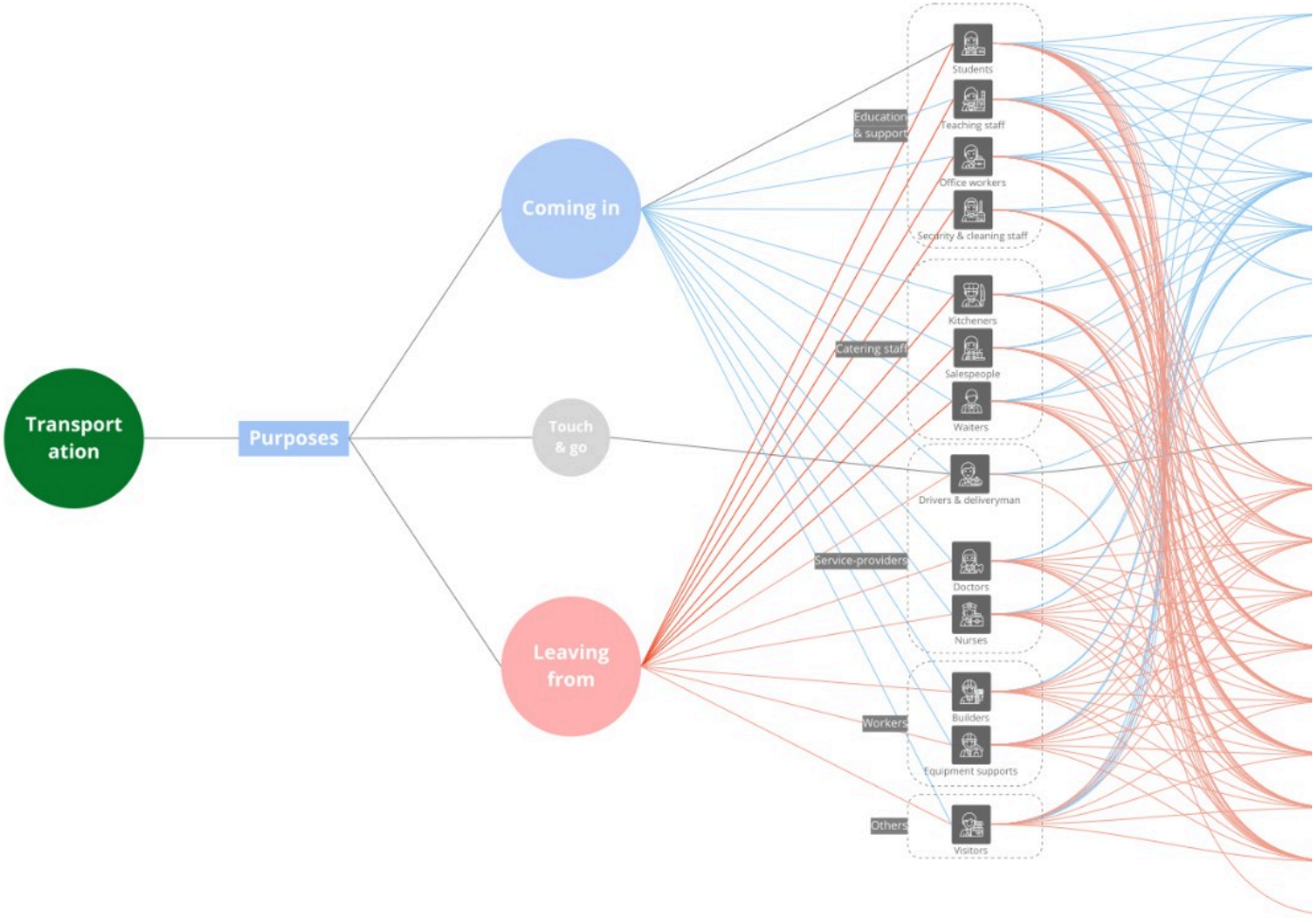


Figure 2.49. Mode share trends of transport options for accessing the Clayton campus choices by students and staff at the Clayton campus (Data originated from the annual travel surveys, which were collected by BPD, graph was designed by the author).

The purpose of this subsection is to review the existing and planned travel options for people commuting to the Clayton campus, as well as related infrastructure and traffic rules (refer to Figure 2.50). The subsection summarises these commuting options by categorising them as follows. i) Private vehicles; ii) University-owned and operated shuttle bus services; iii) Public Transport Victoria (PTV) transportation network; iv) Shared mobility; v) Electric Vehicles; vi) Micro mobility; vii) Planned transport options.


Transport ation
Purposes
Coming in
Touch & go
Leaving from
Education & support
Students
Teaching staff
Office workers
Security & cleaning staff
Catering staff
Kitcheners
Salespeople
Waiters
Drivers & deliveryman
Service-providers
Doctors
Nurses
Workers
Builders
Equipment supports
Others
Visitors

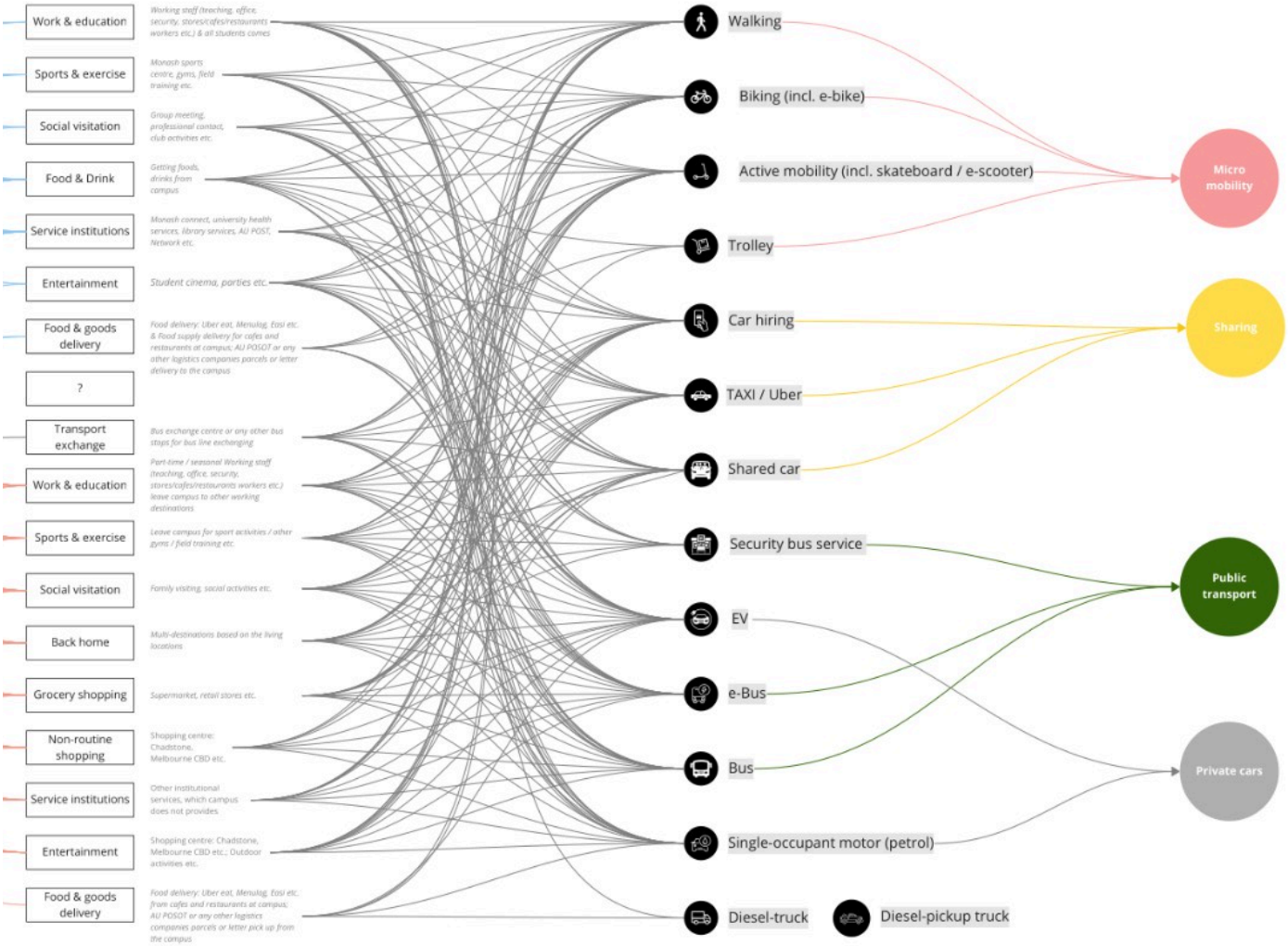


Figure 2.50. Overview of the diverse objectives and transportation choices available to people seeking access to the Clayton campus (Author's infographic)

2.8.1.2. Private motorised transport dependency

Private car dependency represents a significant barrier to achieving sustainable mobility transitions within suburban university precincts.

The traffic survey data collected on Bayview Avenue (eastbound) on 4 March 2024 by BPD, which is a key arterial route connecting residential areas to the N1 multi-level carpark building, demonstrates the magnitude and temporal distribution of private car use in this context (see Figure 2.51). The classified vehicle counts over a 12-hour period on a typical teaching day in the 2024 semester revealed that cars accounted for the predominant share of private-mode vehicular movements, whereas motorcyclists and bicycles comprised only a small portion of the observed traffic at the Clayton campus. Moreover, two distinct commuter peaks are observable, including a morning inbound peak between approximately 7:15 and 9:45 AM, during which private automobile volumes surpassed 200 cars per 15-minute interval, and an afternoon outbound peak from 3:15 to 7:45 PM, but at reduced levels compared to the morning surge.

The following subsections examine these patterns in detail, integrating BPD statistical data with reflexive field observations. The discussion first focuses on single-occupant cars and then on motorcycles to more deeply understand the behavioural and infrastructural drivers and barriers underlying private motorised transport dependency at the Clayton campus and how future design interventions could address these challenges.

- **Car (single occupant)**

As mentioned above, choosing a single-occupant car to access the Clayton campus is the most common travel option for Clayton's commuters nowadays. There are three main public car parks located within the Clayton campus, specifically north (N1), south-east (SE 1 to 5), and centre (C12). As well as the roads that connect these car parks to the regional

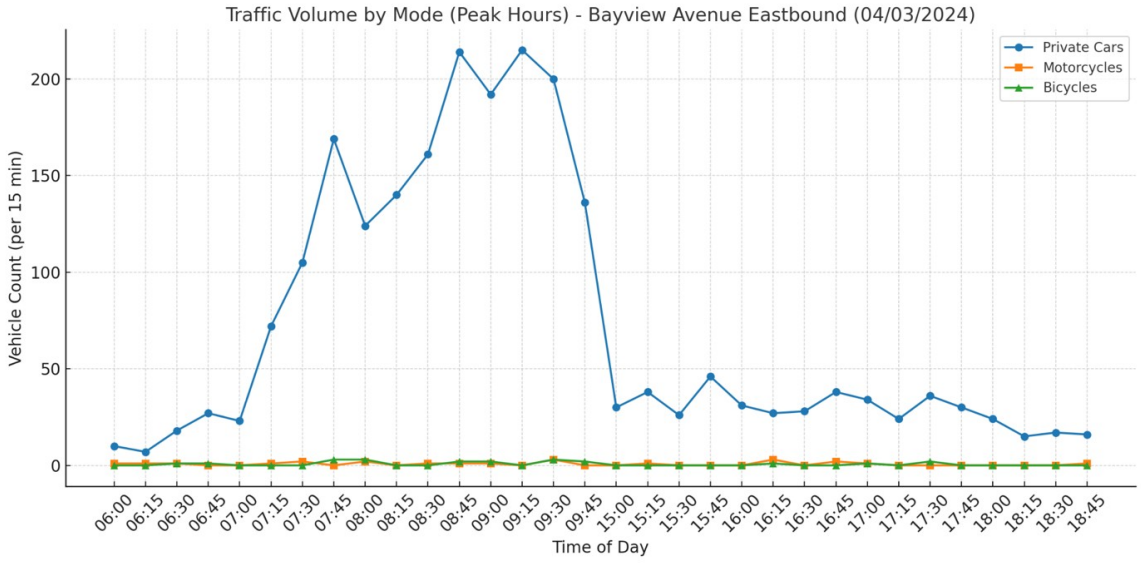


Figure 2.51. Traffic volume by modes at the Bayview Avenue (Eastbound) on 4 March 2024, data collected by BPD.

roadways, the main vehicular access roads are Bayview Avenue, which connects Research Way and N1 and W1 car parks; Wellington Road, which directly connects SE car parks; and Scenic Blvd, which connects the C12 car park. The manual traffic counts recorded by BPD on each of these roadways are significant.

The line graph of transportation mode share (see Figure 4.2) shows that single-occupancy vehicle (SOV) consistently remains the dominant transportation mode throughout the entire survey-investigated period, ranging between approximately 28% and 45% of total modal share. After an initial decline from 2008 (~39%) to 2009 (29%), SOV usage maintained relative stability until 2018, after which it demonstrated a significant upward trajectory, culminating in its peak (~45%) by 2023.

> "As a researcher who spent a lot of time in the Clayton precinct, I kept coming back to the problem of convenience versus sustainability. At the start of my field observations, I frequently visited the campus in the morning to observe a stream of cars entering the multi-level car park building (N1), most of which contained only one person. This pattern of single-occupancy vehicle usage was a visible sign of the auto reliance that characterises much of the Clayton community's mobility culture, like most suburban areas of Australia.
>
> Despite my research on sustainable transportation and my intention to model the behaviours I seek to promote, I have found myself heavily dependent on driving to campus. Private car usage often provides convenience and time efficiency, particularly given my research commitments and irregular working hours, which frequently outweigh my aspirations to consistently adopt more sustainable commuting modes, such as public transport or active mobility. This self-observation highlights the complex interplay between individual circumstances, infrastructural conditions, and the behavioural changes required to transition towards more sustainable mobility practices." (FN-08-MAR-2023-CLAYTON-N1)

- **Motorcycle**

Engine-powered motorcycles, although representing a small proportion of overall commuter journeys, occupy a unique place within the mobility system of the Clayton campus. Their categorisation as a form of motorised micro-mobility situates them between private automobiles and active mobility, providing spatial economy and movability but still contributing to greenhouse gas emissions and noise pollution (Litman, 2025). Nevertheless, when compared to single-occupancy private cars, motorcycles generally produce lower greenhouse gas emissions and require significantly less spatial infrastructure for driving and parking (refer to Figure 2.52).

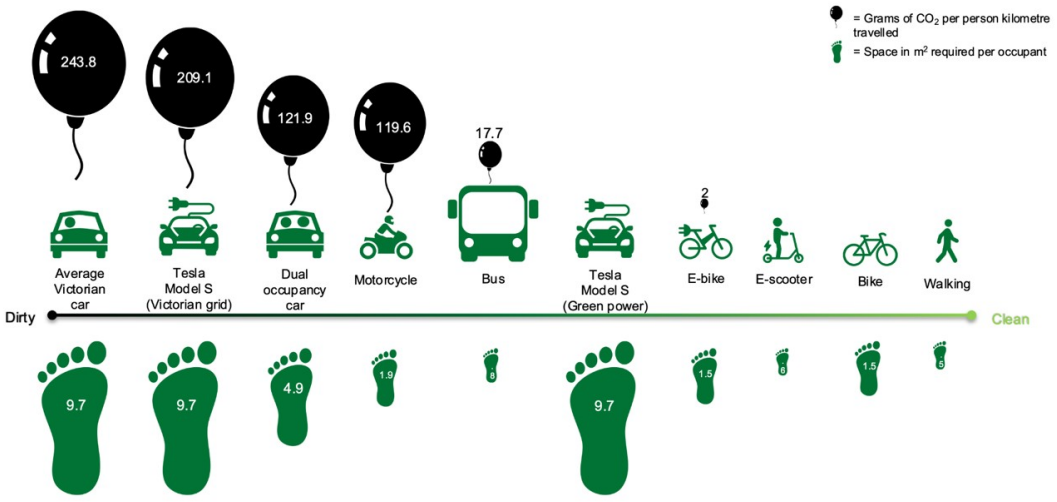


Figure 2.52. Carbon emissions, comparing different travelling modes at Clayton campus. Redrawn from Sensible Transport (2018).

Monash University Clayton campus supports motorcycle commuting by providing free parking in designated bays across all public car parks, and it is regulated by strict guidelines to ensure orderly use and safety (see Figure 2.53). The lack of direct parking expenses provides a financial motivation for use, particularly compared to car parking fees. However, this policy may unintentionally contradict broader institutional sustainability goals by maintaining demand for fossil fuel-powered modes of transport, which aligns with RQ1 on how current infrastructural and regulatory frameworks promote car-dependent behaviours.

> "During morning peak observational sessions, I noted that motorcycle parking areas were rarely filled beyond half capacity at the G-floor of N1 carpark and C12 carpark, where the car parking lots were at saturation. This discrepancy between supply and actual usage prompted a reflection on the allocation of campus transport resources. The allocation of underused motorcycle parking spaces may be reassessed to prioritise enhancing more outdoor bike parking spaces or future micromobility docking stations. From a design researcher perspective, this observation emphasises the need to question whether existing spatial and regulatory frameworks really correspond with the mode-shift ambitions outlined in campus sustainable transportation strategies." (FN-20-SEP-2024-CLAYTON-INNER-MOBILITY)



Figure 2.53. Motorcycles parked at C12 car park near the Woodside building for technology and design (Photos taken by the Author in February 2023)

2.8.1.3. Public transport services

The mobility framework for Monash University's Clayton campus consists of two primary interconnected public transportation systems, including (1) the University-owned and managed intercampus shuttle bus services and (2) the Public Transport Victoria (PTV) metropolitan transport network. Public transport plays a vital role in large-scale passenger-traffic patterns of students, staff, and visitors at the Clayton campus, although these services differ significantly in their governance structure, access policies, and service objectives. The following subsections outline the infrastructural features and interactional experiences, drawing on BPD statistical data and field observation notes.

- **University-operated shuttle bus services**

Monash University operates several inner-campus shuttle bus services that connect the three Australian campuses. The free shuttle services are restricted to people with valid Monash IDs. On the Clayton campus, two campus shuttle bus lines carry students to the Caulfield and Peninsula campuses during the two teaching semesters each year under the fixed running timetables (see Figure 2.54). Students and staff can use their Monash IDs to access the intercampus shuttle bus services at the Clayton bus interchange station every weekday during the teaching semesters and the bus stops in Bay O (to the Caulfield campus) and Bay P (to the Peninsula campus).



Figure 2.54. Clayton campus bus interchange Bay O signage for intercampus shuttle to Caulfield, captured on 8 Aug 2023 (FN-08-MAR-2023-CLAYTON-BUS-SOUTH)

These shuttle services are critical to the university's strategy to provide affordable, direct connections between campuses, especially for students enrolled in courses across various locations. Nevertheless, in recent years, with the continued growth of student enrolment, the shuttle services have faced considerable pressure, particularly during the two main teaching semesters each year. Field observations and BPD statistics (refer to Figure 2.55) reveal persistent occurrences of overcrowding, long boarding queues, and inconsistent seat availability during peak times. The capacity restrictions are intensified by the limited number of buses and scheduling constraints, leading to passenger flow pressures that may compromise the perceived reliability of the service.

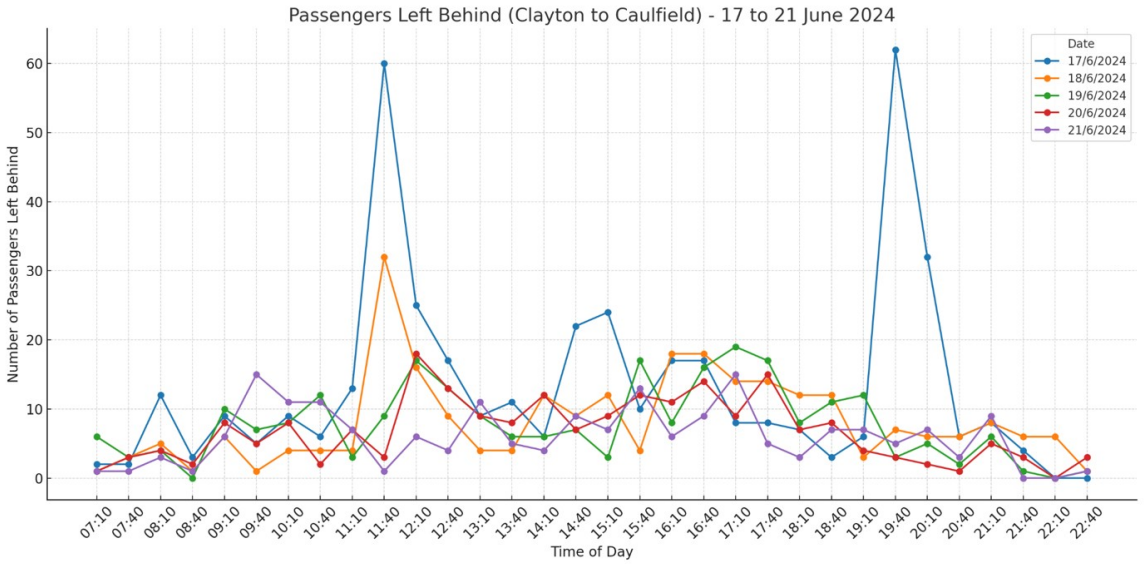


Figure 2.55. Passengers left behind on the inner-campus shuttle service from Clayton to Caulfield between 17 and 21 June 2024, based on manual traffic count data from BPD.

> "During morning and mid-afternoon peak observational sessions, I saw many students being left behind as buses reached full capacity at the Clayton bus interchange. On one occasion, while I was waiting in line for the Caulfield service (one of the highest demand inner-campus shuttle services departing from the Clayton campus), I noticed several students leaving after estimating that their waiting time would exceed 30 minutes (referred from the fixed timetable). They instead went to bus route 900, a PTV service that costs around $3 AUD for the journey from Clayton to the Caulfield campus." (FN-08-MAR-2023-CLAYTON-BUS-SOUTH)

The existing shuttle bus system demonstrates the university's commitment to providing free, sustainable intercampus connectivity services for their students and staff. Nevertheless, the operational constraints may pose a danger of reverting to private car use. This conflict highlights an opportunity for design-driven solutions that might enhance future mobility service reliability and user experience. Throughout the contextualised observation sessions, several features could be strategically integrated into the proposed MaaS platform. These features include

- **Real-time capacity monitoring, which** incorporates live passenger count data, may enable students to foresee overcrowding and modify their travel arrangements appropriately.
- **Predictive scheduling alerts** could minimise perceived waiting time and improve queue management through embedding machine learning-driven projections of arrivals and departures.
- **Multimodal integration**, which connects shuttle schedules with on-campus micromobility services, such as shared bikes and e-scooters, could provide first/last-mile options seamlessly.
- **Behavioural incentives**, through gamified rewards for travelling during off-peak hours during teaching semesters, may facilitate the redistribution of

passenger flow while aligning with sustainability objectives.

The design opportunities, grounded in DQ and RQ1, highlight the potential of digital platform interventions designed to address infrastructure constraints and behavioural motivators. Through incorporating operational transparency and choice architecture into the future user experience, the MaaS platform may transform the perception of the shuttle service from an unreliable and chaotic hindrance to a valued, essential element of a sustainable intercampus transportation option.

- **Public Transport Victoria (PTV) transportation network**

Public Transport Victoria (PTV) administers Melbourne's integrated public transport system, which contains metropolitan trains, trams, and bus networks, providing several modes of public transportation for the Clayton campus, including buses and trains. The Clayton campus is in a suburban area without direct rail connections, therefore, accessibility to the broader metropolitan network depends on a series of feeder services, particularly from Huntingdale train station on the Cranbourne or Pakenham railway lines.

The primary bus station serving the Clayton campus is the southern bus interchange, located on the southern edge of the campus adjacent to the Learning and Teaching Building (see Figure 2.56). This interchange serves as a crucial mobility hub in the campus's public transportation system, facilitating connectivity between the university and surrounding metropolitan areas. The location of this interchange facilitates convenient access for both arriving and departing passengers, supporting large passenger volumes during peak travel times. The interchange provides PTV bus lines, but it also accommodates the university-operated intercampus shuttle bus services (see above), thereby integrating regional and campus transport services into a concentrated mobility hub.



Figure 2.56. Bus routes via Monash Clayton campus (left) & Clayton bus interchange station (right) (Photos taken by the Author in February 2023)

The key PTV bus routes connect Clayton campus to surrounding areas, including Huntingdale, Middle Brighton, Box Hill, Oakleigh, Croydon, Dandenong, Caulfield train stations, Waverley Gardens, and Chadstone shopping centres. Significantly, some high-frequency routes, such as the 601, which links Huntingdale train station (the closest train station near the Clayton campus), and other routes, including 630, 703, and 900, provide connections to major suburban centres and other train stations (see Figure 2.57).



Figure 2.57. Clayton Bus interchange loop, redrawn from Monash University.

Field observations and traffic counts from BPD (refer to Figure 2.58) reveal that several PTV bus routes have peak-hour congestion; particularly, the 601 provides rapid shuttle service between the Huntingdale train station and the Clayton campus.

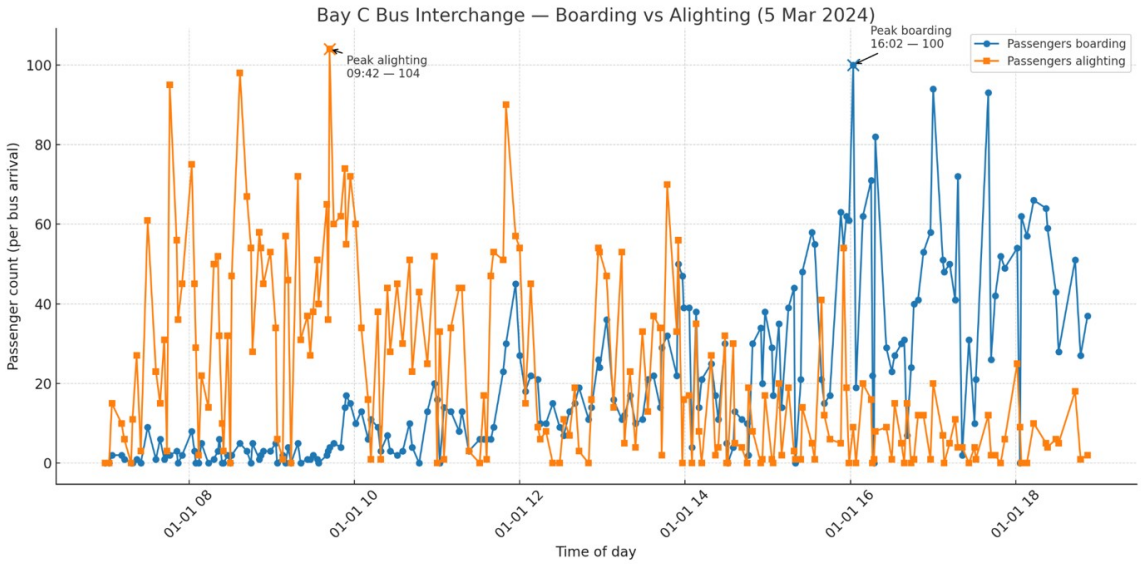


Figure 2.58. Passenger boarding and alighting activity at Bay C (shuttle service between the Clayton campus and Huntingdale train station) of the Monash University Clayton bus interchange on 5 March 2024, recorded for each bus arrival

2.8.1.4. Shared mobility and carshare initiatives

Shared-mode mobility is a transportation approach wherein various people use diverse modes of transportation instead of individual usage or ownership and single-occupant modes (Machado et al., 2018). Several shared mobility options recently emerged on the Clayton campus, including shared bike trial programmes and shared car services. However, only commercial car-sharing services are underway (Sharp et al., 2023). Monash University has operated several bike-share schemes in recent years (see Figure 2.59), including blue (2013), green (2016), and red bike (2016) trial programmes.

The blue bike-share trial programme was trialled in 2013 with Monash staff participants from departments and faculties, followed by the successfully implemented student bike-share scheme. The bikes were equipped with a security lock, and departments or faculties that signed up for the trial programme were given keys to get around the Clayton campus (Monash and Monash Sport, 2013). Each key costs three hundred Australian dollars (Sharp et al., 2023, p. 63). This was followed by the green bike-share scheme in 2016, which required a specific key to access. Due to the missing helmets provided while people borrowed a bike, the scheme brought significant security issues to the campus.

After the implementation of the green bike-share programme in 2016, which also required a designated key to access the service. The absence of helmets provided to people while borrowing bicycles has resulted in a significant security concern for the campus (Sharp et al., 2023).

The red bike scheme was the most recent shared bike trial since 2016 (refer to Figure 2.60). Monash University provides three membership types for users with different purposes to access this shared bike service, comprising single, semester, and annual payment (Monash and

Monash Sport newsletter, 2016). The red bicycles can be reserved through online platforms or a dedicated smartphone application, and they would arrive with essential accessories such as a helmet, a bike loop for securing, and a solar panel located on the rear to support the basic functions of the shared bikes, including location tracking. Nevertheless, such a heavy-duty bicycle also inconveniences the rider's riding experience (Sharp et al., 2023).

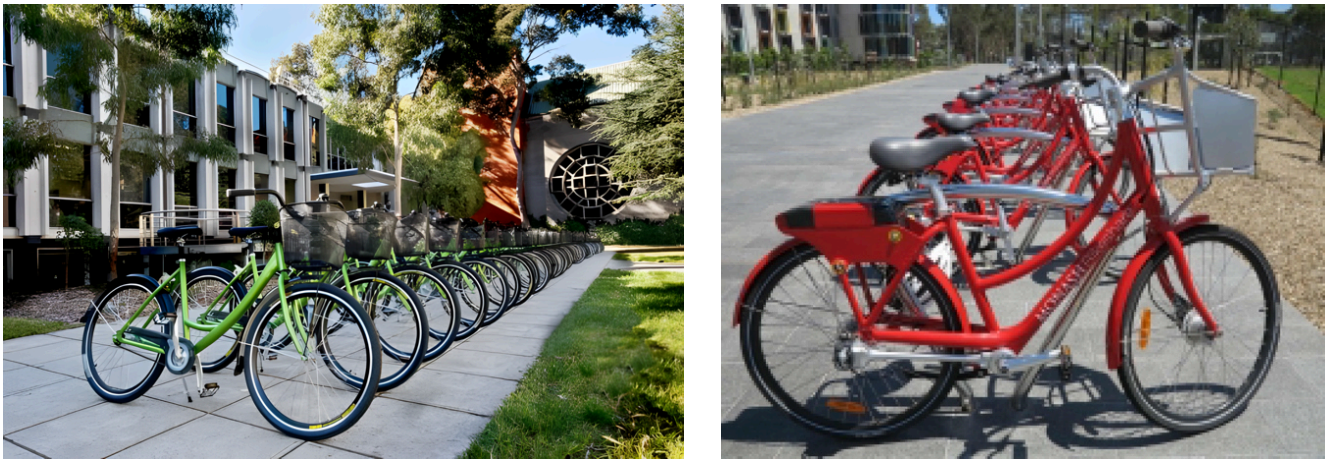


Figure 2.59. Blue bike-share programme (left) and red bike-share programme (right) at the Clayton campus (Monash & Monash Sports, 2013; Sustainability at Monash, 2017)

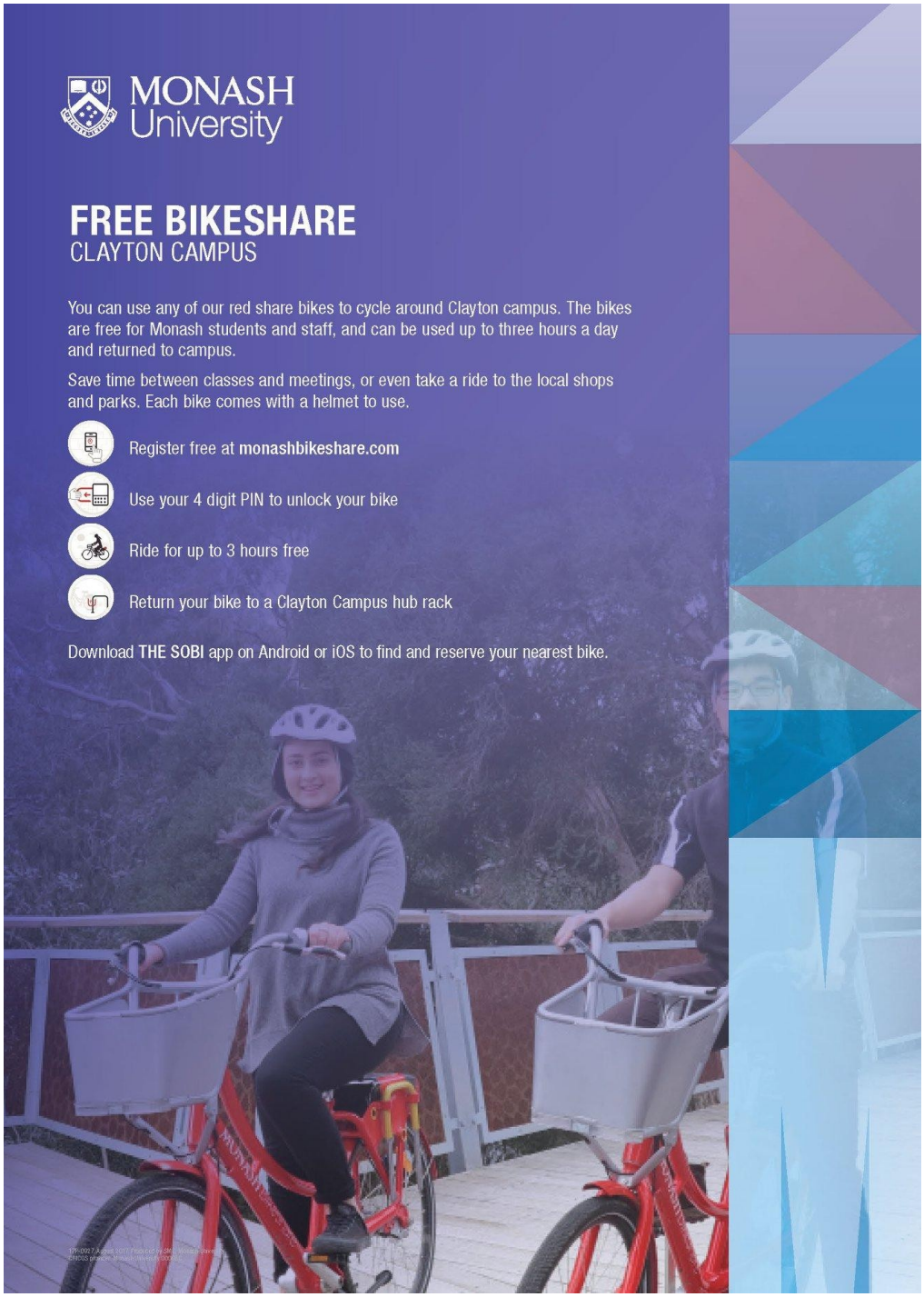


Figure 2.60. Free Bike Share program promotion page at the Clayton campus (source: Monash Sport, 2018)

In addition, the Clayton campus provides on-demand car-sharing services, which Flexicar and GoGet operate. Car-sharing services offer convenient accessibility for registered users to rental vehicles via designated parking zones on the Clayton campus. According to the Monash University car share website, Flexicar provides two vehicles at the C12 car park, two at the RC4 car park, and three at the S1 car park. GoGet provides one vehicle at the C8 car park, three at the N1 car park, and three at the S1 car park.

Finally, Monash University also offers pool vehicles for registered staff for business use only. The registered Monash staff

member could hire the pool vehicles, which are four-door Holden Cruze hatchbacks with automatic transmissions, on the Pool Vehicle Hire system portal. According to the Monash University Pool Vehicles website, the cost associated with the rental of a pool vehicle is contingent upon the duration of its usage and is billed on a monthly schedule. When pool cars are inaccessible to staff members requiring transportation, Monash University offers several alternative shared-mode travel options mentioned above for business purposes. These alternatives include intercampus shuttle buses, car-sharing services, PTV transport, and Taxi or Uber services. At the Clayton campus, taxi ranks are located at 59 Scenic Boulevard.

2.8.1.5. EVs and relevant infrastructure

Electric vehicles (EVs) are increasingly considered a viable transportation option for Clayton commuters accessing the campus. Monash University provides free charging stations for EVs to encourage students and staff to choose sustainable transport to access the Clayton campus (see Figure 2.61). Two main charging stations are provided on the Clayton campus for EV drivers, comprising fast charging (22 kW) and rapid charging (50 kW). Currently, only the fast chargers, located in the N1 and S2 car parks, are available for public use (Monash University, 2023a).

2.8.1.6. Micromobility and e-scooters

Micro-mobility is a term used to describe "small vehicles" (O'Shea, 2021) that provide travel options for short distances, especially first- and last-mile travel (Clewlow, 2018; Tiwari, 2019). Micro-mobility features of flexibility, sustainability, cost-effectiveness, and on-demand availability (Shaheen et al.,



Figure 2.61. Charging station at N1 car park (Photos taken by the Author in February 2023)

2020) are becoming more popular and could reduce greenhouse gas emissions from gas-engine vehicles. Electric-powered or human-powered devices, such as bicycles, scooters, skateboards, Segways, and hoverboards, typically support micro-mobility, an increasingly popular travel option. These devices can be classified as privately owned or shared (Abduljabbar et al., 2021; Dia, 2019).

Micromobility is one of the most common travel options for commuters living near the Clayton Precinct, as it offers convenient access to the campus. Students and staff use two major micromobility transport options to commute to the Clayton campus, namely bikes and scooters.

Cycling

Bikes are the most common micromobility mode to access the Clayton campus (see Figure 2.62). The predominant mode of transportation selected by commuters in Clayton is the conventional human-powered bicycle, utilised by individuals for short-distance travel within or near the campus's surrounding area. In recent years, electric-powered bicycles have emerged at the Clayton campus; however, the campus lacks fundamental charging infrastructures for electric bicycles.

Monash University provides basic facilities for cyclists, such as designated cycling lanes around the campus (see Figure 2.63), bike hoops across the campus, and bike arrival stations (BAS) at the entrances of the Clayton campus (refer to Figure 2.64), to foster a community conducive to cyclists' needs. The Southern BAS is located underground at 19 Ancoras Imparo Way, which provides 98 bike parking spaces and 186 digital access lockers. At the same time, the James Gormley BAS is located on the G-level of the N1 car park at 5 Rainforest Walk, which provides 143 bike parking spaces and 172 lockers. These BAS facilities offer complimentary services such as bike locking, shower infrastructure, and storage for personal equipment. Simultaneously, riders may park and secure their bikes in bike cages or bike hoops near their destinations across the campus (Monash University, 2023b).



Figure 2.62. Bike on campus (Photos taken by the Author in February 2023)



Figure 2.63. Designated cycling lane that shared usage with pedestrians in the Research Way (Photos taken by the Author in February 2023)



Figure 2.64. James Gormley Bike Arrival Station in the G-floor of N1 car park (Photos taken by the Author in February 2023)

E-scooter

The e-scooter, as a growing representative of micro-mobility, assumes a crucial function in fostering sustainable development and facilitating the advancement of future personal mobility. The state of Victoria has implemented and released a series of traffic regulations for e-scooters. This initiative is a promotional strategy to encourage commuters in Victoria to adopt micro-mobility solutions, which can effectively address the issues of traffic congestion and carbon emissions (VicRoads, 2023; Victoria). Simultaneously, the e-scooter serves as an emerging mode of transportation for individuals seeking to access the campus via micro-mobility.

However, the Clayton campus does not provide facilities and amenities for e-scooters, such as parking docks with specific lockers, recharging stations, and designated riding ways within and around the campus. Presently, the electric scooter is limited to conventional bicycle parking docks for parking and locking, and it lacks the capability to safely recharge within designated charging facilities on the campus (refer to Figure 2.65).



Figure 2.65. An e-scooter parked near the Southern Bike Arrival Station

2.8.1.7. Planned transportation projects

To address the issue of the increasing number of students in recent years (Monash University, 2022), there are two main public transport options under construction, including the Suburban Railway Loop (SRL) and Trackless Rapid Transit (TRT). These massive passenger transportation plans set up stations near the Clayton campus.

SRL will construct a new underground railway station (see Figure 2.66) in the north entries of the Clayton campus, between Normanby and Ferntree Gully roads (SRLA, 2022). The SRL east line will link the Clayton campus with various communities, including Burwood, Box Hill, Glen Waverley, and Cheltenham (see Figure 2.67).

TRT is an emerging transport option in Melbourne, Australia. The proposed TRT system aims to efficiently facilitate the transportation of passengers between the Caulfield campus and Rowville (see Figure 2.68). The proposed location for the construction of the TRT station is Blackburn Road, near the Victorian Heart Hospital situated east of the Clayton campus (refer to Figure 2.69). The TRT transport system will also connect the Clayton campus with the Caulfield campus and other designated destinations (Monash University, n.d.b; Eastern Transport Coalition, 2022).



Figure 2.66. Concept view of SRL Monash Station (SRLA, 2022)

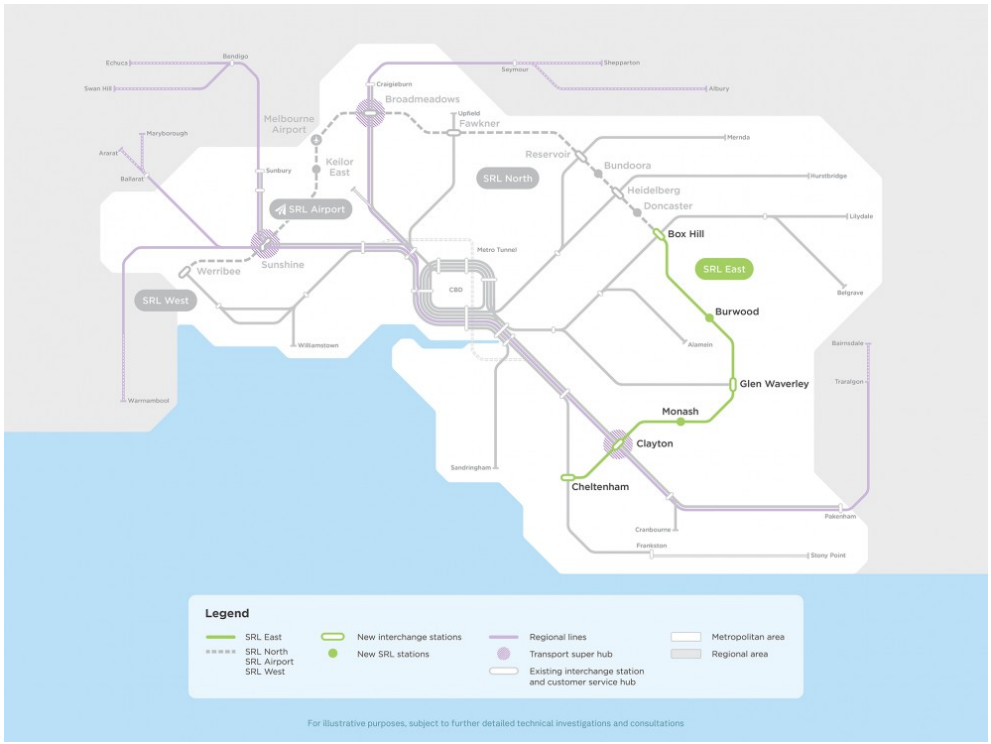


Figure 2.67. Map of Suburban Rail Loop (SRL) East (SLRA, 2022)

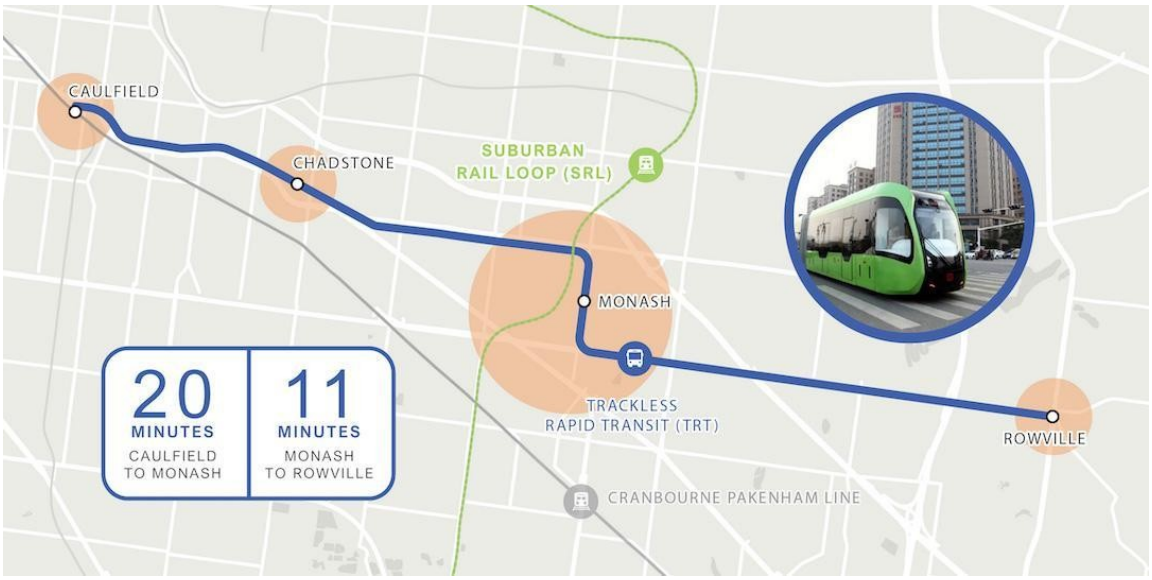


Figure 2.68. Map of Caulfield-Rowville Trackless Rapid Transit (Monash University, n.d.b)



Figure 2.69. Station of Trackless Rapid Transit at Monash Precinct (Monash University, n.d.b)

2.8.1.8. Environmental impacts of light duty vehicles and their emissions profiles

The Light Duty Vehicle (LDV) generic includes passenger cars (PCs) and light commercial vehicles (LCVs) or light trucks. However, the definitions of PCs and LCVs might vary based on the fuel consumption labelling and emission standards in different regions (Khan & Yang, 2023). In Australia, Light Commercial Vehicles (LCVs) are defined as the category of motorised conveyances specifically designed and manufactured for the transportation of goods or specialised equipment, with the limit of Gross Vehicle Mass (GVM) to 3.5 tonnes. PCs are motor vehicles for the carriage of passengers and contain less than ten seats, excluding motorcycles and buses (Bureau of Infrastructure, Transport, and Regional Economics, 2017).

Due to the scale of the Clayton campus, which encompasses multifunctional buildings, it operates as both an education and residential setting that supports everyday living, working, and study for faculties, departments, staff, and students. This scale also generates regular visits by light-duty vehicles that provide essential maintenance and support services, such as plumbing, electrical, and other building and energy-related works (refer to Figure 2.70). Nevertheless, recent studies have demonstrated that emissions generated by LDVs constitute a noteworthy contributor to carbon dioxide emissions in the section of road transportation and proposed innovative approaches to reduce the GHG emission from LDVs, such as biofuel (Puricelli et al., 2021), electric-powered vehicles (Spangher et al., 2019), and renewable hydrogen (He et al., 2020). In particular, the average carbon emissions from heavy Sports Utility Vehicles (SUVs) and LCVs in Australia amount to 212.5 grammes per kilometre, nearly twice the emissions observed for passengers and light SUVs, which record an average of 146.5 grammes per kilometre (National Transport Commission, 2022).



Figure 2.70. A light-duty vehicle for plumbing service parked near the campus centre (left); a light-duty vehicle for electric service parked in the Scenic Boulevard

2.8.2. Mobility within the Clayton precinct

As mentioned earlier, people commute to the campus mainly by driving a car, taking buses (including intercampus shuttle bus services), and active mobility (including walking, bikes, scooters, etc.). Monash University has implemented an extensive car-free zone within the central area of the Clayton campus. Hence, when people approach the campus, they must access multiple "connection ports" that cater to various transportation alternatives, such as car parking lots, bus stops for public transport, bike arrival stations for cyclists, and loading dock areas to deliver goods.

Regarding the early studies, Dulken (1992, p. 24) noted that the traditional university campuses were located in the centre of a "self-contained neighbourhood," characterised by a high level of connectivity between various

destinations through walking (Nelson et al., 2023). The pedestrian pathway network comprises ten walking paths connecting the Clayton campus's various locations. Therefore, walking represents the primary mode of movement for students and staff as they navigate within or near the campus. A limited proportion of students and staff opt to use bicycles or electric scooters for their short-distance travel on campus.

The following sub-section will summarise people's existing inner-campus travel options for different purposes, including education and support team, catering staff, service providers, workers, and visitors (refer to Figure 2.71).

2.8.2.1. Walking as the primary mode of movement

Walking is a predominant means of transportation, particularly on a university campus. According to Sharp et al. (2023), walking is the primary mode of travel for people getting around the Clayton campus. However, the large campus size necessitates considerable walking time for students and staff to traverse between classes and/or meetings.

The Clayton campus features a network of ten primary pedestrian pathways (see Figure 2.72) that serve as routes for various destinations, which include teaching and departmental buildings, major lecture theatres, residences, loading docks, bus stations, BAS, shared car parking bays, drop-off and pick-up locations, taxi ranks, and public car parks (see Figure 2.73).

The Clayton campus also constructed a 200-metre-long nature walk and footbridge near the Jock Marshall Reserve (see Figure 2.74). This infrastructure allows people to engage in environmentally friendly walking activities while establishing a secure and efficient

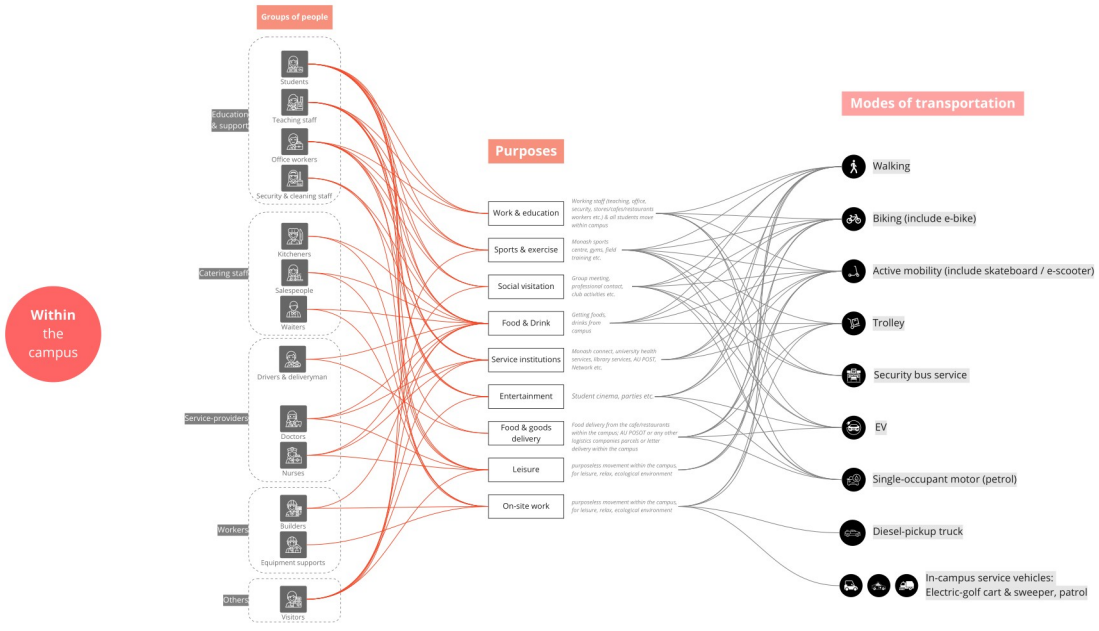


Figure 2.71. Summary of people's movement within the Clayton campus with various purposes and related travelling options (Author's own infographic)

link between the campus and Blackburn Road for pedestrians (Monash University Jock Marshall Reserve, 2023; Monash Masterplan, 2018).

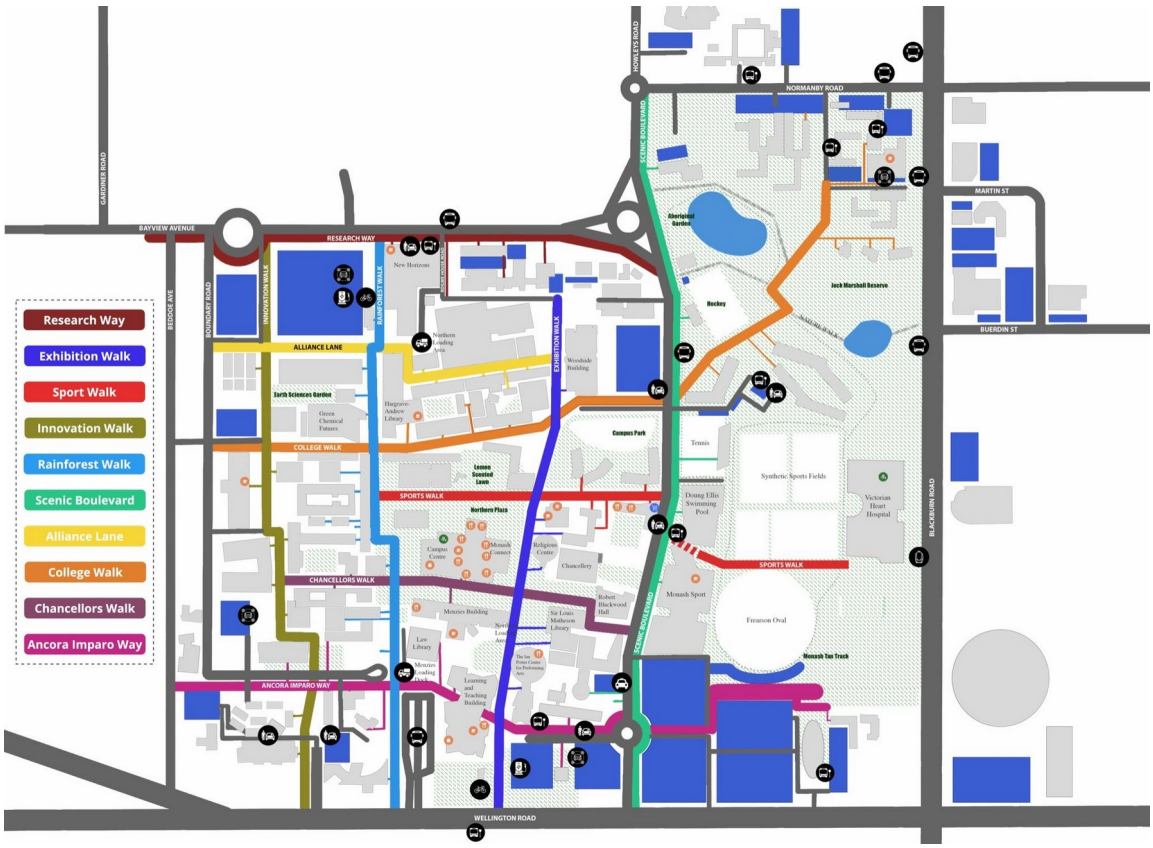


Figure 2.72. The map of walking paths at Clayton campus, redrawn from Monash University (2023c)

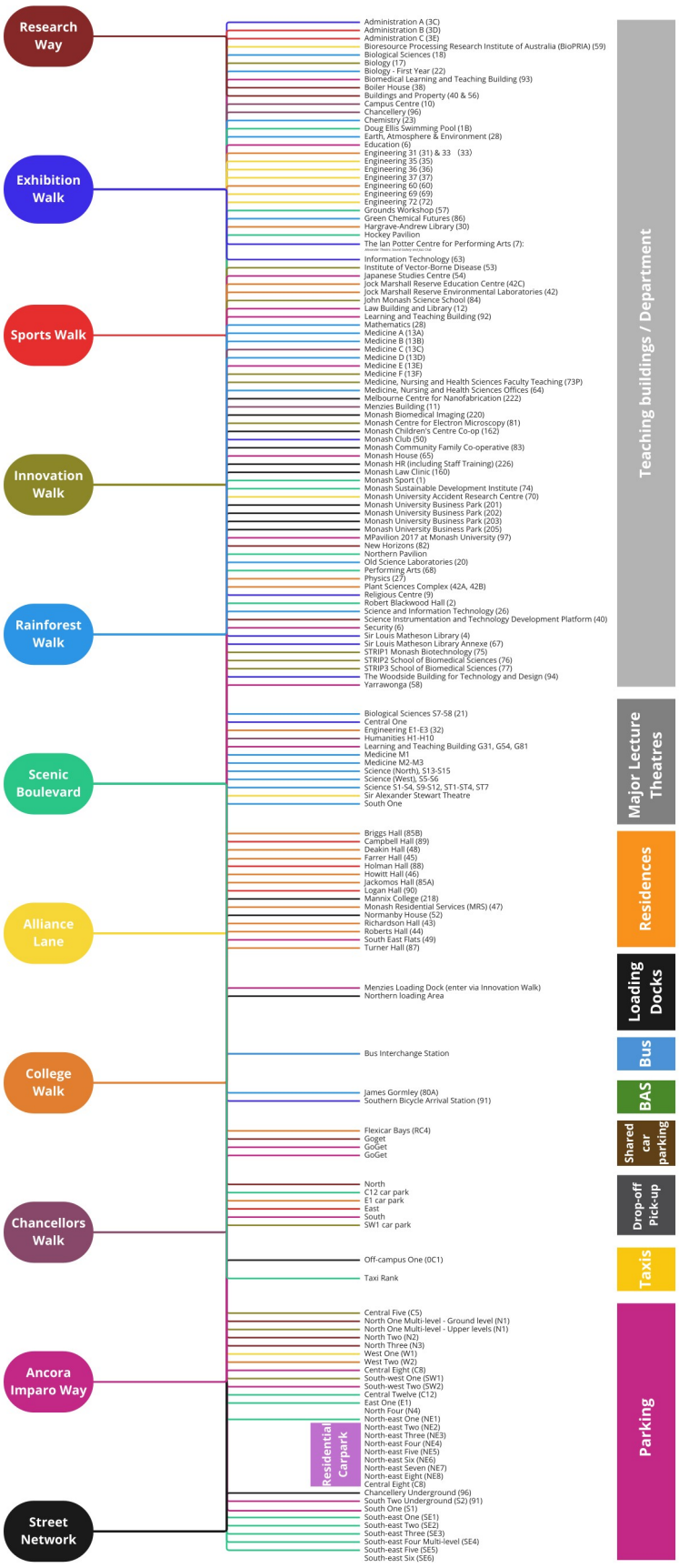


Figure 2.73. The destinations are connected by ten walking paths at the Clayton Campus, adapted from the map of the Clayton campus by Monash University (2023)

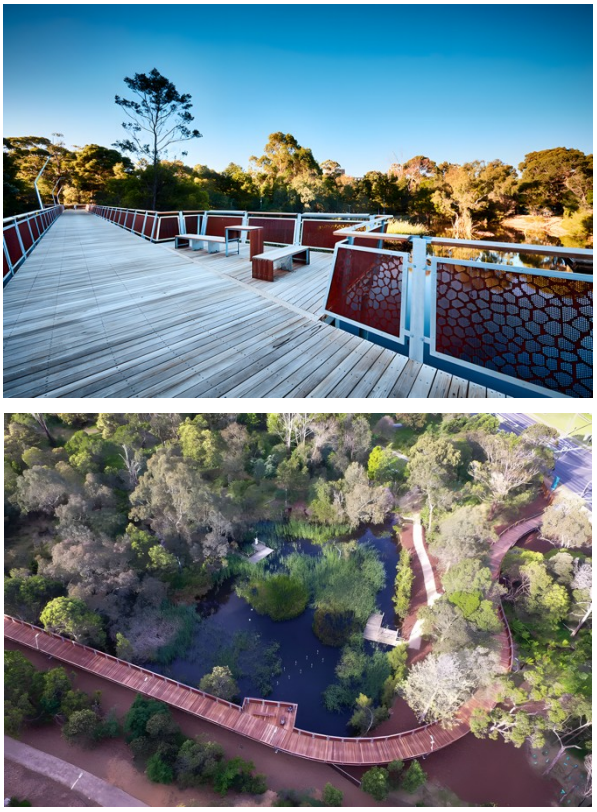


Figure 2.74. The nature walks and footbridge at Jock Marshall Reserve (left: Monash University[5]; Right: Ricardo[6])

2.8.2.2. Campus service fleet

Monash University has provisioned a variety of vehicular equipment for the utility of campus employees, encompassing a spectrum of roles such as cleaners, security personnel, catering staff, and gardeners (see Figure 2.75 & Figure 2.76). The array of vehicles allocated includes those powered by batteries as well as those that operate on conventional fuel. For example, the university furnishes electric golf carts, which are designated for a multitude of tasks, including, but not limited to, street cleaning, the delivery of tools, and patrol missions. This deployment of varied vehicular resources exemplifies the university's commitment to addressing the diverse operational needs of different service departments within the campus, thereby fostering an environment conducive to operational efficiency and ecological responsibility.

5 Monash University. (2023). JOCK MARSHALL RESERVE NATURE WALK MONASH UNIVERSITY CLAYTON. Rhiannon Slatter Photographer. https://rhiannonslatter.com.au/photographer/work/public/jock-marshall-reserve-nature-walk-monash-university-clayton/ (Accessed 26 Jul 2023)

6 Ricardo Ricky. (2018). Bridging the divide: Jock Marshall Reserve Nature Walk. Landscape Australia. https://landscapeaustralia.com/articles/jock-marshall-reserve-nature-walk/ (Accessed 26 Jul 2023)



Figure 2.75. A security CCTV patrol vehicle parked near the Northern loading area at the Clayton campus (Photos taken by the Author in February 2023)



Figure 2.76. A security CCTV patrol vehicle parked near the Northern loading area at the Clayton campus (Photos taken by the Author in February 2023)

2.8.3. Digital navigation tools

Nowadays, a number of map-based mobile applications are used by people to navigate to and within the Clayton campus, such as Google Maps, Lost on Campus, and the Public Transport Victoria (PTV) app (Sharp et al., 2023). These applications provide users with real-time information, facilitating them to efficiently navigate their way around the campus and access vital resources. Additionally, these mobile applications often include features like public transport schedules and walking directions, enhancing the overall experience for students and visitors alike.

Google Maps is one of the most essential map applications for people who commute to the Clayton campus, which provides users the most efficient travel route in multi-selectable transportation modes, including driving, public transport, cycling, and walking. However, due to the limited resources and coverage of the digital map system, Google Maps cannot provide wayfinding solutions and detail the cycling routes at the Clayton campus. This constraint may cause problems for riders attempting to traverse the campus efficiently. Consequently, users may need to depend on local maps or university

resources (such as Monash Digital Wayfinding, road, or map-information signs around the campus) to identify optimal bicycle routes or find the rooms (such as meeting spaces, kitchens, or toilets) inside buildings.

Additionally, another map-based app used to navigate on campus is *Lost on Campus*, which is a mobile platform that integrates 42 Australian campuses mapping information. The digital platform operates on iOS, Android, and the web. Compared to Google Maps, users of Lost on Campus can search and navigate their destinations on-campus in detail, including lecture theatres, rooms, labs, and toilets. At the same time, based on the detailed mapping information of the campuses, this app also provides users with photos of most of the corresponding destinations, contributed by students, along with rating and feedback functions (see ***Figure 2.77***). This increases the accuracy of map navigation on campus and enhances the interaction between users and the campus physical environment.

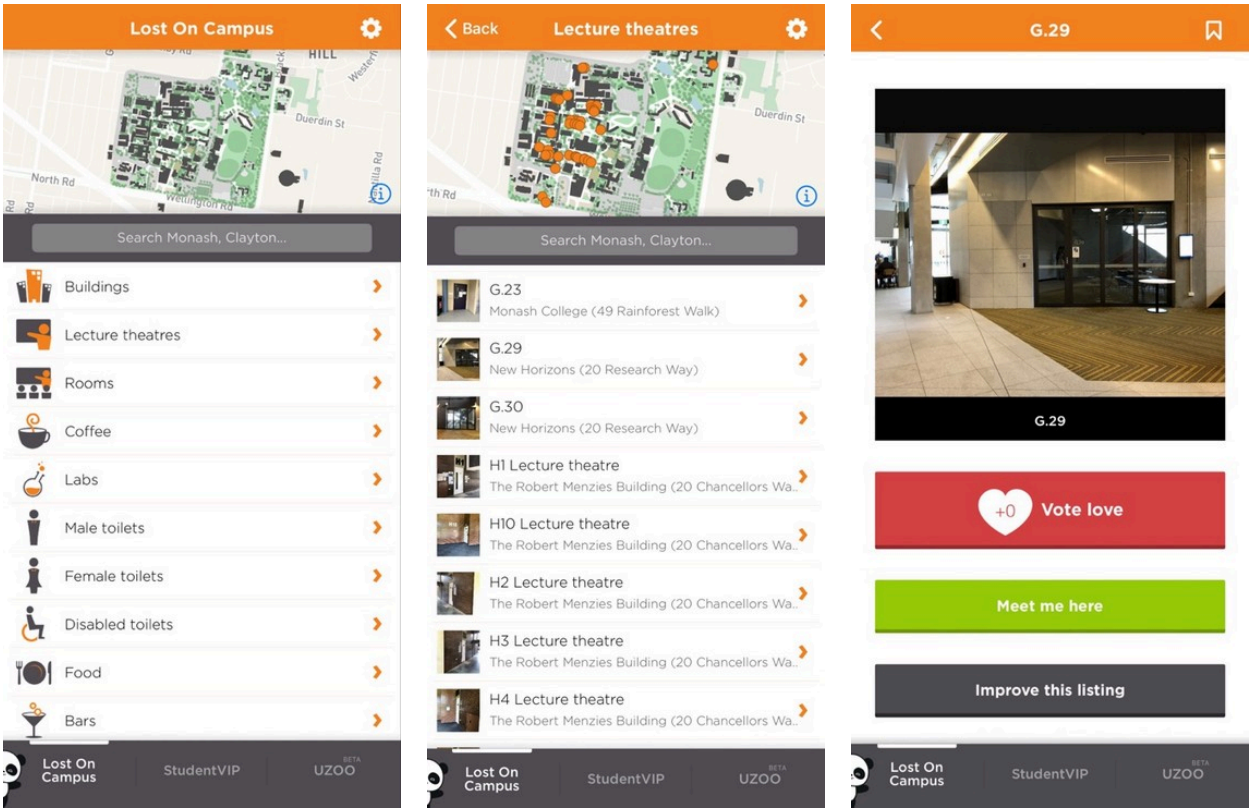


Figure 2.77. App interfaces of Lost on Campus (source: StudentVIP webpage)

Beyond that, Monash University also provides an official mobile application, which provides access for student users to visit the Monash Digital Wayfinding online platform. The platform details a variety of destinations on a level scale, including bus stops, car parks, kitchens, toilets, libraries, lecture theatres, offices, and other common facilities at the Clayton, Caulfield, Parkville, Peninsula, and Kuala Lumpur campuses. At the same time, Monash University also provides security shuttle bus services for its students at night during the formal teaching semesters. The university has introduced an app named Monash bSafe, which integrates various security support services, including 24/7 phone

counselling support, GPS-embedded emergency call access, and security support (see Figure 2.78). The app offers access for students to locate the security shuttle bus locations on each campus and their hours of operation (see Figure 2.79).



Figure 2.78. App interfaces of Monash bSafe (source: Monash University current student services webpage)

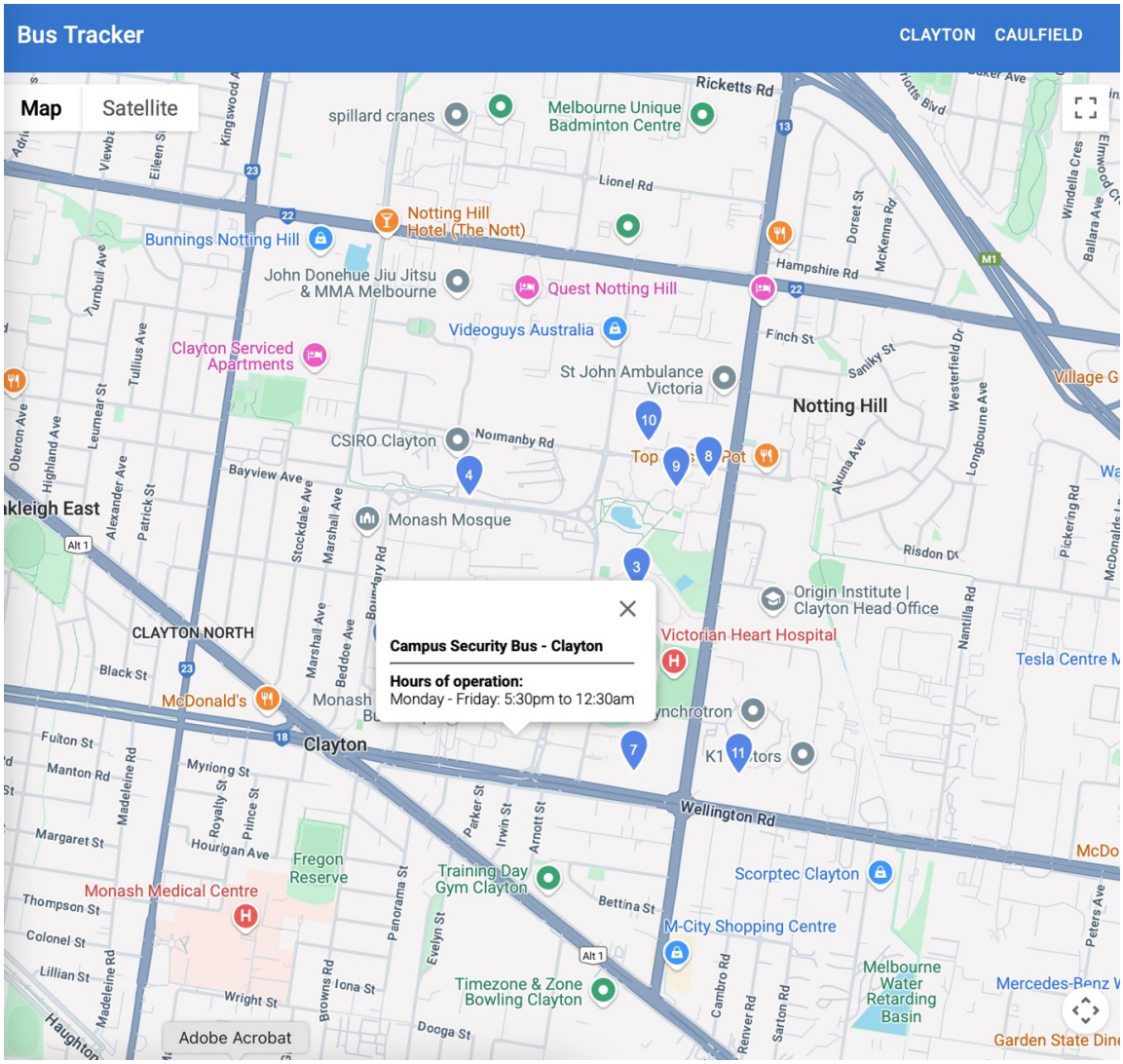


Figure 2.79. Snapshot of the security bus tracker with information about hours of operation at each location from the Clayton campus (source: Monash campus bus website)

2.8.4. Review of sustainable transport initiatives at the Clayton campus

In earlier years, several studies investigating travel behaviour change programmes at the Clayton campus, such as TravelSmart, have shown success in reducing single-occupancy vehicle use and increasing public transport adoption among student populations (B. Cooper & Meiklejohn, 2003; Rose, 2008). Rose (2008) introduced TravelSmart, a sustainable travel programme that provides tailored travel information and resources to first-year students at the start of the 2004 and 2005 academic years. Students were encouraged to make sustainable travel decisions by trained programme officers and receive personalised travel packs, including a visual map of the Clayton campus with various transportation options, such as public transport, carpooling, walking, and cycling (see Figure 2.80), concession card applications, and carpooling resources.

Monash University Clayton campus TravelSmart Map



This TravelSmart map was developed by Monash University and Melway to provide sustainable transport information on a pocket-sized street map with standard Melway references.

Walking and cycling, like any physical activity, should be undertaken using common sense. Stay within your abilities and follow any applicable laws.

This map was accurate at the time of printing.

For up-to-date public transport information and timetables visit **ptv.vic.gov.au** or call **1800 800 007** (6am to midnight daily).

Thanks to Yarra City Council for allowing us to use their Top Tip cycle maps.

Printed January 2015 on carbon neutral Forest Stewardship Council-certified paper.

CRICOS Provider: Monash University 00008C

TravelSmart

Monash University's Clayton campus has great sustainable transport options, particularly public transport.

Research shows that those who adopt healthy and sustainable travel habits at university are more likely to travel sustainably after university too.

Monash has good reason to care about your travel choices! With limited space available at Clayton campus, every new car park Monash has to provide costs $14,000 and takes up room that could be used for a new laboratory or lecture hall – our core business.

This map shows you how to travel smart at Monash.

If you live...	You should consider:
0–5 km from Clayton	
5–10 km from Clayton	
10–20 km from Clayton	
20–30 km from Clayton	
>30 km from Clayton	

Like us on facebook.com/monashgreen

Travelling to Monash Clayton

Choosing sustainable transport has never been easier, with a range of options available for travel to and from Monash University's Clayton campus.

Bus routes running directly to campus

601, 630, 631, 703, 733, 737, 742, 800, 802, 804, 862, 900, and the intercampus shuttle buses (see below).

Bus routes running from train stations to campus

Belgrave and Lilydale Lines
From Box Hill Station take bus route 733.

Frankston Line
From Oakleigh Station take bus route 630.

From Caulfield Station take the intercampus shuttle bus, bus route 900, or take the train to Huntingdale Station and take bus route 601.

Glen Waverley Line
From Mount Waverley Station take bus route 733.

From Syndal Station take bus routes 703, 733, 737.

Pakenham and Cranbourne Lines
From Huntingdale Station take bus routes 601, 630, 900 or the intercampus shuttle bus.

From Clayton Station take bus routes 631,703,737.

From Caulfield Station take the intercampus shuttle bus or bus route 900.

Sandringham Line
From Gardenvale Station take bus route 630.

For more information about these routes refer to the list of bus routes on this map.

Visit **ptv.vic.gov.au** or call 1800 800 007 (6am to midnight daily) for further information and timetables.

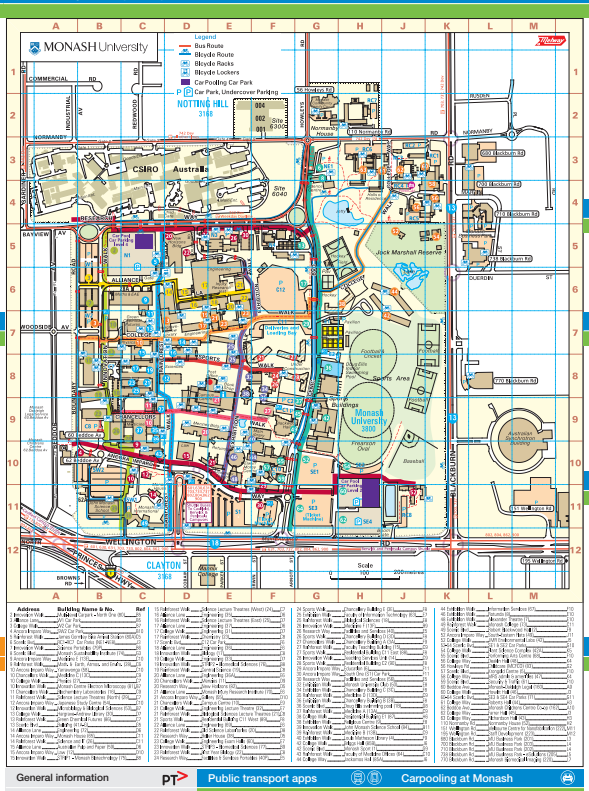
Cycling to Clayton

Why not cycle to Monash University's Clayton campus? You can stay fit and healthy, and it can be quicker than other transport options. Cycling routes are marked on this TravelSmart map or visit Bicycle Victoria at **www.bv.com.au**

or VicRoads at **www.vicroads.vic.gov.au**.

Lockers and showers are available in the James Gormley Bike Arrival Station.

Monash Clayton campus map



Discounted travel

Many Monash students are eligible for discounted public transport. The discounts available differ for domestic and international students. Typically, undergraduate students who enrol in full time study are eligible. To check your eligibility go to www.monashedu.au/connect/travel-concession.html.

- Eligible domestic undergraduate students can order a transport concession form in the Web Enrolment System (WES) – go to the 'Student Services' section and click 'Apply for transport concession'.
- Eligible international undergraduate students can purchase an ESEpass (www.iusepass.vic.gov.au) to receive 50% off the cost of an annual myki. Eligible students can order the discount code via WES – go to the 'Student Services' section and click 'Apply for international travel discount'.
- Part-time and postgraduate students (as well as staff) are typically ineligible for transport concessions. They may benefit from signing up to Monash Commuter Club in order to obtain 10% off an annual myki (see below).

If you are unsure about your eligibility or have a question contact Monash Connect.

Monash Commuter Club

Monash offers all staff and non-coterm students the opportunity to participate in the Monash myki Commuter Club. By joining, not only are you doing your bit for the environment, but you can also:

- get a 10% discount on your 365-day myki pass
- avoid fare increases and the need to top up your myki for 12 months.

To register or get more information, visit **fsd.monash.edu.au/environmental-sustainability/monash-commuter-club**.

Bike parking at train stations

Bike lockers

Bike lockers are available at selected Metro and V/Line train stations across Victoria, and can be used for free after paying a refundable bond ($100 for a locker with a built in lock or $50 for a locker that requires you to supply a lock).

At Premium Stations, lockers can be hired for up to three months at a time and renewed without paying any additional bond, provided the locker is kept in good condition. Lockers can be used for storing your bike, helmet, clothes and shoes. Items stored in lockers remain your responsibility.

For more information visit **metrotrains.com.au** or call **1800 800 007**.

Bike lockers are located at the following stations on this map:

Bike lockers		
Ashburton	Hughesdale	Sandown
Clayton	Huntingdale	Springvale
Glen Waverley	Mt Waverley	Westall
Holmesglen		

Parkiteer bike cages

There are 78 Parkiteer bike cages at train stations across Melbourne and key regional centres. Each bike cage provides undercover, free, secure parking for around 25 bikes.

To access your nearest Parkiteer cage you need to register for an access card. Cards are available through Parkiteer for a refundable $50 deposit.

Parkiteer cages are available for use at Oakleigh, Huntingdale, Westall, Springvale, Glen Waverley, Holmesglen and East Malvern Stations.

To locate other Parkiteer bike cages visit **parkiteer.com.au**.

Bike arrival station

The James Gormley Bike Arrival Station on Clayton campus (see map on right, ref C5) features secure, weather protected bicycle parking spaces, showers and private change areas, lockers, a DIY bike repair bay, toilets, and a drinking fountain.

The bike arrival station provides an outstanding 'end of trip' facility for students and staff and supports sustainable transport at Monash.

To register to use the bike arrival station, visit **www.fsd.monash.edu.au/environmental-sustainability/bike-arrival-station-registration-page**

Bikeshare

All students and staff have access to a new fleet of share bikes on Clayton campus.

The bikes can be booked online and are available for use by anybody at a low cost, with a wide range of memberships available to suit your needs (eg, pay-as-you-go, semi-annual, or annual).

You can ride the bikes in and around campus and lock up at any designated hub at the end of your ride. For more information and to register, visit the Bikeshare website at **monashbikeshare.com**.

Bike shops

	Phone no.	Mel Ref
Action Cycles 843 Princes Hwy, Springvale	9558 4088	80 A4
Bikes Direct 1062 Dandenong Rd, Carnegie	9572 3155	68 J3
Bicycle Recycle 670a South Rd, Moorabbin	9555 8692	78 C6
Cycle Centre 951 Centre Rd, Bentleigh East	9579 5640	78 C2
Cycle Science 363 Springvale Rd, Glen Waverley	9560 2744	79 K10
Fitzroy Cycles 1034 Dandenong Rd, Carnegie	9571 8100	68 H3
Fuel Performance Bike Mechanic 98a Murrumbeena Rd, Murrumbeena	9563 3281	69 A5
Sparta Motorised Bicycles 504 Nepean Rd, Mornington	9588 4494	69 B5
Mulgrave Cycles 5 Dunrobin St, Mulgrave	9547 4418	80 B5
Oakleigh Cycles 61a Atherton Rd, Oakleigh	9563 2433	69 G7
Open Road Cycles 218 Blackburn Rd, Blackburn South	9803 8268	70 J1

The Bikery is a volunteer-run bike shop that sells parts, accessories, and refurbished bikes, performs small repairs, and gives general cycling advice.

The Bikery is located at Monash Sport, 42 Scenic Boulevard, Clayton campus.

Open during semester Mon-Fri 10am–4pm

Ph: 9905 8017

E: rmsa-bikery@monash.edu

A list of bike shops across Melbourne can be found at **www.bicyclenetwork.com.au/find/shop**

Public transport tips

If you travel most days in the week you could save money by purchasing a myki pass¹ instead of using myki money (see above for more information about the Monash Commuter Club).

Two-hour fares touched on at or after 9pm are valid all evening (until 3am).

The time you spend on public transport can be used to 'catch up' on things. You can work or catch up on emails on your phone. Or you can relax by reading, meditating or playing games on your phone. So be sure to bring a device, a book, or some work along with you.

Take the opportunity to stretch while you wait for your train, tram or bus.

For more public transport tips, including a list of information sources visit **www.ptua.org.au/tips**.

Car sharing

Why buy a car when you can share one? Car share gives you 24/7 access to clean, new cars whenever you need them. There's no registration, petrol, insurance or maintenance to pay – just a simple sign up process and fee, based on your use. Join one of Melbourne's car share programs to receive an access card or key, then book a car online. Sharing a car isn't just good for the environment – if you drive less than 15,000 km a year, it will save you money as well.

Two Flexicar car share bays are conveniently located on Clayton campus (see map on left).

Flexicar.com.au
1300 35 37 80

CarNextDoor.com.au
Ph 03 9946 4106

GoGet.com.au
Ph 1300 769 389

GreenShareCar.com.au
Ph 1300 576 878

ShareCar.com.au
Ph 03 9008 5440

Access and mobility

Trains

All train stations are wheelchair accessible, except Heyington Station.

If you need help boarding a train, wait on the platform near the front of the train. The train driver will help you board and depart the train by producing a ramp.

Premium Stations are staffed from the first to last train every day and have accessible facilities including toilets, public phones and parking.

For station and stop profiles visit **ptv.vic.gov.au**

Trams

There are more than 100 low-floor trams on Melbourne's tram network, which offer allocated spaces for passengers using wheelchairs or mobility aids. This area is inside the double door and marked with a wheelchair symbol.

Some low-floor trams have buttons that alert the driver to activate a 'bridging plate' to bridge the gap between the tram and the platform, while other trams have a specially marked call button that overrides the automatic door closing mechanism to allow extra time to enter and exit the tram.

Buses

More than 80% of Melbourne's bus services have step-free access, including SmartBus, SkyBus, and NightRider buses. At the stop, the bus driver places a ramp between the front door of the bus and the kerb of the road.

For station and stop profiles visit **ptv.vic.gov.au**

Taxis

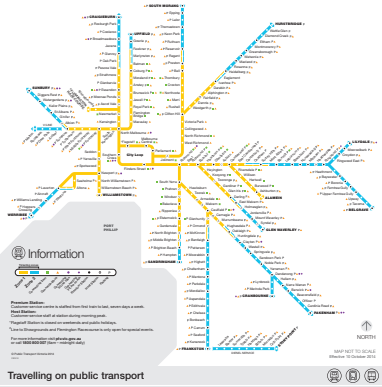
Wheelchair accessible taxis (WAT) can be booked with Silver Top Taxis on **131008** or Yellow Cabs on **13CABS**.

Travellers Aid

Travellers Aid provides practical travel-related support and aid to travellers that helps them travel independently and confidently, no matter what their background.

For more information visit **www.travellersaid.org.au**.

Melbourne train network



Travelling on public transport

Melbourne's public transport network can help you explore every corner of this vibrant city. Trains, trams and buses offer comprehensive public transport services extending from the central business district to the suburbs in all directions.

Train and tram services operate between 5am and midnight, Mon–Thu, with extended hours to around 1am on Fri and Sat nights. On Sunday, trains and trams operate from 7am to 11pm. Many of Melbourne's bus routes run 6am–9pm Mon to Fri, 8am–9pm on Sat and 9am–9pm on Sun.

Public Transport Victoria

Public Transport Victoria (PTV) is your central stop for information on public transport services, fares, tickets and initiatives.

For public transport information in Victoria visit ptv.vic.gov.au or call **1800 800 007** (6am to midnight daily).

Journey planner

Enter your origin and destination into PTV's online journey planner for travel anywhere in Victoria and you'll be provided with a tailored travel plan including maps, connections and estimated travel times.

PTV Hubs

For face-to-face customer information visit a PTV Hub at Southern Cross Station or 750 Collins Street for all your public transport travel needs.

myki

myki is your ticket to travel on Melbourne's trains, trams and buses. The reusable smart card is easy to use.

Simply top up before your journey and then touch on and touch off at a myki reader as you travel. Once you have a myki, you can travel as many times as you want in your chosen zone/s for the duration of your pass.

You can buy and top up your myki at over 800 retailers including all 7-Eleven stores, the ticket office window at Premium Stations, from a myki machine (full fare myki cards only) located at all train stations and major tram and bus interchanges. You can also buy or top up your myki online at **ptv.vic.gov.au** or by calling **1800 800 007** (6am to midnight) daily, allowing 24 hours to process top ups.

There are two options for using myki – myki money and myki pass.

myki money

With myki money you pay as you go. Once topped up, your myki will automatically validate when you touch on. The lowest fare possible according to the zone/s you travel in as you touch on and off. You can also set up a nominated credit card or bank account to automatically top up your credit whenever your myki money balance falls below a nominated amount.

myki pass

myki pass is a great option if you're planning on travelling regularly. Simply choose the zone/s you wish to travel in and the number of consecutive days of travel you need. You can buy a 7-day myki pass, or anywhere between 28 and 365 consecutive days of travel (also see Monash Commuter Club).

Monash bus routes

601	**Huntingdale to Monash University Clayton Shuttle**
612	**Box Hill to Chadstone** via Surrey Hills, Camberwell, Glen Iris
623	**Glen Waverley to St Kilda** via Mt Waverley, Chadstone, Carnegie
624	**Kew to Oakleigh** via Caulfield, Carnegie or Darling, Chadstone
625	**Elsternwick to Chadstone Shopping Centre** via Oakleigh, Chadstone
626	**Middle Brighton to Chadstone Shopping Centre** via Bentleigh, Oakleigh
630	**Elwood to Monash University** via Gardenvale, Ormond, Huntingdale
631	**Southland to Waverley Gardens** via Clayton, Monash University
691	**Boronia to Waverley Gardens** via Ferntree Gully, Stud Park
693	**Belgrave to Oakleigh** via Ferntree Gully, Brandon Park
701	**Oakleigh to Bentleigh** via Mackie Road, Brady Road
703	**Middle Brighton to Blackburn^** via Bentleigh, Clayton, Monash University
704	**East Clayton to Oakleigh** via Clayton and Huntingdale
705	**Mordialloc to Springvale** via Braeside, Clarinda, Clayton
733	**Oakleigh to Box Hill** via Clayton, Monash University, Mt Waverley
736	**Glen Iris to Glen Waverley** via Ashburton, Ashwood, Mt Waverley
738	**Mitcham to Blackburn** via Vermont South, Glen Waverley, Forest Hill
737	**Croydon to Monash University** via Boronia, Knox City Shopping Centre, Glen Waverley
742	**Eastland to Chadstone** via Vermont South, Glen Waverley, Oakleigh Occasional trips via Monash University
753	**Glen Waverley to Bayswater** via Wheelers Hill, Knoxfield, Boronia
754	**Rowville to Glen Waverley** via Caulfield, Glenmyar, Wheelers Hill Express via Ferntree Gully and Springvale Roads
767	**Chadstone to Oakleigh** via Chadstone, Jordanville, Deakin University
800	**Dandenong to Chadstone** via Princes Highway, Oakleigh
802	**Dandenong to Chadstone** via Mulgrave, Monash University, Oakleigh
804	**Dandenong to Chadstone** via Wheelers Hill, Monash University, Oakleigh
811	**Dandenong to Brighton** via Heatherton Road, Springvale
813	**Dandenong to Waverley Gardens**
814	**Springvale South to Dandenong** via Waverley Gardens, Springvale
821	**Southland to Clayton** via Heatherton
822	**Chadstone to Sandringham** via Murrumbeena, Southland
823	**North Brighton to Southland** via Moorabbin
824	**Moorabbin to Keysborough** via Moorabbin, Westall
848	**Dandenong to Brandon Park Shopping Centre** via Waverley Gardens Shopping Centre
850	**Dandenong to Glen Waverley** via Mulgrave, Brandon Park
862	**Dandenong to Chadstone** via Monash University, Oakleigh
885	**Glen Waverley to Springvale** via Wanda St
900	**Rowville to Caulfield*** via Monash University, Huntingdale Station, Oakleigh Station, Chadstone Shopping Centre (SmartBus Service)
903	**Altona to Mordialloc*** via Sunshine, Essendon, Coburg, Preston, Heidelberg, Doncaster, Box Hill, Oakleigh (SmartBus Service)

* SmartBus is a network of premium bus routes that operates across Melbourne. SmartBus services run more often and for longer hours than most bus services. Services run along major arterial roads, making journeys shorter and more direct.

For more information visit **ptv.vic.gov.au** or call **1800 800 007** (6am to midnight daily).

Monash bus loop layout





Intercampus shuttle buses

Monash shuttle bus services run in both directions from Clayton to Berwick, Clayton to Caulfield and Clayton to Peninsula campuses.

All shuttle bus services run from Monday to Friday during the academic year only. The Clayton–Caulfield service also operates on a modified timetable outside this period.

The shuttle buses commence every year during O-Week in late February and finish along with exams in late November. Shuttle Buses are free of charge to passengers with a valid Monash University student or staff card.

Clayton–Caulfield shuttle buses

Three buses run consecutively in both directions, stopping at Clayton campus bus loop and at Monash University's Caulfield campus. Go to **www.monash.edu.au/people/transport-parking/inter-campus-shuttle-bus** to view the timetable.

Clayton–Berwick shuttle bus

This bus runs in both directions, stopping at Clayton campus bus loop and at bus bay in front of Building 901 on Berwick campus.

Departure Time Clayton	Departure Time Berwick
7.15 am	7.50 am
9.30 am	10.15 am
11.00 am	11.45 am
12.30 pm	1.15 pm
2.15 pm	3.15 pm
4.15 pm	5.15 pm
6.15 pm	7.15 pm

Clayton–Peninsula shuttle bus

This bus runs in both directions, stopping at Clayton campus bus loop and at George Jenkins theatre on Peninsula campus.

Departure Time Clayton	Departure Time Peninsula
7.15 am	7.50 am
9.15 am	10.15 am
11.15 am	12.15 pm
1.15 pm	2.15 pm
3.15 pm	4.15 pm
5.15 pm	6.15 pm

PenBus

Students, jobseekers, apprentices and trainees living in the Frankston and Mornington Peninsula region can catch a free bus service to Monash University called PenBus.

The PenBus service makes travelling to tertiary education, training and employment easy with services scheduled to ensure morning passengers arrive at their destination in time for standard business and campus opening hours.

For more information on PenBus routes and timetables or to check if you are eligible for the service visit **www.mompan.vic.gov.au/Services_For_You/Roads_Transport/PenBus**.

General information

Need more information?

For more information on public transport in Victoria visit **ptv.vic.gov.au** or call 1800 800 007 (6am to midnight daily).

Information in other languages

Public transport information is available in other languages. Call the number next to the language in the table.

Arabic	9321 5440
Cantonese	9321 5441
Croatian	9321 5442
Dinka	9321 5452
Greek	9321 5443
Italian	9321 5444
Macedonian	9321 5445
Mandarin	9321 5454
Somali	9321 5446
Spanish	9321 5447
Sudanese	9321 5453
Turkish	9321 5448
Vietnamese	9321 5449
All other languages	9321 5450

Public transport apps

There are a number of apps that provide personalised train, tram and bus information.

PTV app (iOS and Android)

The free PTV app has journey planner, service times, and real-time train arrival information. See **ptv.vic.gov.au/getting-around/mobile-apps**.

tramTRACKER

Use tramTRACKER® to check real-time tram arrival information and personalise your results to see individual routes and find low-floor trams. See **yarratrams.com.au/tramtracker**

metroNotify

Use metroNotify to receive push notifications with information about your selected train lines. See **metrotrains.com.au/metronotify**

Melbourne Train Trapper

Use Android app, Melbourne Train Trapper to find times for Metro trains, detect your location, and display upcoming trains at your nearest station.

TrainTracker

Use iOS app, TrainTracker to look up your next train arrival time and report a delay.

Carpooling at Monash

Still want to drive? Why not gear up your act and carpool? Carpooling to Monash reduces traffic congestion and pollution by encouraging people to share rides. Registered users can be matched with other people in their area looking to travel to the same destination.

Carpooling is a great way to help the environment and, if you share petrol costs, save money as well. As an added incentive, we'll reward you with cheaper parking on campus.

All you need to do is register and park in one of our allocated carpooling spaces.

Carpooling spaces at Monash's Clayton campus are located on the top level of the two multi-level carparks (see map above, refs B5 and H11). Spaces can fit fast, so it's first come, first served.

For more information or to register to search for and advertise rides go to **www.monash.edu.au/campuses/transport**

MONASH University

TravelSmart Map Clayton campus

Cycling, walking and public transport

Melbourne | Greening up our act

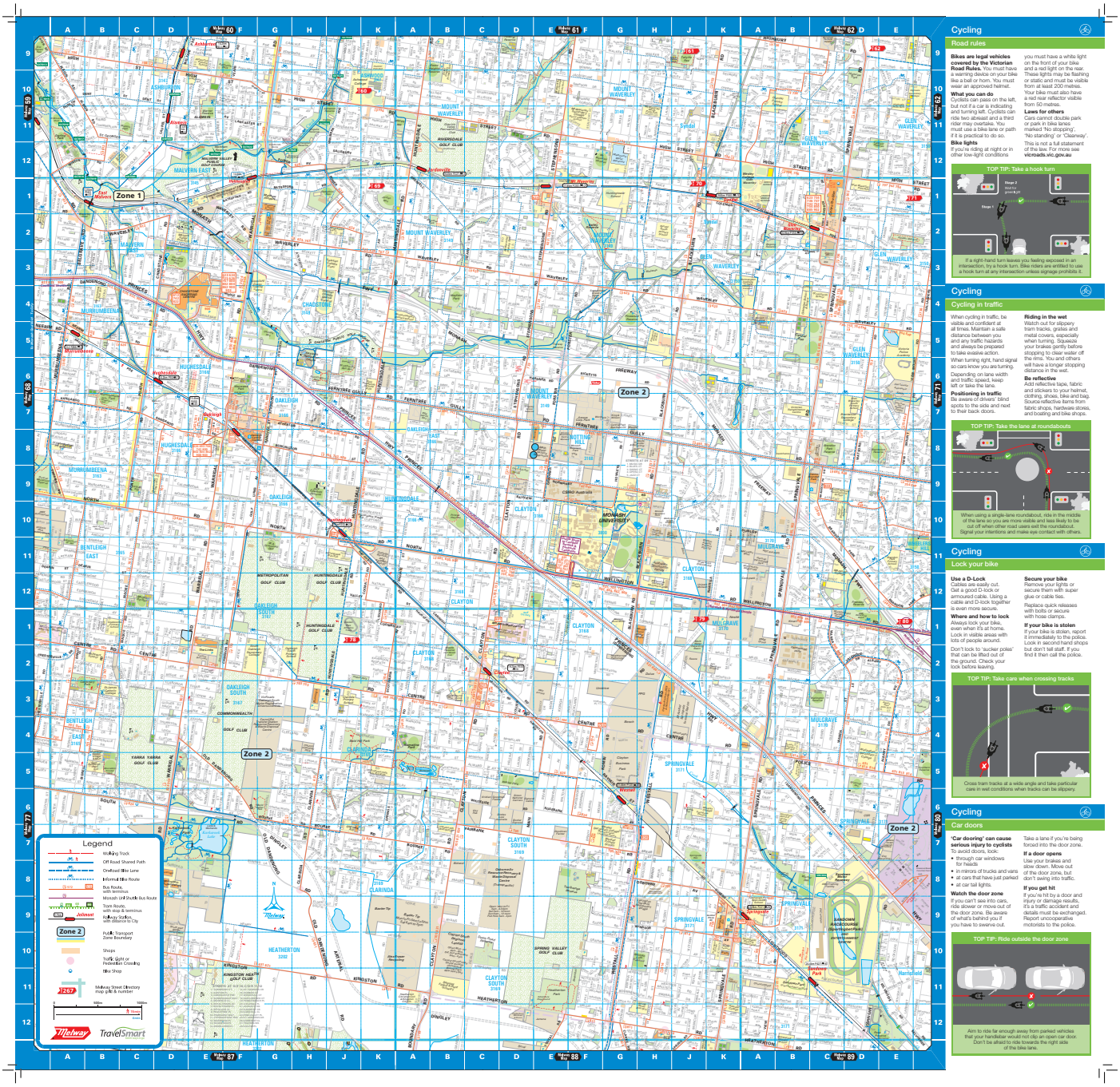


Figure 2.80. The two sides (top: face, down: back) of the map of TravelSmart (Monash University, 2023)

However, in recent years, some empirical evidence indicated that the number of people who accessed the Clayton campus by driving private cars was increasing, especially post-COVID when the campus returned to the regular teaching semesters. Due to biosecurity concerns and a preference for maintaining personal safety, the COVID-19 pandemic has significantly impacted university students' commuting patterns, with a notable shift towards private car use as well as active transportation (Bagdatli & Ipek, 2022; Naaman et al., 2023; Soltani et al., 2024). Although overall travel decreased during the pandemic, leading to significantly reduced carbon emissions, a return to pre-pandemic travel patterns could potentially increase emissions above previous levels (DeWeese et al., 2022). This continuing trend increases the pressure on traffic conditions and road carbon emissions. Therefore, universities, including Monash University, and cities are now challenged to adapt to these changes, potentially through implementing sustainable solutions. As mentioned above, Monash University established its 2030 net-zero emissions initiative in 2021, which aims to reduce the usage of private cars and encourage their staff and students to access the campuses through sustainable transport. However, in 2023, an annual self-report survey (refer to Figure 2.49) conducted by BPD shows that the number of people who commute to the Clayton campus by car accounts for up to 45 percent of overall mode share (including walking, bicycle, shuttle bus, public bus, tram, train, motorcycle/scooter, rideshare, dropped-off, and carpool).

The gap between the net-zero objective and the increasing automobile mode share indicates a distinct design opportunity for MaaS at the Clayton precinct. A campus-based MaaS platform may enhance TravelSmart's customised or personalised travel packs by providing a mobile, real-time solution that integrates multimodal planning, dependable departure coordination, and visualised comparisons of time, cost, and carbon emissions in a single interface. It also facilitates campus-based incentives and community elements, including relevant carbon-saving rewards, carpooling matching or peer support, which may make shared and public transportation choices safer and more accessible.

2.9. Research questions

The literature review has provided the project scope and context for the research and design work ahead. It clarifies how this PhD project sits at the intersection of three scholarly domains, including the decarbonisation of quotidian travel through mode shift, the evolution and adoption of future mobility services and MaaS, and practice-based design research employing participatory methodologies and prototyping to produce knowledge.

This research project asks the following question.

How can participatory design with international student drivers inform the interface and service design requirements of a campus-based

Mobility-as-a-Service proposition that supports sustainable commuting decisions at the Monash Clayton precinct?

This is explored within the specific design project questions set out below.

How might insights generated through participatory design with international student drivers be translated into an interface prototype and service blueprint for a campus-based MaaS service that supports alternatives to private-car commuting at the Monash Clayton precinct?

The research and design project investigation is also supported by several subsidiary questions that have emerged throughout the design practice and research.

RQ1. What behavioural, cultural, informational, and infrastructural barriers and facilitators influence international student drivers' use of alternatives to private-car commuting at the Clayton precinct?

RQ2. How can participatory workshops and iterative prototyping translate international students' situated mobility experiences into traceable design requirements for a campus-based MaaS service?

RQ3. How can participant-informed design requirements be translated into and evaluated through a campus-based MaaS interface prototype and service blueprint?

2.10. Discussion and summary of the chapter

In this chapter, a narrative synthesis of the interdisciplinary literature was conducted to address the first two research questions concerning the contextual, behavioural, and technological dimensions of sustainable mobility for international students. The review included the theoretical framework from sustainable transition design, the conceptual development of MaaS, theories of behavioural change, and the design strategies of digital service design to enhance sustainable travel choices.

Several essential themes emerged. First, MaaS is typically portrayed as a revolutionary framework or innovative mobility solution for enhancing the transport sustainability transition in urban areas, while its interface design and potential implementation lack context-specific requirements, especially in suburban university settings like the Monash University Clayton campus. Second, international students who are new to the host countries, as one of the most substantial commuter groups in road transportation systems, are mostly underrepresented in current transportation studies. Their distinctive adoption patterns, difficulties in cultural and infrastructural navigation, and growing dependence on automobiles indicate an urgent need for more inclusive and participatory service design methodologies. Finally, while behavioural

frameworks, such as the Theory of Planned Behaviour, help explain individual commuting intentions, they do not by themselves translate into design interventions. What those frameworks leave unresolved is therefore a design question instead of a further explanatory one, namely how the determinants they identify can be given form in an interface and tested with the people whose travel is at stake.

In summary, the review authorises three moves and forecloses a fourth. It authorises treating the Clayton precinct as a niche, treating international students as a group whose travel habits are still forming, and treating interface design as a site where sustainability aims are either realised or lost. It does not authorise a claim that an integrated platform will reduce car use, since no study reviewed here demonstrates that outcome in a dispersed suburban setting. This project aims to deliver a practical framework for developing more inclusive, responsive, and low-carbon transportation systems in suburban university communities through a design-oriented approach.

Three limits of the review should be recorded before the enquiry proceeds. Comparing to a systematic review, as narrative methodology, its coverage reflects the search terms set out in Table 1 and the judgement applied in selecting sources, not an exhaustive scope. The review draws on English-language publications, which under-represents scholarship on student mobility produced in the country's most participants come from. While some case review of MaaS trials in some university campuses in Section 2.4, the MaaS literature it surveys is weighted towards dense European cities, which is what makes the suburban campus case worth investigating and means the review provides few direct comparators. The insights gained from this literature review provide the basis for the subsequent design enquiry. The following chapter will elucidate the methodology used in this design studio-based research project, including the design process, methods, and design outcomes as new knowledge for responding to the research questions.

3. Methodology for design research grounded in practice within a MaaS context

CHAPTER OVERVIEW

The previous chapters have described and gathered insights from the nature and scope of the research challenge. This methodology chapter addresses the project's theoretical stance, design process, and methods, corresponding to the relevant knowledge gaps identified in the literature review. The research methodology employs (Findeli, 2010) practice-based approach, which situates the design question, practice, and methodology within the overarching framework of the research, incorporating a phenomenological perspective on design practice grounded in constructivist epistemology. The methodology identifies the methods appropriate for carrying out the research activities in the given industrial design discipline, justifying the choice of chosen methods (Findeli, 2008). Additionally, this chapter maps the research process under the Double Diamond framework, detailing each phase and its associated research methods.

3.1. The methodological paradigm, framework, and method

The research employs a practice-based and participatory design approach to explore how MaaS can be designed to reduce car dependency among international students at the Monash University Clayton campus. The methodological framework (refer to Figure 3.1) is structured by the integration of design practice, participatory engagement, and futures-oriented service design to generate novel insights into sustainable mobility.

This research conceptualises design practice as a method of enquiry in which knowledge is generated through the making, evaluation, and revision of designed artefacts, instead of relying merely on observation. Prototype interfaces, journey mapping artefacts, and future scenario-based service concepts function as epistemic objects that externalise assumptions, facilitate discussions on commuting norms, and enable the negotiation of conflicting values, such as convenience, cost, perceived safety, and awareness of carbon emissions in tangible terms. This position aligns with a MaaS environment, since mobility options are influenced by contextual limitations and habitual decision-making. Therefore, the research requires methodologies that can reveal implicit preferences and convert them into practical interface and future service frameworks from a particular user group,

international student car drivers from Chinese backgrounds.

The language of design research remains contested, as similar terms are frequently used to describe different practices, while different terms are often applied to comparable forms of enquiry (Frankel & Racine, 2010; Stappers & Giaccardi, 2017). Terms such as participatory design, co-design, service design and research through design circulate across communities of practice that assign them materially different scopes, and the resulting ambiguity has been identified as a persistent impediment to methodological accountability in design research (Sanders & Stappers, 2008; Vaughan, 2017). This section addresses the sense in which each term is used in this exegesis before the process is described, on the principle that a methodology is answerable for the terms it invokes.

Three terms carry the methodological weight of this exegesis, and they are distinguished by the question each answers. Participatory Action Design Research (PADR) answers how the enquiry is organised. Research through Design (RtD) addresses how that enquiry produces knowledge. Participatory design answers how the people whose circumstances are at issue enter it. They operate at different levels and are not substitutable for one another; every remaining term used in this exegesis designates a component within this structure instead of an alternative to it.

Participatory Action Design Research (PADR) provides the fundamental methodology for this study. PADR structures enquiry through iterative cycles in which design action and reflection constitute the means of investigation. Participants contribute to framing the problem and evaluating proposed responses. This choice follows from the character of the problem. Car dependency at a suburban campus is a situated practice sustained by infrastructure, routines, and social expectations, not a knowledge deficit that can be addressed through description alone. Such practices may be examined more effectively through an attempted intervention than through external observation.

RtD supplies the epistemology of this research. Where PADR determines how the enquiry proceeds, RtD determines what may be claimed as its outcome. It is the argument for treating designed artefacts as constitutive of knowledge instead of as illustrations of knowledge secured by other means (Section 3.1.2). Without this methodological grounding, the prototypes and service blueprints would remain design artefacts that accompany the written exegesis. Within a RtD framework, however, the designed interventions function as epistemic artefacts through which design knowledge is generated and expressed, making them integral to the research contribution instead of supplementary outputs.

Participatory design provides the method. Workshops and semi-structured interviews bring participants' situated knowledge into the enquiry (refer to Sections 3.2.1 and 8.1), and

Section 3.2.4 states precisely what authority participants held within them. The remaining terms occupy subordinate positions. Thematic coding informed by constructivist grounded theory is the analytical procedure applied to workshop and interview data (Section 4.2.2). Service design contributes two representational techniques, including journey mapping and service blueprinting, through which the design proposition is articulated at the scale of a complete commuting journey (Chapter 7). The Double Diamond functions as a process reference model that describes the shape the enquiry assumed; it is not a methodology and carries limited epistemological commitments (Section 3.3).

Within the PADR cycle described in section 3.2, participatory engagements produce situated narratives of commuting practice; design actions transform those narratives into prototypes and service concepts; and reflective synthesis examines the tensions and trade-offs disclosed in that transformation to direct subsequent iterations. The cycle is therefore not a sequence of stages but a recurring movement between engagement, making, and critique, in which each pass reformulates the problem as well as the response.

The epistemic work performed by the artefacts follows from the position established in Section 3.1.2 (refer to Section 3.1.2). Prototypes, interface sketches, service blueprints and scenarios operate as instruments of enquiry instead of as its illustrations. Each renders an assumption explicit and thereby exposes it to testing and contestation by participants. An assumption embedded in a working prototype can be disagreed with in terms that an assumption stated in prose cannot. The designed prototype serves as a representation of a potential MaaS service and a tool to refine research enquiries, reveal underlying constraints, and assess how specific presentations of mobility alternatives influence user perception and decision-making.

The workshop techniques give this cycle its operational form, as detailed in Section 3.3 (see section 3.3). Techniques such as Say-Do-Make (see section 3.1.2) facilitate the documentation of articulated experiences, performed routines, and tangible concepts, while workshop activities including journey mapping, co-ranking, and scenario building promote collaborative contemplation of daily travel barriers. These techniques are subordinate to the logic of the PADR cycle and to the epistemic stance supplied by RtD; they are procedures for eliciting and materialising participant knowledge, not methodologies. The roles of these design sessions are practical and procedural, serving as the tools that make participant experiences comprehensible as design material, which may be synthesised into requirements, interaction logic, and prototype features.

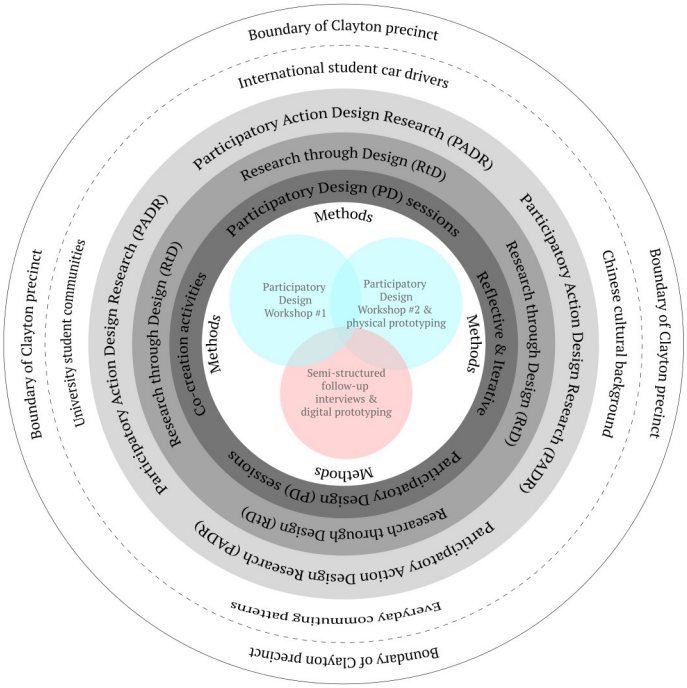


Figure 3.1. Layer map of the project's methodology, showing how the practice-based paradigm, the PADR framework and participatory techniques such as Say-Do-Make nest within one another to structure how participant knowledge becomes design outcomes

The researcher assumes the role of a designer-researcher grounded in design practice, involved with guiding the investigation through iterative synthesis and prototyping processes. The researcher's positionality significantly influences the conduct and interpretation of the enquiry. The researcher of this project, a Chinese cultural background international student and a car driver in the same context, possesses partial insider knowledge of the routines, constraints, and social expectations influencing car dependence at the Clayton precinct, yet necessitates systematic participatory work to avoid overgeneralisation from personal experience. The positionality of the researcher is addressed through a distinctly reflexive approach (Scott, 2019), wherein interpretive choices and design actions are regarded as transparent, flexible, and subject to evaluation throughout iterative cycles.

3.1.1. Practice-based design research

Research through Design (RtD) serves as the foundation for the design practice undertaken in this project. This approach provides a means of articulating and communicating design and research knowledge (Cross, 2007a). In RtD, research and practice strive for knowledge and impact collaboratively, where new insights are embodied in creating artefacts and design outcomes (Durrant et al., 2017; Redström, 2017). Zimmerman et al. (2007a) articulated that design research is a legitimate method for generating knowledge in HCI (Human Computer Interaction), and they stated that "the process of iteratively designing artefacts as a method of investigating the space of possible designs allows for researchers to continually reframe the problem as they attempt to make the right thing".

As a dynamic and future-oriented approach that combines research and design activities, including two participatory workshops, interviews, and iterative prototyping sessions with recruited participants, to generate knowledge and effect change, the outcomes relate to the world's preferred and intentional future states (Boess, 2009; Golsteijn et al., 2014; Savic & Huang, 2014; Stappers et al., 2023). As Chow and Jonas (Chow & Jonas, 2010) articulated, "the purpose, function, and context of use are determined by the interaction between the new artefact and people and, therefore, come after its introduction … the future [is] facilitated by the new artefacts".

In this study, embodied knowledge is grounded in phenomenological data concerning international students' everyday commuting experiences and their interactions with the proposed mobility service platform. Enquiry through studio practice and design research supports the initial development of a MaaS platform intended to reduce private car use and carbon emissions among international students at Monash University's Clayton campus. The study's human centred and experience centred design process (P. Wright, 2010) constitutes a mode of knowledge generation associated with designerly ways of knowing (Cross, 2007a). Schön (2016) characterises reflection in action as a knowledge generating practice in which designers "become researchers in the practice context" and "construct a new theory of the unique case".

"For me, design methodology includes the study of how designers work and think, the establishment of appropriate structures for the design process, the development and application of new design methods, techniques and procedures, and reflection on the nature and extent of design knowledge and its application to design problems. The study of design leaves open the interpretation of the nature of design."

- Cross (2006)

Findeli (2010) and Russel (2010) have developed operational and methodological models for project-grounded research that offer a robust framework for advancing design inquiry within the phases of scientific research and exploration (see Figure 3.2). In this paradigm, the design project is seen as an integral component of the broader research endeavour. According to Findeli (2010), comprehending a phenomenon requires embedding it within a project context. The design outcomes and the creation of artefacts resulting from this study address the specific design question, which is formulated in response to the overarching research question. Consequently, these outcomes contribute directly to responding to the primary research question and advancing the overall objectives of the study.

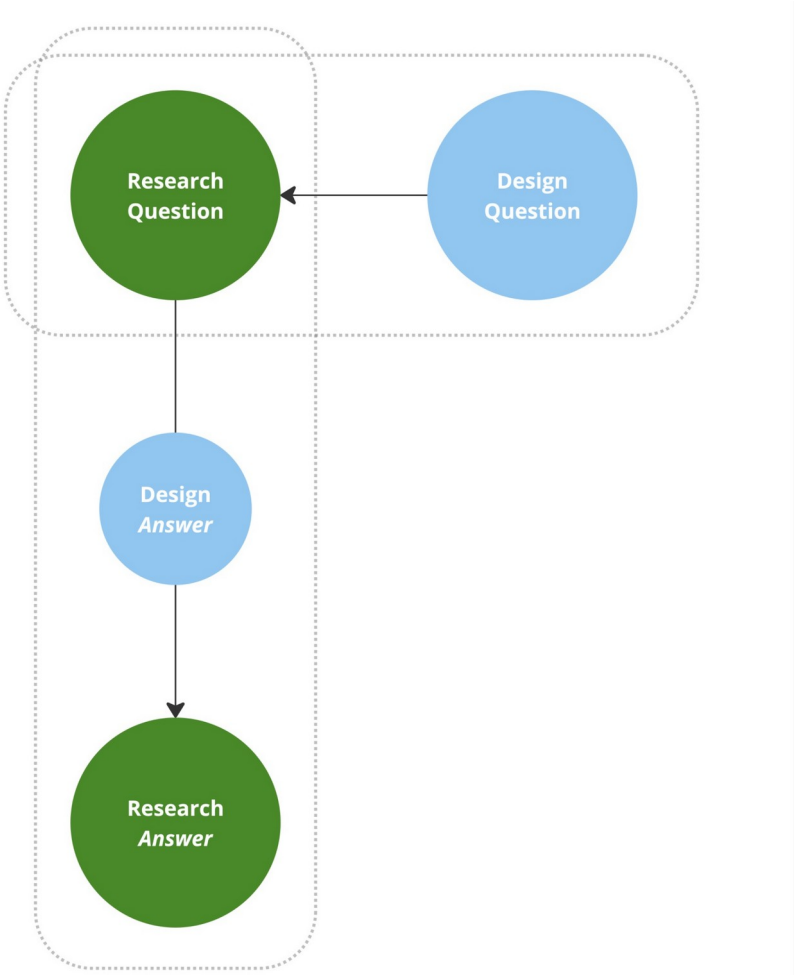


Figure 3.2. The project-grounded research model, adapted from (Findeli, 2010).

3.1.2. Knowledge generation through situated design practice

"The architectural or design project today is no longer an act intended to alter reality, pushing it in the direction of order and logic. Instead the project is an act of invention that creates something to be added on to existing reality, increasing its depth and multiplying the number of choices available."

- (Branzi, 1988: 17)

In this research, knowledge was generated through the iterative interaction between empirical investigation and design practice (Frayling, 1994). Practice-based research constructs knowledge through creative and iterative design practice, in contrast to conventional scientific research, which attempts to explain phenomena through empirical observation and hypothesis testing (L. Candy, 2006). The research unfolds through the design and development of a MaaS digital prototype, iteratively refined through participatory engagement with the intended users, international students.

This research positions knowledge generation as emerging from situated design practice, where comprehension is derived from active involvement with contexts, participants, materials, and everyday conditions. In practice-based design research, knowledge is regarded not as an isolated outcome but as a construct developed through creation, experimentation, reflection, and iteration in real-world contexts (Bredies et al.,

2020; Koskinen et al., 2011; Schön, 2016; Vear, 2021). This study utilises the Monash University Clayton campus as an experiential research setting, where the mobility choices, infrastructure constraints, and cultural conflicts of international students are directly engaged through design activities.

Situated design practice recognises that design activities are invariably contextualised within social, cultural, and material environments. Suchman's (2006) theory of situated action emphasises that human behaviour cannot be entirely anticipated or elucidated outside of the contexts in which it occurs. In the context of mobility research, everyday commuting decisions are influenced by rational planning as well as by temporal constraints, meteorological conditions, safety perceptions, social influences, and familiarity with local transportation systems. This research project utilises participatory design workshops, prototype interactions, and future mobility scenario-building activities with international student car drivers to capture tacit and experiential knowledge that is rarely captured through conventional surveys or quantitative transport models.

From an epistemological perspective, this approach aligns with constructivist and pragmatist traditions in design research, wherein knowledge is understood as provisional, context-dependent, and action-oriented (Cross, 2006). The research generates context-specific insights that elucidate how and why international students navigate mobility within a particular suburban university setting. These findings are integrated into design interventions, encompassing future sustainable mobility service concepts, interaction flows and conceptual MaaS platform interfaces, which function as research contributions (Gaver, 2012).

3.2. Participatory Action Design Research (PADR) as the overarching framework

In this project, participatory workshop is the primary method for knowledge production in context. From this perspective, knowledge is an attribute possessed by a person and constructed and reconstructed by engagement in communal activities, language, tools, and norms (Wenger, 1998).

The subsections below elucidate how participatory action design research is positioned in this project, how the participatory workshops were structured as a research method, how participant roles are conceptualised during the design research process, and how participation is understood as situated knowledge generation.

3.2.1. Participatory workshops

Participatory design workshops serve as the primary venue for convergence of experience, interpretation, and propositions for designs. Workshop-based engagement is prevalent in participatory design since it provides defined and comfortable studio-like spaces where people may articulate tacit knowledge through actions such as doing, producing,

mapping, rating, and lived storytelling, instead of only through abstract discourse (Brandt et al., 2012; Sanders & Stappers, 2008). This is significant for mobility research since the everyday commuting experience is generally habitual, time-constrained, and challenging to express without signals that evoke the route.

This project involves workshops that are both structured and flexible, facilitating three types of objectives, including revealing everyday commuting experiences, converting those experiences into shared representations, and exploring and refining future possibilities through scenarios and interface designs. The adoption of both scenario-based and narrative-driven methodologies of the participatory design workshops facilitates an in-depth investigation into potential future mobility service, specifically the concept of MaaS, while the iterative nature of the process enables the potential design interventions to be both innovative and practical. The emphasis on backcasting highlights the significance and necessity of aligning current design efforts with long-term sustainability goals, ensuring the outcomes of the workshops contribute to the overarching objectives of the research project, which aims to reduce carbon emissions and enhance sustainable travel at the Clayton precinct.

As discussed above, two main design workshops (refer to Figure 3.3) were designed and conducted with the aims of (1) understanding international student drivers' daily routine travelling to the Monash University Clayton campus and discovering the barriers to adopting sustainable transport options; (2) envisioning the future mobility service scenarios, including the envisioned interactive touchpoints of the potential mobility service platform during the future journey; and (3) field-testing the designed interactive interfaces of the MaaS platform at the Clayton campus.

This section outlines the methodology employed in conducting the participatory design workshops, including the recruitment of participants and the development of discussion guides and workshop activities, and the process of thematic analysis used to analyse the data captured during the workshops. The methodology ensures that the insights gathered are robust, relevant, and reflect the experiences and needs of international student drivers from Monash University Clayton and Caulfield campuses.

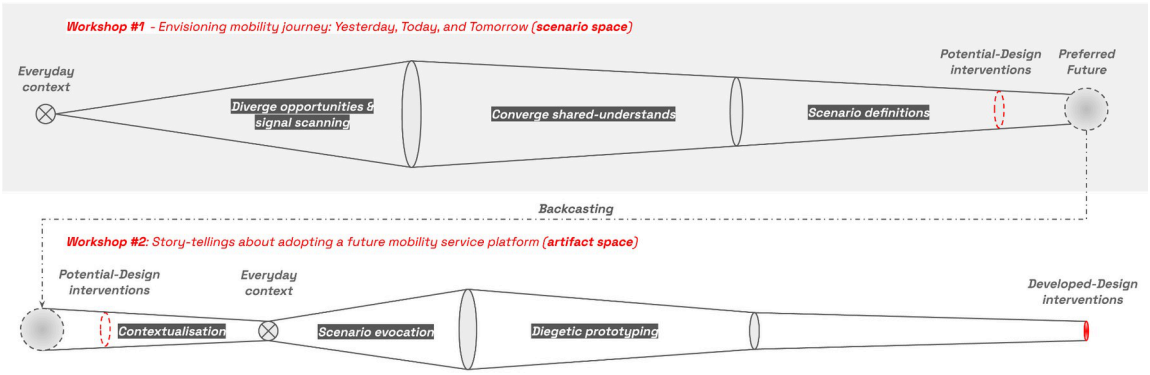


Figure 3.3. The framework of participatory design workshops

3.2.2. Roles of Participants in the Design Process

The framework of participatory design workshops focuses on international students from the Clayton precinct who regularly drive their own cars to the campus, treating them as situated experts whose lived commuting practices inform the design, prototyping, and refinement of the proposed MaaS platform. Their contribution extends beyond providing feedback on predefined design concepts to influencing the framing of problems, prioritising their commuting challenges, and shaping what kinds of commuting futures are considered plausible or desirable. This realignment signifies a change from extractive research relationships, where researchers primarily collect data from participants without engagement, to collaborative knowledge-making. Collaborative approaches, including Integrated Knowledge Translation (IKT) and Community-Based Participatory Research (CBPR) emphasise the importance of engaging people as equals throughout the research process, integrating both community and researcher expertise to inform and enact change (Gallant et al., 2025; Jull et al., 2017).

In practical aspects of this research project, participants take on multiple roles during the workshops and follow-up interviews. Primarily, they serve as narrators of personal experiences, recounting their commuting histories, moments of change, and routine difficulties related to driving, public transportation, or multimodal travel.

The participatory design approach in this research facilitated generative and collaborative methods to interrogate underlying assumptions, uncover beliefs, and reveal the perspectives of participants engaging with initial MaaS interface development. Sanders (2016) articulates the techniques by drawing on the model of say, do, and make. Compared with relying solely on verbal articulation, in this research project, participants were encouraged to express their thoughts and emotions through interactive storytelling and playful prototyping, aligning with the approach advocated by Royalty and Roth (2016). Building on the framework developed by Sanders et al. (2010), the approach was structured to guide participants through three interconnected modes of engagement (refer to Figure 3.4):

- **Saying:** through structured discussions, participants articulated and reflected upon their mobility experiences, facilitating the co-construction of narratives that contextualised their interactions with the proposed interventions.
- **Doing:** the performance and playful investigation enabled exploratory interaction with future mobility scenarios, enabling participants to prototype and access new service interventions in a dynamic and interactive way (Sanders, 2016).
- **Making:** the act of making or designing facilitated the production of tangible artefacts, enabling participants to manifest and materialise their ideas, externalise latent knowledge and foster a shared understanding of mobility-related challenges and opportunities.

The evolution of these roles is significant as it facilitates the emergence of various kinds of knowledge. Experiential knowledge arises from participants' storytelling and journey mapping during the workshop sessions and interviews, whereas reflective and anticipatory knowledge is manifested through scenario development and explorative design activities. The study does not presume that participants possess professional expertise in mobility design. Instead, it acknowledges them as authorities in their own mobility practices, whose perspectives are essential for comprehending the intersection of MaaS concepts with daily life. The role of design researcher is to facilitate, translate, and synthesise these insights into design interventions and research conclusions.

3.2.3. Participation as situated knowledge production

"Learning is an integral part of generative social practice in the lived-in world."

Lave and Wenger (1991, p. 35)

This project conceptualises participation as the production of situated knowledge, wherein knowledge is not conventionally "collected" as a stable object and transferred unchanged into analysis. It is generated in a workshop environment through speech, drawing, ranking, and story sharing, remaining connected to the material and social contexts of its creation. This role corresponds with established theories in practice-based design research and participatory design, asserting that



Figure 3.4. Methods that investigated what participants say, do, and make, (redrawn from Sanders & Stappers, 2012: 67)

everyday meanings and practical judgement are influenced by context, becoming apparent when participants are encouraged to articulate, externalise, and challenge their routines while interacting with others in the shared design-studio settings. Everyday commuting behaviours and decision-making by international student drivers are frequently made under time pressure and uncertainty, relying on local perceptions of reliability, safety, cost, social comfort, and normative behaviours. These forms of knowing are not merely personal attitudes. The suburban campus environment, transportation infrastructure, and peer discussions also contribute to the learning and reinforcement of these assumptions, making the workshop a venue for articulating and reconfiguring them as design probes.

At the same time, engagement is about "voice" from workshop participants; more importantly, it concerns what kinds of knowledge are brought into the design situations, and how multiple knowledge forms are recognised and integrated.

Regarding co-creation, Christiaans (1992) elucidates that design activity relies on multiple knowledge sets, which operate differently across domains (refer to Table 7). Christiaans (ibid.) differentiates between process knowledge, fundamental knowledge, and design knowledge, asserting that process knowledge is not confined to a particular domain, but design and basic knowledge are domain specific. This difference provides a pragmatic framework for understanding the outcomes of engagement. International student car drivers typically provide valuable foundational knowledge on the socio-cultural and everyday travel landscape, including perceptions of safety, reliability, and acceptable trade-offs within their campus routines. The researcher and design practice provide insights into interaction patterns, service concepts, and prototyping methodologies, while procedural knowledge is manifested and disseminated through the workshop format, encompassing the transition from lived experiences to representational artefacts, and from artefacts to design opportunities.

Table 3.1. Types of knowledge and definitions, adopted from (Christiaans, 1992; Drain & Sanders, 2019)

Types of knowledge	***Definition***
Process knowledge	Understanding of the required design steps, ability to work within ill-defined projects, and possessing a mindset conducive to design work.
Basic/fundamental knowledge	General understanding of a range of topics that provide a wide breadth of knowledge and the ability to draw from a range of disciplines. This includes knowledge in the socio-cultural and problem domains.
Design Knowledge	In-depth understanding of specific industrial design and engineering concepts, existing solutions, methods, and techniques.

By considering these knowledge sets as integral to workshop interactions, participation can be understood as more than mere "feedback." This constitutes a systematic narrative of how various participants introduce distinct forms of knowing into the collaborative design environment, and how workshop artefacts

integrated that knowledge for future review, comparison, and translation into interfaces and service decisions. The workshops generate a contextual, negotiated knowledge foundation that facilitates the design of a MaaS platform, grounded in the practical realities of international student daily commuting, while remaining receptive to emerging possibilities that can be explored through scenarios and prototypes.

3.2.4. Participatory Action Design Research framework

Participatory Action Design Research (PADR) constitutes the primary methodological framework for this study because it integrates collaborative enquiry with iterative design practice. The framework combines the iterative planning, action, observation, and reflection associated with Action Research (Kemmis, 2006; Lewin, 1946) with the constructive epistemology of Research through Design (Frayling, 1993; Zimmerman et al., 2007b). It also draws on Design Science Research, a problem-solving paradigm in which artefacts are created to extend knowledge and address practical problems (Gregor, 2009; Hevner et al.,& Reymen, 2025). The study consequently adopts a prescriptive orientation that uses artefact development to move from existing conditions towards preferred interventions. This orientation differs from descriptive enquiry focused primarily on explaining observed phenomena (Cross, 2007b; Hevner et al., 2004). Within sustainable mobility design, PADR positions international students as contributors to design judgement. Participants may influence problem framing and accept or reject proposed directions for emerging MaaS interventions within the limits of authority specified below.

Participatory Design (PD) posits that decentralising the design process is critical for reallocating control over technological systems (Ehn, 2008). This formulation articulates the normative aspiration of the tradition, and intellectual honesty requires an account of the extent to which a doctoral project can satisfy it. The Scandinavian workplace studies from which the tradition derives were conducted with organised labour possessing an institutional mandate to negotiate the systems under design; participation in that setting was underwritten by structural power that the participants in this study did not hold. The present participants were volunteers whose stake in the outcome extended no further than their own commuting, and who possessed no standing to require the adoption of any proposal.

A more defensible account distinguishes between authority exercised within the design sessions and authority over the research programme that contains them. Within the sessions, participants exercised consequential authority. Specifically, they determined which barriers were treated as significant, and their rejection of design directions proved decisive instead of advisory, as evidenced by the withdrawal of the cash-based reward mechanism and the reconfiguration of the social features following participant objection (Sections 8.3.1 and 8.3.3). Beyond the sessions, however, the formulation of the research questions, the selection of MaaS as the

object of design, the analytical coding of transcripts and the final interface decisions remained with the researcher.

This project therefore claims participation in the sense of shared authority over design judgement, and does not claim the stronger democratic sense of distributed control over the research programme or its implementation (Maboudi, 2020; van der Velden & Mörtberg, 2015), and the distinction of this research is sustained in the articulation of the methodological contribution discussed in Section 9.3.3. Within these bounds, the approach shifts design intent towards human authenticity by enabling participants to frame problems and propose interpretations.

Participatory Design (PD) positions the decentralisation of design as a means of redistributing control over technological systems (Ehn, 2008). In this project, PD was implemented through two workshops and semi structured subsequent interviews (refer to Figure 3.5). The approach treated international students' lived experiences as the primary empirical basis for enquiry and enabled participants to frame problems and propose interpretations. Participants developed accounts of mobility routines and explored potential commuting scenarios through making as a way of knowing (Sanders & Stappers, 2014). Observations documented across the sessions suggest that the design activities supported iterative thematic refinement, consistent with the view of users as authorities on their own experiences (Visser et al., 2005).

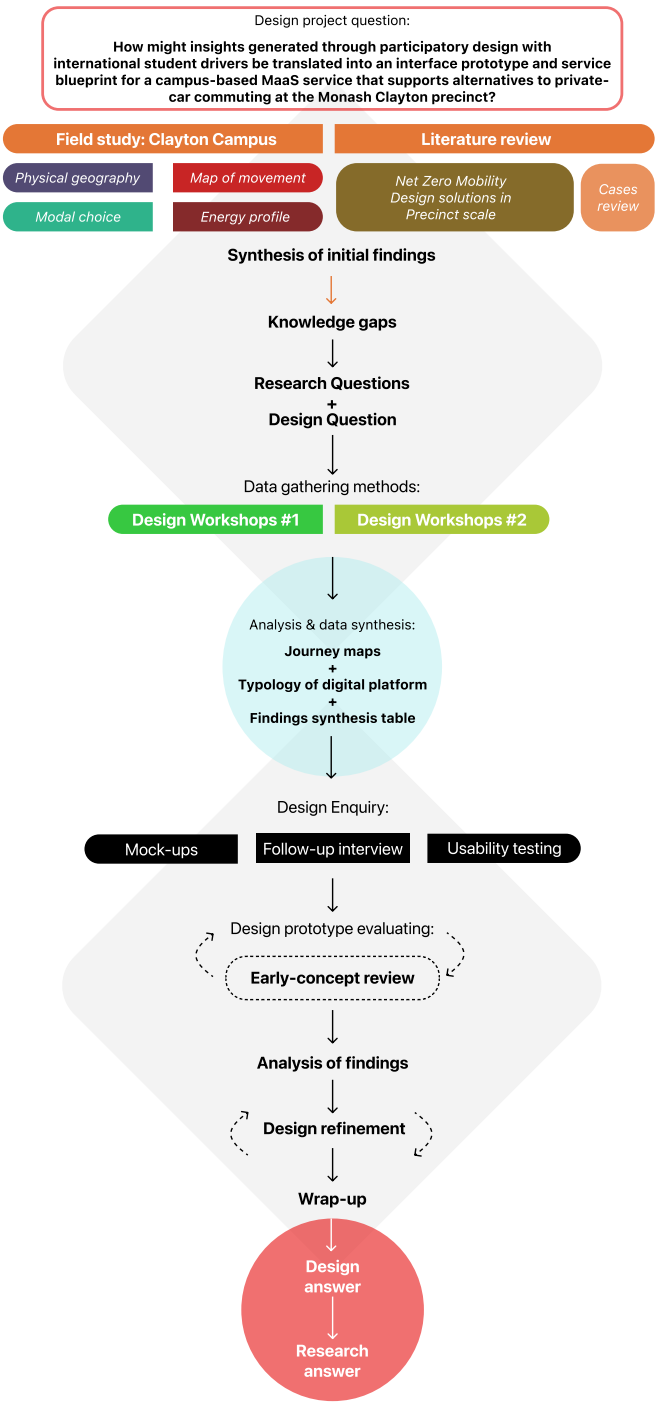


Figure 3.5. The research framework, mapping the sequence of two participatory design workshops and follow-up interviews onto the project's phases and locating the points at which participants exercised authority over design decisions

Contextual enquiry and situated engagement are among the most essential components of the PADR of this project. Drawing on Suchman's (2006b) theory of situated action, this project posits that human behaviour cannot be effectively understood independently of the material and social context in which it occurs. Consequently, participatory engagements were integrated within the familiar environment of the university campus instead of being placed in decontextualised laboratory settings. This approach enabled international student participants to reflect on their daily commuting issues from home to the

campus while physically engaged in the environments they navigate. This immersion in the physical environment was crucial for uncovering implicit knowledge (Fernie et al., 2003; Straub et al., 2025) (refer to Figure 3.6), particularly the insights that participants might not articulate in a standard interview. The context brought to the surface subtle phenomenological realities, such as the high cognitive load required to interpret scheduling interfaces and the specific anxiety or apprehension students felt during inter-modal transfers when they first navigate the unfamiliar transportation service systems.

3.3. Research design and process

"The exchange value between mobilities and design research is twofold. For mobilities research, this means getting closer to the 'material' and engaging in the creative, exploratory and experimental approaches of the design world, which offer potential for innovative research. Design research, on the other hand, might enter into a fruitful relationship with mobilities research, offering a 'mobilized' design thinking and a valuable basis for an approach, which can recognize mobility, contingency and relationality in the design of structures, spaces and systems of mobilities."

- (Jensen & Lanng, 2014: 3)

Mobility research examines multifaceted dynamics through which individuals, locations, entities, or values integrate into diverse networks and connections or interactions (see Figure 3.7), dispersed across distinct temporal and spatial dimensions (Salazar et al., 2017). While scholars categorise mobility research under the "umbrella" of social science (Faist, 2013), this study situates itself in

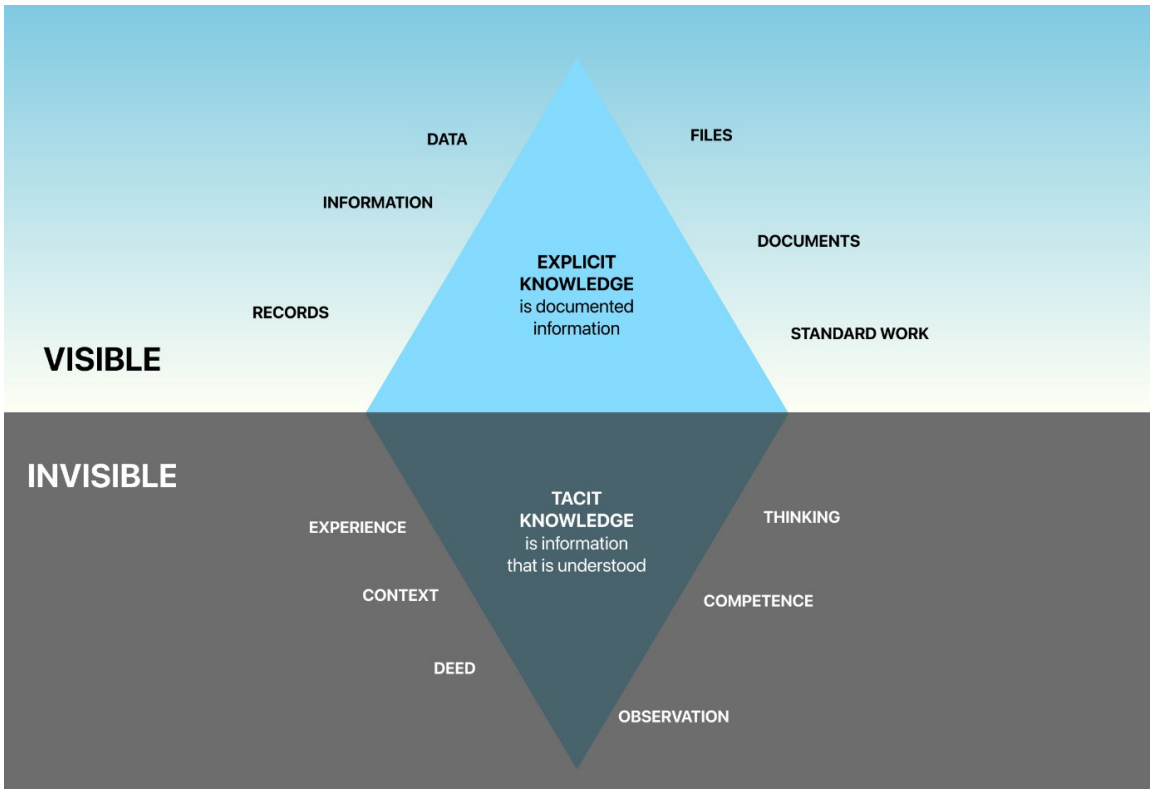


Figure 3.6. Knowledge iceberg (redrawn from Whale Design)

the realm of design-oriented mobility research. This comprehensive approach, as shown in the framework, aligns with (Jensen & Lanng, 2014) term "designing mobilities", where transportation planning is considered as an iterative creative process instead of a sequential technical task. The triangular relationship between values, locations, and commuters is supported by Banister's (Banister, 2008c) sustainable mobility paradigm, which emphasises the equilibrium of societal values, geographical factors, and human needs within transportation networks. Therefore, this project adopts relevant approaches of design anthropology to enhance the investigation, facilitating a deeper understanding of the ongoing connections of social ideals, physical environments, and human mobility patterns.

The Double Diamond (DD) is a process reference model widely used to organise design projects and support interdisciplinary collaboration (Abensur et al., 2023; Shen et al., 2024; West et al., 2018). This exegesis adopts it as a descriptive structure (Daly-Smith et al., 2020; Oliver et al., 2024). The model records movement between divergent and convergent activity and has been used in this descriptive capacity alongside participatory design in comparable studies (Caiado & Springer, 2022; Devan Shah et al., 2020). The enquiry proceeded through four phases, including Discover, Define, Develop, and Deliver, which are described in the following subsections. Two qualifications guide this mapping. First,

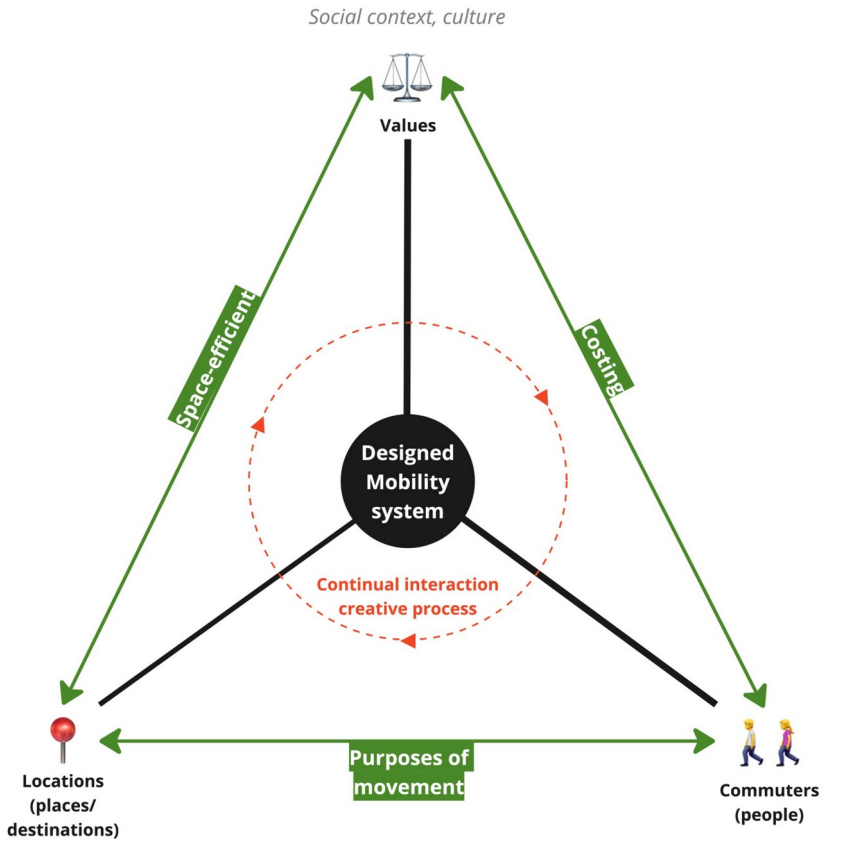


Figure 3.7. The continual interaction of commuters (people), locations (places/destinations), and values (social context, cultural background), centred by the designed mobility system

the DD imposes a linearity that iterative practice does not exhibit because the phases overlapped during the enquiry. The model is therefore retained for expository clarity and not as a literal representation of the process. Second, the difference between the process phases and the chapter structure is a deliberate editorial decision. The mapping enables readers to reconstruct the process independently of the order in which the argument is presented.

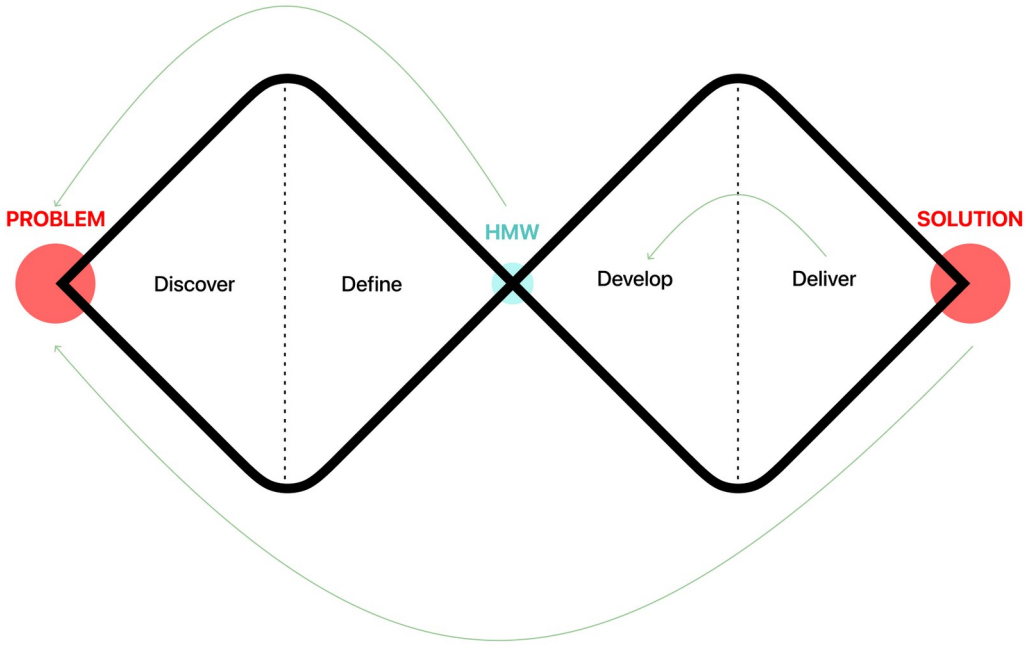


Figure 3.8. The double-diamond research process, redrawn from the Design Council (2024)

3.3.1. Discovering the problem through contextual enquiry at Clayton

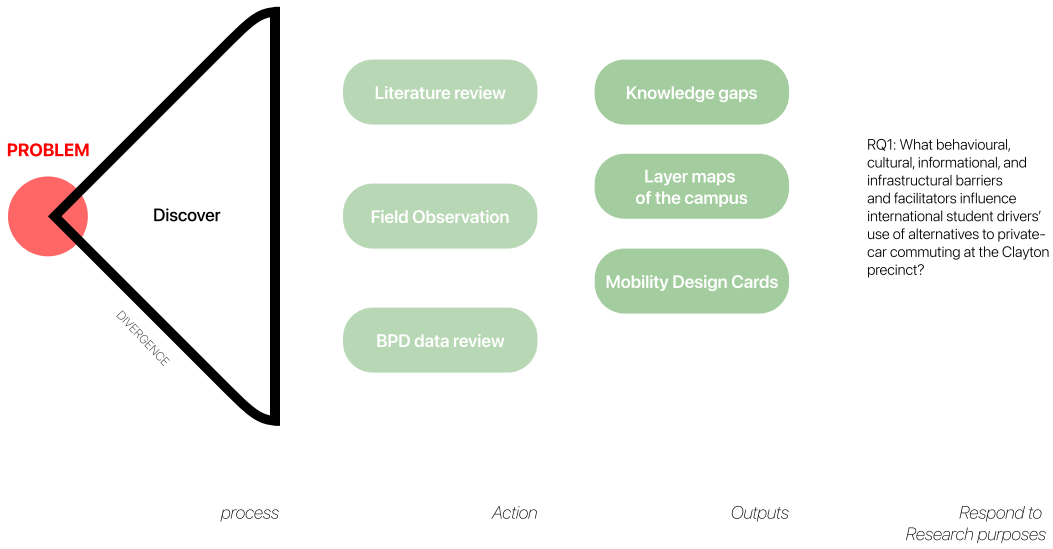


Figure 3.9. The Discover phase of the Double Diamond, in which contextual enquiry frames commuting at Clayton as a wicked problem instead of moving directly to solutions

The Discover phase is the preliminary segment of the Double Diamond design process, concentrating on examining the contextual environment and revealing the intricate nuances of the research problem. As articulated by Archer (1979) and formalised by the UK Design Council (2023), this stage plays a critical role in framing *wicked problems*, which are complex, ambiguous situations that lack definitive solutions, by interacting with real-world contexts and affected communities.

The discovery phase initiates the research process within the Double Diamond design framework, focusing on divergent inquiry to uncover the complex structural landscape surrounding international student mobility behaviours. This phase aims to frame the research problem by generating an in-depth and multifaceted understanding of the existing barriers and facilitators influencing international student drivers' adoption of sustainable MaaS solutions, which corresponds to sub-research question #1 (see Figure 3.9). Framing design problems within an intricate social system, such as university campus-based mobility, necessitates more than mere identification of needs; it requires contextual and iterative investigation (Buchanan, 1992a; Dorst, 2015). Based on these purposes, the primary research methods employed in this phase are set out below.

- **Narrative literature review**. This method established a conceptual understanding of sustainable mobility transitions, transition design strategies, and the conceptual development of MaaS (refer to Figure 3.10). The review also engaged with the Net Zero Precinct stage *one report (Sharp et al., 2023), which* provides qualitative ethnographic insights into campus mobility practices. The report

presents findings from interviews with 25 stakeholders across Monash University; local and state government; small and medium sized enterprises; and nongovernmental organisations. These interviews offer perspectives on the institutional, infrastructural, and personal dimensions of sustainable mobility transitions in the Clayton precinct.

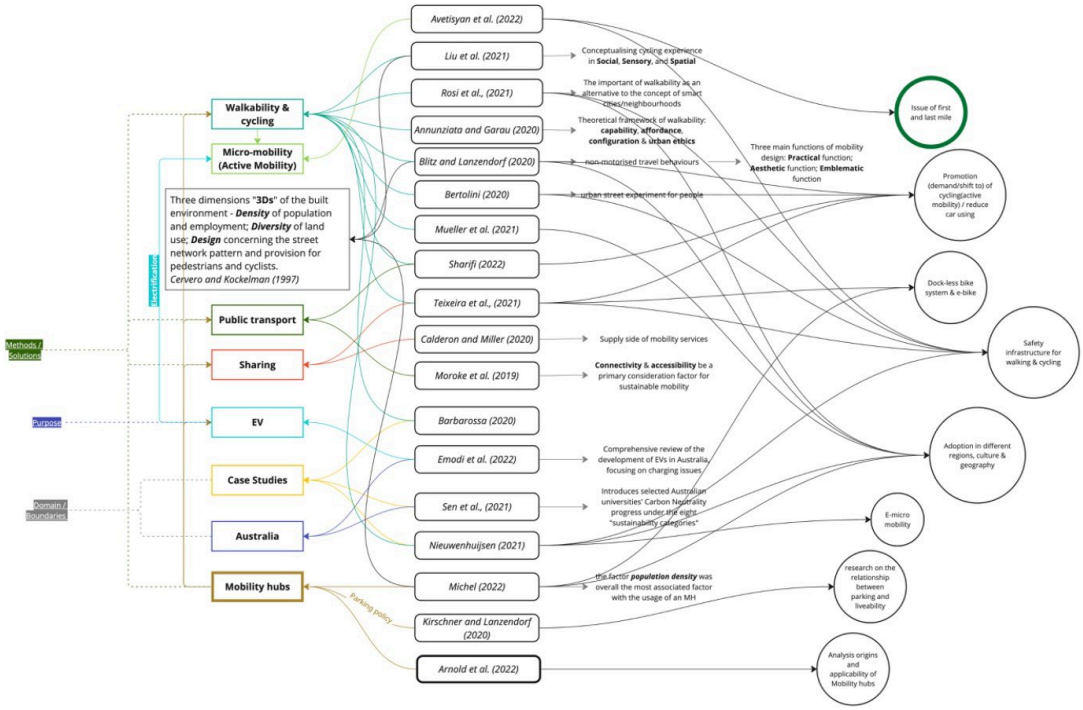


Figure 3.10. An example of a literature map, which was generated during the scoping review phase to visually organise key themes and research clusters related to sustainable mobility, based on preliminary searches conducted through Google Scholar.

➢**BPD quantitative data review**: drawing on databases provided by the Building and Property Division (BPD), the research examines quantitative mobility trends among Clayton commuters, including modal shares, car park usage, and peak travel times, to understand habitual commuting patterns (refer to Chapter 2.8).

➢**Site-based mobility environment audit**: conducted at primary campus mobility-related service touchpoints, such as bus loop stations, car parks, bike arrival stations, this method yields insight into mobility practice and infrastructure affordances (refer to Appendix J. Fieldnotes with reflexive accounts).

Additionally, a visualised map (see Figure 3.11) was developed to synthesise transportation infrastructure and modal options around the Monash University Clayton precinct with ethnographic insights during the Discover phase. Through integrating the summary of various transportation options and related services available around the campus precinct with qualitative interpretations from ethnographic research database input, this visual artefact functions as a research tool and a design stimulus. It facilitates a holistic understanding of the tensions between individual attitudes and the external conditions shaped by surrounding transport infrastructure.

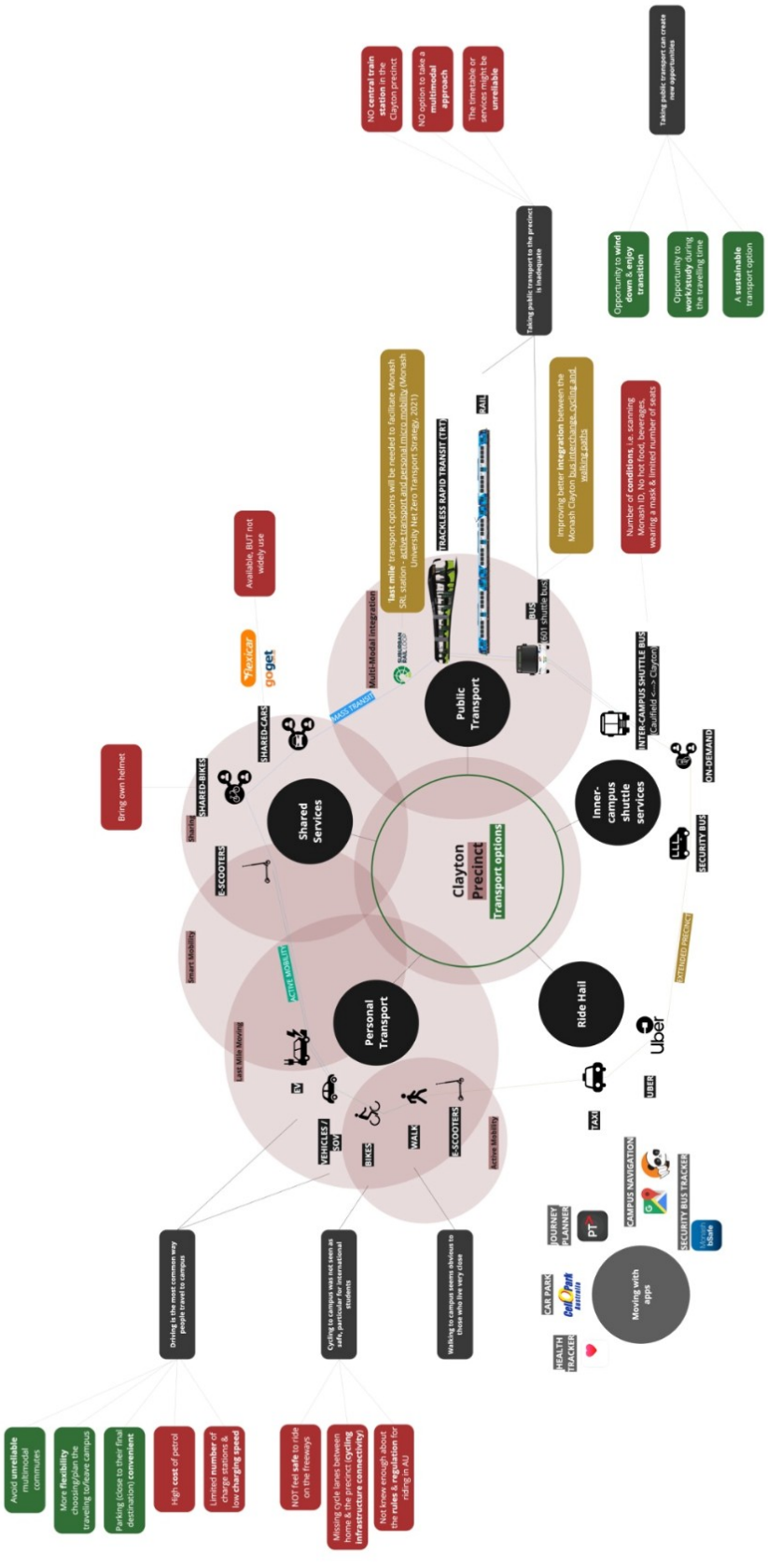


Figure 3.11. A visualised map of transportation alternatives around the Clayton precinct with ethnographic data insights

These research actions generated a set of designed artefacts, including the annotated Clayton campus map (see Figure 3.12) and Mobility Design Cards (see Figure 3.13), which serve as tangible representations of the contextual knowledge developed during this phase. Synthesised from field observations, secondary data review, and ethnographic insights, these artefacts visualise mobility patterns, conditions of current transportation infrastructures around the campus, and experiential narratives of everyday commuters from the Clayton precinct. Their creation embodies the designerly conversion of empirical discoveries into tangible forms that facilitate further exploration and reflection in the subsequent design stages. As the outputs of the Discover phase, these artefacts facilitate framing the problem space and identifying the knowledge gaps essential for formulating focused participatory design investigations and interventions in subsequent research phases.



Figure 3.12. The physical map of the Clayton campus was redeveloped to enhance the geographic understanding of the campus layout, mobility patterns, and related transport infrastructures surrounding the site.



Figure 3.13. A series of Mobility Design Cards developed to synthesise and visualise empirical evidence about campus mobility and to communicate key insights and user experiences

Critically, these artefacts generated during the Discover phase enable the researcher to externalise latent perceptions and behavioural tendencies, making tangible the basic socio-spatial dynamics that influence mobility choices around the Clayton campus precinct. On the other hand, these visual artefacts functioned as boundary objects (Star & Griesemer, 1989), which serve as interfaces for knowledge integration, enabling diverse individuals to span the boundaries of their specialisations and integrate knowledge (Caccamo et al., 2023). Within the subsequent participatory investigation into international student drivers, such artefacts provided a shared platform through which the participants as co-designers or design facilitators, could collaboratively explore and negotiate insights regarding their mobility patterns, infrastructural challenges, and behaviour change drivers. This capacity to bridge disciplinary or experiential divides is critical in complex, socio-technical contexts such as sustainable mobility, where actionable knowledge emerges from the convergence of multiple situated perspectives (Akkerman & Bakker, 2011). Additionally, these designed artefacts reflected a broader shift in design research toward material-led and visual methods (Pink, 2012a) that facilitate critical engagement with infrastructure and behavioural complexity (R. Cooper et

al., 2011; Manzini, 2015). Krippendorff (2006) argues that artefacts have undergone an ontological reconceptualisation from physical entities to meaning-generating mediators that facilitate the reconstruction of our understanding of the world.

The argument that these artefacts operated as boundary objects depends on demonstrating the circumstances in which they mediated communication and collaboration across different social contexts. This requires specifying the settings, the artefacts, and the practices through which they acquired this function. The workshop was the boundary crossing setting, which brought participants whose knowledge of commuting was experiential and held in daily routine, and a researcher whose knowledge was spatial, infrastructural, and design based. Neither body of knowledge was complete on its own, and neither was directly available to the other through conversation alone.

Three artefacts carried that crossing during the participatory design workshop sessions. The radar journey maps produced in Workshop 1 (Figure 3.15) held each participant's routine commute in a form others could read, so that a private sequence of decisions became something the group could compare and question. The future scenario sheets, completed with design props, held expectations that participants had not previously articulated, and supplied a common structure of journey steps, information channels, thoughts, and dramatic arc through which to state them. The physical prototype card set produced at the close of Workshop 2 (Figure 3.18) held provisional interface decisions in a movable form, so that disagreement about a feature could be expressed by rearranging cards instead of through argument alone.

Four practices performed the boundary work. Mapping externalised routine and made it inspectable. Storytelling placed each map and scenario within a first-person account that others could recognise or contest. Negotiation occurred where a participant revised a shared artefact after another participant's account contradicted their own. Prototyping tested whether a jointly held idea survived being made concrete. Across these practices the artefacts were flexible enough to carry different meanings for participant and researcher, yet stable enough to remain the same object of attention, which is the condition Star and Griesemer (1989) set for a boundary object.

3.3.2. Defining the problem through Workshop 1

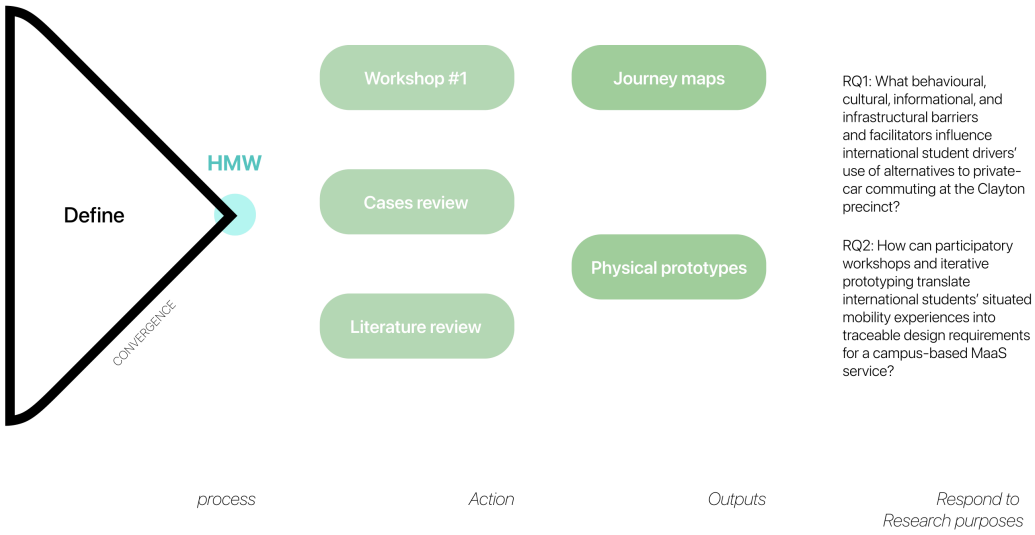


Figure 3.14. The Define phase, converging the artefacts generated in Discover, journey maps and boundary objects, into a bounded design problem for the Clayton precinct

Define is the second phase of the Double Diamond and represents a point of convergence at which findings from Discover are synthesised into a bounded account of the design problem (Design Council, 2023). This function is particularly relevant to wicked problems, including sustainable mobility, whose environmental, social, and behavioural dimensions are uncertain and closely interconnected (Coyne, 2005; Farrell & Hooker, 2013; Sweeting, 2018). Sustainable mobility design therefore requires approaches capable of working with unknown conditions and contested problem definitions (Hill, 2012; Berger et al., 2014). Such approaches may support the development of contextually grounded responses to complex climate related challenges (Hoogma et al., 2002; Gabrielli et al., 2014; Bandeira et al., 2021).

Building on the data analysis and field observations presented in Chapter 2, the study combined multiple methods to examine the interests, concerns, and expectations shaping sustainable commuting within the Clayton precinct (see Figure 3.14). The outputs informed the development of How Might We questions that framed subsequent ideation and prototyping. The research activities undertaken during this phase are set out below.

- **Participatory design Workshop 1**, which examined mobility journeys across the past, present, and future, involved international student drivers recruited at the Clayton campus. The workshop explored participants' lived commuting experiences and their expectations of future travel. It spans the boundary between Define and Develop. Retrospective journey

mapping (see Figure 3.15) converged the contextual material gathered during Discover into a bounded account of the problem. Generative activities, including Crazy 4s and future scenario building, then opened a divergent search for design directions that continued into Develop. Chapter 4 presents the workshop in detail.

➢**Cases review** of MaaS implementations to examine how mobility service platforms have been developed in diverse geographic and demographic groups, with a particular focus on cases with documented outcomes related to reducing car dependency, multimodal integration, and user behaviour shift (refer to Chapter 2).

➢ **Targeted round of literature review** was conducted to investigate design strategies that facilitate behavioural change through digital platforms, with a focus on sustainability, mobility, and smartphone platform-mediated interaction. This review synthesised findings from human-computer interaction (HCI), service design, and behavioural science, employing a triangulation approach to explore how design, interaction, and social context intersect in shaping user decision-making. This analysis guided the development of How Might We (HMW) design questions to direct the ideation and prototyping activities in the subsequent phase of the Double Diamond.

In this phase, insights were gathered and synthesised through the retrospective activities of participatory design workshop 1, in which participants produced journey maps of their existing commutes; the envisioned interactions with future MaaS platforms that participants articulated in the same sessions belong to the generative work carried into the Develop phase. The visual model (see Figure 3.16) further elucidates the temporal orientation of experience central to the Define phase, which represents how the participants' understanding of the present



Figure 3.15. One workshop participant described his radar map as a visual narrative of his entire commuting experience from home to campus, capturing the emotional, practical, and temporal dimensions of each stage of the journey.

("now") is rooted in past experiences ("memories") and shaped by aspirations for the future ("dreams"). Drawing on reflective practice theory (Schön, 2016) and anticipatory design approaches (S. Candy & Dunagan, 2017), the process of participatory workshop 1 supported by the model enables participants to connect their current mobility behaviours with both retrospective insights and imagined

participants to reconnect with emotionally resonant past experiences and to envision more sustainable commuting alternatives, thereby fostering a comprehensive understanding of behavioural change and personal barriers. The adoption of this model during the workshop 1 was pivotal in the Define phase, facilitating the integration of user requirements, design opportunities, and future-oriented

3.3.2.1. Framing design opportunities through "How might we?" questions and scenario-based design activities

Within the Define phase of the research process, the transition from insight generation to design opportunities futures. The workshop encouraged

framing was facilitated through the structured use of "How Might We?" (HMW) questions, a common practice in human-centred and participatory design to translate observed challenges into actionable provocations for ideation (Brown, 2019; Craven et al., 2019; Liedtka, 2015). In this study, the HMW question was generated at the conclusion of the Define phase as a transitional design prompt, synthesising the contextual findings of Discover into questions that the participatory work of the Develop phase would address, where participants collaboratively reinterpreted their everyday commuting challenges as designable opportunities, particularly with the primary purpose of reducing private car use and envisioning more sustainable commuting behaviours or decision-making facilitated by the designed future MaaS platform.

Two activities supported creative ideation and futures thinking during the generative component of Workshop 1. Participants completed Crazy 4s and built future scenarios using tailored worksheets

mobility scenarios.

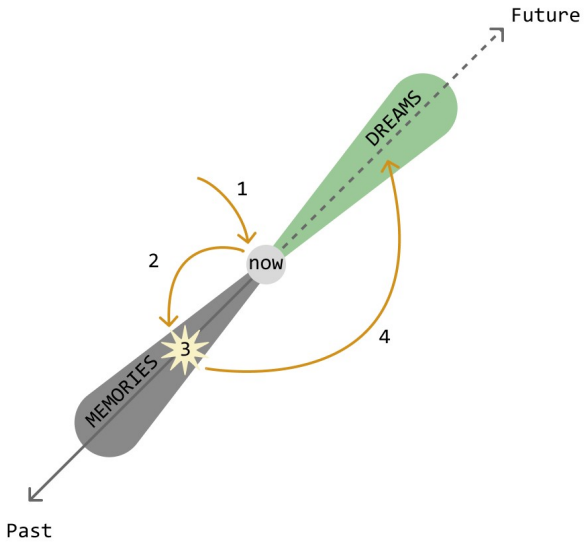


Figure 3.16. The model for understanding current experience (now), which is connected to past and future through memories and dreams, redrawn from (Sanders, 2016b)

and design props. These activities mark the transition from Define to Develop because they move from a bounded problem towards potential design directions preferred by participants. Crazy 4s, a rapid ideation method adapted from the Crazy 8s technique (Knapp, 2016), asked participants to sketch four responses to their commuting challenges (see Figure 3.17). The time-limited exercise prioritised breadth before refinement and enabled participants to generate multiple responses before evaluating a single direction. Participants then shared their sketches, and recurring ideas informed the subsequent future scenario activity.

Subsequently, participants were directed through a future scenario building activity facilitated by a structured design sheet and props. This exercise was built on futures-oriented design approaches (S. Candy & Dunagan, 2017; Dunne & Raby, 2013), enabling participants to envision preferred futures by contextualising their ideas within plausible, desirable, or provocative commuting scenarios. The design sheets of future mobility scenarios prompted participants to articulate their envisioned scenario elements, including steps of the journey, visualised storyboard, information channel, thoughts, and dramatic arc (refer to Chapter 5).

By the end of the Define phase, Workshop 1 had produced two principal tangible outcomes. The first comprised each participant's journey map, which documented a routine commute from home to campus and concluded the convergent work of Define. The second comprised an initial card set of physical MaaS interface concepts, which emerged from the workshop's generative activities



Figure 3.17. Participants' actions during the workshop 1.

and opened the Develop phase (see Figure 3.18).

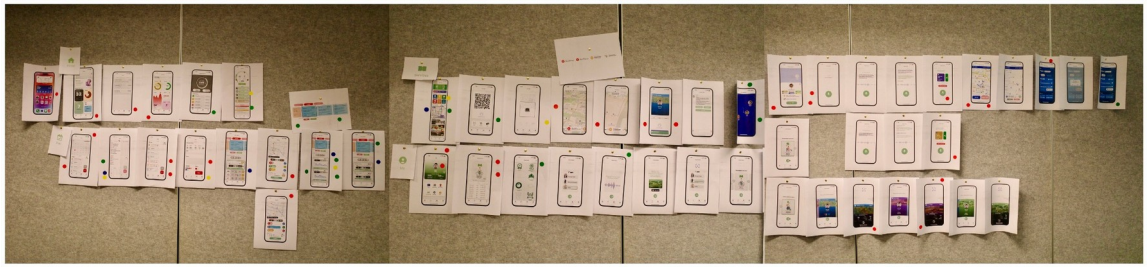


Figure 3.18. Flowchart of the physical prototype card set produced in the generative half of Workshop 1, at the transition from Define to Develop, showing the sequence of MaaS interface screens carried forward into Workshop 2

3.3.3. Developing insights through Workshop 2, thematic analysis, and iterative prototyping

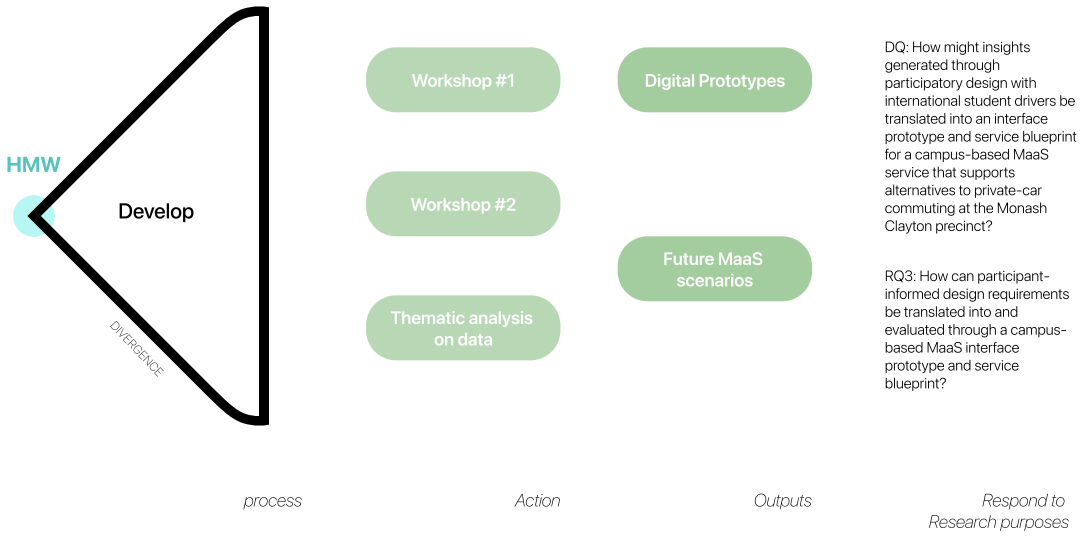


Figure 3.19. The Develop phase, in which a triad of activities, participatory workshops, thematic analysis and iterative prototyping, generates candidate design directions from the defined problem

The Develop phase of the Double Diamond is a collaborative process of ideation and creation through which a design researcher may investigate potential responses with stakeholders or prospective users. In this study, Develop began with the generative component of Workshop 1, whose rapid ideation and scenario activities provided its initial inputs. The phase subsequently comprised three interconnected activities, including participatory design workshops, thematic data analysis, and iterative development of prospective MaaS prototypes (refer to Figure 3.19). Together, these activities addressed the design question and RQ3.

These research questions explored how participatory design methods can engage international students in shaping contextually relevant MaaS platform proposals, and how design interventions might facilitate their sustainable travel and multimodal choices. The research actions in this phase are set out below.

➢ **Participatory design Workshop 2.** Building on the insights and artefacts generated during Workshop 1 in the Define phase, Workshop 2 served as the principal generative method for developing exploratory MaaS interface concepts. It positioned international student drivers as co designers who contributed ideas, feedback, and scenario based inputs. Workshop 1 examined past and present mobility routines and participants' expectations concerning the prospective integration of MaaS into everyday life. Workshop 2 subsequently developed and evaluated the associated interface concepts through physical and digital prototyping (refer to Chapter 5).

➢ **Thematic data analysis** was conducted following the workshops on the visual and transcript textual data, combining inductive coding with grounded theory techniques (Charmaz, 2006a). This method enables the research endeavour to identify latent patterns across participants' responses and designed artefacts during the participatory investigation procedure (refer to Figure 3.20). The analysis contributed to refining the design directions and served as a conceptual bridge between participant narratives and design outcomes, ensuring that the subsequent designed interventions were grounded in participants' lived experiences, addressed their concerns, and projected their preferred sustainable mobility commuting futures.

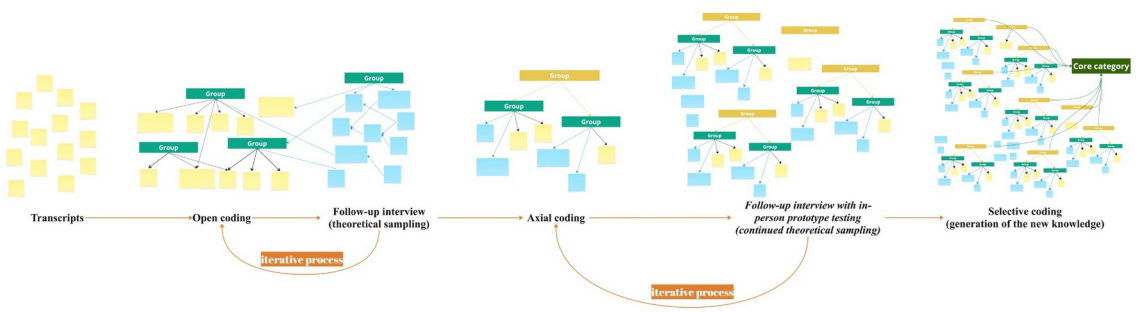


Figure 3.20. The thematic analysis process applied to workshop transcripts and visual artefacts, combining inductive coding with grounded theory techniques to surface the latent cross-participant patterns that refined the design directions

The Develop phase produced a range of concrete and abstract outcomes that collectively progressed the research from ideation to prospective intervention. The outputs resulting from participatory design activities, thematic interpretation and interactive prototyping were digital platforms and future MaaS scenarios.

3.3.4. Delivering the design through subsequent interviews and iterative refinement

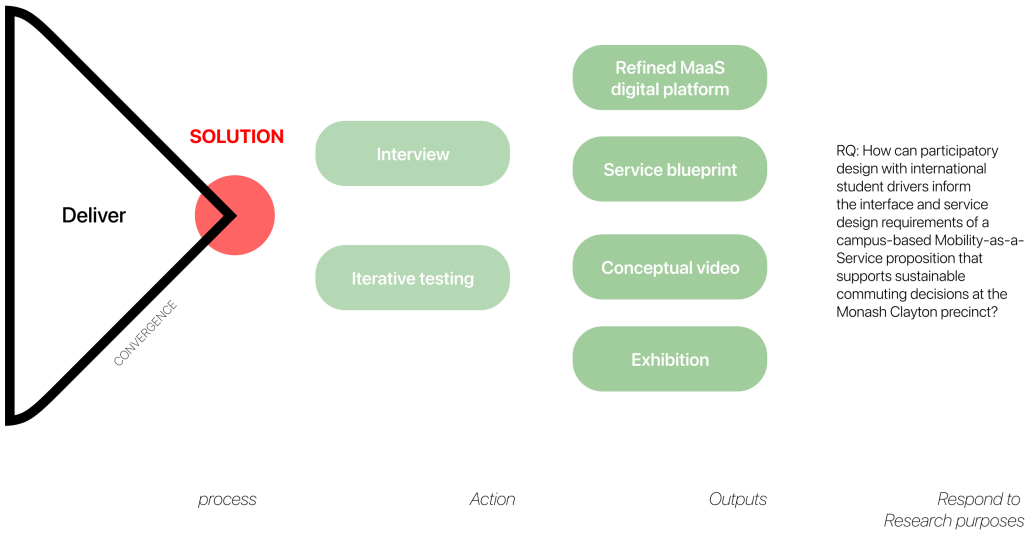


Figure 3.21. The Deliver phase, in which the MaaS digital prototypes are evaluated with returning participants against the requirements established during Discover and Define

Deliver formed the final phase of the design research process and connected the proposed design outcomes with participant evaluation. The phase examined whether the interventions addressed the requirements and expectations established during the preceding phases. A subsequent interview was conducted with selected participants from the earlier workshops to evaluate the digital prototypes (refer to Figure 3.21). The iterative activities undertaken during this phase are set out below.

- **Semi-structured follow-up interviews** were conducted with selected participants from previous participatory design workshops (see Figure 3.22) to gather in-depth evaluative feedback on digital prototypes. These interviews provided qualitative insights into usability, relevance, and perceived effectiveness of the designed interventions.



Figure 3.22. A follow-up interview with one participant in February 2025

➢**Iterative testing and design refinement.** Cycles were employed to refine designed interface features, service interactions, and system logic based on user feedback.

➢**Future commuting storyboards** were developed from insights and feedback gathered during the preceding prototype sessions. The storyboards provided a narrative representation of prospective commuting experiences with the MaaS platform at the Clayton campus.

The outputs from this phase included a refined MaaS platform, a future service blueprint outlining the user experience, a conceptual video synthesising design intent and use cases, and an exhibition that presented the complete design research journey and its implications for sustainable mobility transitions in university precincts. These deliverables collectively translate research-driven design practice into feasible, service-centred solutions. The Deliver phase emphasised iteration, co-creation, and contextual sensitivity, as it is positioned within a reflective design research paradigm (Schön, 2016) and informed by principles of design for social innovation (Manzini, 2015).

3.4. Chapter conclusion

This chapter has set out the epistemological stance, the methodology, and the research methods structuring the project, with the process through which the enquiry proceeded (refer to Table 3.2). Participatory Action Design Research supplies the methodology, Research through Design the epistemology, and participatory design the method; the Double Diamond is used in a descriptive capacity only, to record the movement between divergent and convergent activity across the four phases of Discover, Define, Develop, and Deliver. What positions the project as practice-based design research is not that process model but the treatment of design activity itself as a

means of knowledge generation, through which insights from contextual enquiry are carried into proposed design outcomes.

The research is based on a constructivist-interpretivist framework that regards knowledge as generated through contextual meaning-making, emphasising how a researcher's preconceptions influence observation, documentation, and interpretation. Phenomenology shapes the treatment of lived experience in the research, not as an isolated autoethnographic action, but as an evaluation of how suburban mobility conditions are experienced, perceived, and understood throughout specific travel and campus navigation. Reflexive fieldnotes and walkthrough-based visual evidence elucidate the intersection of infrastructural conditions, mobility cultures, and decision-making restrictions at certain junctures of the route, and how these interactions influenced potential future mobility service design.

Participatory Action Design Research constitutes the fundamental methodology, as established in Section 3.1, with participatory design workshops serving as its principal method. A selection warranted by the practical and value-laden character of the project topic, as well as by the need for collaborative interpretation of future mobility service concepts or scenarios with those who experience the commuting context. The project involves international student car drivers as participants and contributors, making their commuting challenges and mode-selection priorities on everyday routes from home to the campus directly shape early-stage sustainable mobility service concepts and interface designs. Table 3.2 delineates the distribution of approaches throughout each stage of the Double Diamond framework and elucidates how each phase addresses the research questions.

Table 3.2. Design methods and research questions in each phase of the project procedure, with the chapters and sections in which each phase is reported

Phases of research procedure	***Research techniques/actions applied***	***Response to the objectives in this research project***	***Reported in exegesis***
DISCOVER	Literature and cases review Secondary data analysis (including numerical & ethnographic data analysis)	Identification and contextualisation of mobility issues faced by international students at the Clayton campus, clarifying knowledge gaps and defining specific research challenges. Addresses subsidiary research question 1. *What behavioural, cultural, informational, and infrastructural barriers and facilitators influence international student drivers' use of alternatives to private-car commuting at the Clayton precinct?*	Chapter 2 (literature, cases, and precinct review); Section 3.3.1

Phases of research procedure	***Research techniques/actions applied***	***Response to the objectives in this research project***	***Reported in exegesis***
DEFINE	Cases review Literature review Site-based mobility audit Workshop 1 (bridging Define and Develop)	Continues to address subsidiary research question 1. *What behavioural, cultural, informational, and infrastructural barriers and facilitators influence international student drivers' use of alternatives to private-car commuting at the Clayton precinct?* Addresses methodological research question 2. *How can participatory workshops and iterative prototyping translate international students' situated mobility experiences into traceable design requirements for a campus-based MaaS service?*	Section 3.3.2; Chapter 2; Chapter 4 (Workshop 1)
DEVELOP	Workshop 1 (bridging Define and Develop) Workshop 2 Thematic analysis on qualitative data	Participatory futures-oriented design practice with international students, to envision future MaaS scenarios, iterative ideation and prototyping. Addresses the design question and research question 3. *How might we design a contextually sensitive and user-centred MaaS platform that addresses the mobility needs and preferences of international students?* and *How can participant-informed design requirements be translated into and evaluated through a campus-based MaaS interface prototype and service blueprint?*	Chapter 4 (Workshop 1); Chapter 5 (Workshop 2); Chapter 6 (design proposition); Chapter 7 (blueprint and prototypes)

Phases of research procedure	*Research techniques/actions applied*	*Response to the objectives in this research project*	*Reported in exegesis*
DELIVER	Semi-structured follow-up interview Iterative design testing	Validation, evaluation, and iterative refinement of proposed MaaS platform, ensuring alignment with participants' expectations and practical effectiveness in fostering sustainable travel choices. Addresses the overarching research question. *How can participatory design with international student drivers inform the interface and service design requirements of a campus-based Mobility-as-a-Service proposition that supports sustainable commuting decisions at the Monash Clayton precinct?*	Chapter 8 (follow-up interviews and refinement); Section 3.3.4

The following chapters will demonstrate how this methodological approach facilitates the emergence of design knowledge that is simultaneously grounded in empirical insights and future-oriented projection, according to what Findeli (2010) articulates as a dialectical relationship between research and practice that contributes to addressing complex societal challenges.

Aligned with participatory design principles, this study engaged international students in shaping the design proposition, within the bounds of authority set out in Section 3.2.4, so that the interface design of the MaaS platform responds to their lived experiences, demands, and expectations. Participatory design, originating from Scandinavian cooperative design traditions (Ehn, 1988; Schuler & Namioka, 2017), emphasises democratic involvement in technology and service development. It acknowledges that international students are not passive users, but co-designers whose participation carries epistemic agency, in that it shapes how the problem is framed and which responses are treated as workable. The wider claim that this group acts as an agent of change in the transition itself is specified in Section 9.3.1.

The participatory aspect of this research is conducted through a series of participatory design workshops and follow-up interviews with the same group of student participants, whose contributions shaped the design directions carried forward, including mapping mobility journeys, envisioning future MaaS service scenarios, and iteratively prototyping and testing the digital prototype. The workshops and interviews are also a means of qualitative data collection and a site of knowledge generation, where design artefacts (i.e., visualised journey maps, envisioned future mobility scenarios and physical prototypes) act as boundary objects facilitating discussion and reflection with participants. The collected data were

analysed using thematic analysis and visual analysis, which facilitates translating research findings into actionable design decisions during the development of future MaaS platforms.

The methodological approach of this research contributes to transport and design research by demonstrating how futures-oriented design techniques and practice-based methods can be employed to explore behavioural change in the design of sustainable mobility digital interventions. While participatory design has been applied in product and interaction design, its integration into MaaS design and research processes remains underexplored. This study extends the application of PD into the field of sustainable transport, providing a methodological model for engaging international students in service design. A reflexive approach is maintained throughout the research process, critically reflecting on the role of the researchers as design practitioners or facilitators and the extent to which the co-design process empowers participants. Through integrating practice-based experimentation with participatory engagement, this research seeks to bridge the gap between user-centred service innovation and sustainability transitions in everyday travel decision-making in university contexts.

4. Participatory investigation with international students

CHAPTER OVERVIEW

This chapter details the participatory design workshop activities with student participants from Monash University's Clayton and Caulfield campuses. The primary objective of this workshop session is to involve students in conceptualising and prototyping a digital platform for sustainable mobility services. This platform is designed to diminish carbon emissions from personal cars by encouraging the use of greener transportation alternatives. The methodology and data collection process are outlined, followed by a presentation of key findings from the investigation. Subsequent chapters elaborate on these findings as the foundation for exploratory design experiments.

The research project was designed to provide an in-depth investigation of the reasons why international students are increasingly relying on private vehicles over time in Australia and the barriers preventing them from adopting sustainable transport options. Potential design strategies could stimulate a shift in behaviour towards shared and public transportation. By engaging international students through participatory design methodologies, this chapter seeks to highlight opportunities for developing a MaaS platform that addresses their needs while responding to broader sustainability goals within the Monash Precinct.

4.1. Introduction to the participatory investigation

"Transformation design asks designers to shape behaviours - of people, systems and organisations - as well as form."

- Chick & Micklethwaite, 2011

4.1.1. A brief introduction

This chapter examines the empirical investigation conducted to understand daily travel experiences of international students, focusing on their interaction with current mobility service systems and the potential future concept of MaaS platforms. Following the methodological framework established in Chapter 3, this chapter describes the research approach and findings of the mixed-method investigation, encompassing participatory design workshops #1 and #2 and follow-up interviews (refer to the following Chapter 7), with particular focus on design testing and evaluation. The study aims to convey in-depth empirical findings about the mobility features, needs, and challenges of international students as they relate to the future of sustainable mobility services.

4.1.2. Aims of the investigation

This study aims to explore and contextualise the test of a hypothetical information display for sustainable mobility services and interactive

interfaces with international student drivers within the context of an Australian suburban university campus. Research on the interaction and reaction of participants during the co-design workshops could contribute to the general understanding of their routine travel behaviours and identify the potential points or barriers to behaviour change for more sustainable travel decision-making. At the same time, testing the designed interfaces of a mobile phone app-based platform with the participants in real-world settings and four main target scenarios could support the generation and refinement of design solutions.

Building on insights from the literature review in Chapter 2, this stage of action investigation addressed the following research subquestions.

RQ1. What behavioural, cultural, informational, and infrastructural barriers and facilitators influence international student drivers' use of alternatives to private-car commuting at the Clayton precinct?

RQ2. How can participatory workshops and iterative prototyping translate international students' situated mobility experiences into traceable design requirements for a campus-based MaaS service?

4.2. Methods

The mixed methods study (refer to Table 9), conducted from August 2024 to March 2025 in the Clayton campus of Monash University, employed a combination of participatory design workshops, semi-structured interviews, and iterative prototyping testing (discussed in Chapter 7). Section 4.2.1 details the data collection procedures with particular emphasis on Workshop 1 as the primary site of participatory engagement. Section 4.2.2 explains the analytical procedures that integrate systematic coding with design synthesis methods.

Table 3.3. Overview of data collection and analysis methods employed in the study

Phase ***(chronologically)***	**Methods**	**Purposes**	**Outcomes/ Artefacts**
Participatory workshop 1	Postcard storytelling, mobility journey mapping, detective wall structuring, future scenario building	To elicit mobility experiences (past and current), materialise commuting challenges, and imagine potential future sustainable mobility scenarios	Radar maps, detective wall artefacts, and future sustainable mobility scenario sheets
Participatory workshop 2	Interactive physical prototyping, design feedback, service scenario refinement *(refer to Chapter 7)*	To evaluate and refine designed MaaS concepts developed from Workshop 1 initial findings, focusing on feasibility, usability, and desirability	Annotated prototypes (physical prototype manual), refined design concepts, service flowchart

Phase *(chronologically)*	Methods	Purposes	Outcomes/ Artefacts
Semi-structured interviews	Follow-up reflective interview sessions with selected workshop participants *(refer to Chapter 7)*	To gain in-depth insights and reflection into cultural, behavioural, and infrastructural factors shaping commuting practices	audio/full text transcripts, thematic notes
Prototyping (iterative rounds)	Digital interface walkthrough, usability feedback sessions (within the structure of follow-up interview sessions) *(refer to Chapter 7)*	To evaluate and further refine the MaaS platform interface and design features	Digital prototypes, video/audio records, annotated feedback
Analysis	Thematic coding, service blueprinting, design synthesis *(refer to Chapter 6)*	Interpretation of qualitative data and translation of findings into design interventions	Thematic categories, visual mappings, a service blueprint

4.2.1. Data collection procedures

The data collection for workshop 1 aimed to document the lived experiences, behavioural patterns, and future-oriented imaginings of international student car drivers at Monash University. The workshop functioned as a productive platform for collecting extensive qualitative data through a participatory design framework, aligned with the objectives of the research project. To accommodate the varying availability of participants, workshop 1 was conducted three times, held on 30 August, 2 September, and 6 September 2024. Each session followed an identical format and structure, ensuring methodological consistency while allowing for a diversity of participants.

Workshop 1 was held in a studio-based environment that facilitated collaborative participation and creative expression, with fabric walls, adaptable furniture, printed artefacts, and designed toolkits.

The preparation and pilot activities that shaped this set-up are documented in Appendix F. Workshop preparation and pilot activities. Participatory design workshop 1 pursued three main aims: recalling past experiences with behavioural change, evaluating current practices for daily commutes from home to the Clayton campus, and imagining a potential or preferred future for mobility service digital platforms that might facilitate sustainable travel choices. Each workshop 1 session lasted around 90 minutes and included four successive phases (see Figure 4.1) aimed at eliciting experiential, behavioural, and near-future-oriented design insights. The four phases of workshop 1 include:

- **Phase 1: Postcard storytelling**
- **Phase 2: Mobility journey mapping**
- **Phase 3: Detective wall building and imagination**
- **Phase 4: Future mobility service scenario building**

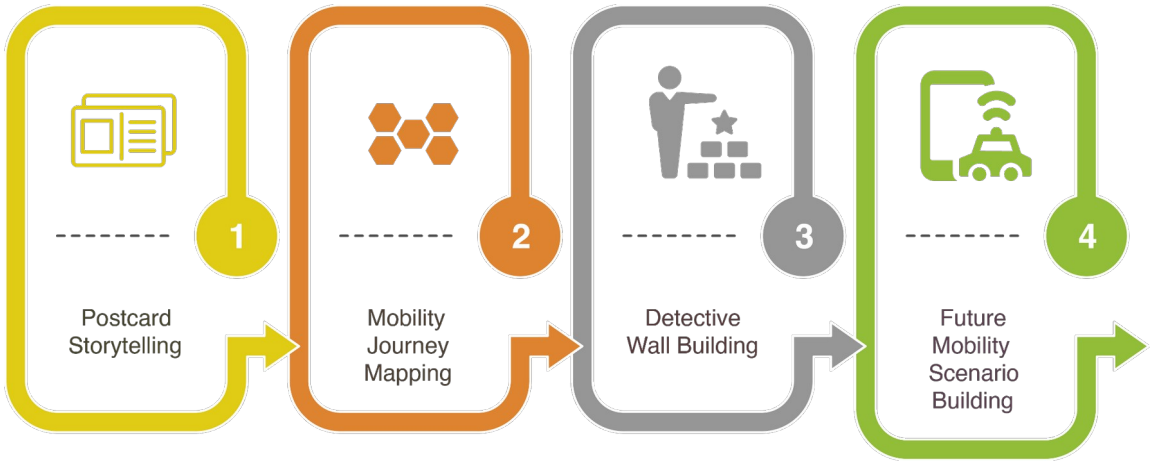


Figure 4.1. The four phases of Workshop 1, sequenced to move participants from recalling past behavioural change, through evaluating their current commute, to envisioning preferred mobility futures

4.2.2. Analytical procedures

This study employs grounded theory with thematic analysis to assess qualitative data collected from participatory design workshops and follow-up interviews. Grounded theory is a structured yet flexible approach that allows theoretical insights to emerge from data instead of relying on pre-existing conceptual frameworks (Glaser, 2017). Through the iterative actions of open, axial, and selective coding, this approach facilitates the identification of patterns and relationships that contribute to an in-depth understanding of international students' mobility behaviours and their engagement with potential future MaaS interventions. Selected raw workshop material and the initial codes generated from it are presented in Appendix G, and the resulting themes, sub-themes and illustrative codes are summarised in Appendix H.

Alongside the qualitative data analysis process, the method of thematic analysis (Braun & Clarke, 2006) is adopted to systematically code and categorise data into themes that encapsulate the speech acts of participants, their future-oriented design insights, and their experiential narratives. Familiarisation with the data set, initial coding, theme generation, refinement, and interpreting analytical outcomes have all been essential to ensuring a rigorous and transparent analytical process.

The collected data was analysed using a Constructivist Grounded Theory (GT) framework (refer to Figure 4.2) (Charmaz, 2001, 2006b). Transcription, note-taking, thematic coding, and memoing were conducted after each workshop, enabling a continuous comparative analysis of previously collected data throughout the research process (Charmaz, 2006b; Corbin & Strauss, 2015; Moghaddam, 2006). This iterative approach informed subsequent stages of investigation, including follow-up interviews and interactive prototype testing. Figure 4.3 shows the coding process at an intermediate stage of this analysis, which demonstrates how transcripts, memos, and codes were compared iteratively across sessions instead of fitted to a pre-existing framework.

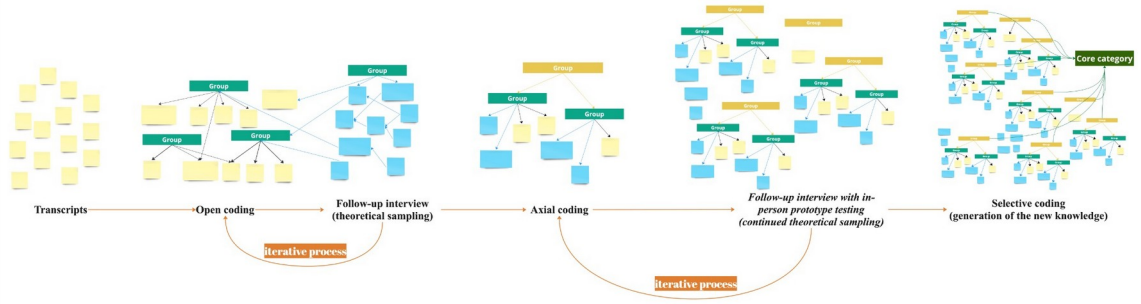


Figure 4.2. The phases of grounded theory, adapted from (Moghaddam, 2006)

Participant quotes and Action	Initial codes	Connecting concepts	Selective Codes
I didn't feel like going out, I just wouldn't. I didn't need to go out every week. I could simply stay at home if I wished, so I didn't really care. After getting married, however, I started thinking about going out each week. Maybe going somewhere to buy a few things or visiting a few different places. At that point, you realise the importance of having a car. (C#2_00:24:21)	Family care		External factors for behavioural change
(the book) suggests finding an accountability partner. For example, I asked my wife to set a password for the screen time limits on my phone, like a child lock. At first, I didn't stop completely—I could still access social media on weekends. (C#1_00:20:38)			
Urbanisation affects our capacity to change ourselves and our ideals. Or rather, when people move into a city… When I was very young, just five years old, I moved from my hometown to Shenzhen. (C#5_0:26)			
[*researcher: So, getting married had a huge influence on your car usage habits?*] Yes, because previously I rarely went out. If I didn't take public transport, I would just take a taxi, and that was fine since I generally wouldn't go very far. (C#2_00:25:08)		Barrier Types (BT)	
I didn't fully know the traffic laws, I had a translated copy of my licence, so I drove straight home. I learned all the rules on the road through experience. I've been fined before. My biggest fine was AUD 471 for not giving way to a tram. That was in the city, on one of the busiest roads. (C#3_00:05:15)	Security of driving		
...where I lived was basically in that area, so everything was pretty close by. If I had classes or anything on campus, I could just walk. Even during my undergraduate years, it took about twenty minutes on foot, which was still acceptable. (C#2_00:25:22)	Living near campus	Travel Motivation (TM)	
To get to campus, I mostly walked, which was a good way to get some exercise. From Clayton, it's actually not too bad to get to other shopping centres. (C#2_00:25:45)	Physcial exercise		
Like you mentioned about seeing the aurora, the car is also a means of earning some extra money for me. I pick people up through Xiaohongshu (a Chinese social media platform) for paid rides. Regarding that aurora event—there have been two major displays since I've been here. (C#3_00:03:34); I drove people twice for these events (aurora). For the meteor shower in Mornington, I also drove people there. It was very crowded. Since my car is just a sedan and can only seat five, I switched to renting a people mover that could seat eight. I rented it through a local car-sharing platform, which is how I earned a bit of side income. I'm very familiar with driving now. (C#3_00:03:34)	Earning tool	Car-Dependency (CD)	
When I first arrived in Australia, during my first month here, I bought a car. Owning a car has had a huge influence on me. Having a car allows me to get closer to nature, so I often drive out to enjoy myself. Before, in China, I sometimes drove as well, but since I was mostly on campus, I didn't really need a car. After coming to Australia, though, I find myself driving almost every day because my campus is in Caulfield, not in Clayton, so I drive to university frequently. On weekends, I drive out to distant places (rural areas). (C#3_00:02:29)	Driving to subub areas		
...once you've bought a car, you feel inclined to visit farther places. (C#2_00:26:23), Previously, I wouldn't consider those places because they were too troublesome to get to. For example, when we wanted to see the aurora recently, we needed a place with minimal light pollution, a wide-open area. You can only reach such places by driving. Without a car, you just can't get there. (C#2_00:26:30)	Convenience of driving		Emotional Drivers (ED)
I saw on social media (like Xiaohongshu) that the tram stops near the aurora-viewing spots were packed in the early hours of the morning—crowded with people. It sounded overwhelming. (C#2_00:26:52)	Information from social media	Mobile Usage (MS) - Social Media	
Like you mentioned about seeing the aurora, the car is also a means of earning some extra money for me. I pick people up through Xiaohongshu (a Chinese social media platform) for paid rides. Regarding that aurora event—there have been two major displays since I've been here. (C#3_00:03:34)			
I decided to stop using social media because I realised, I was spending way too much time on it every day. (C#1_00:19:27); Social media often contains repetitive or trivial content. Scrolling through it doesn't really add much value to your life. I find it more rewarding to spend time reading or doing something more meaningful. (C#1_00:22:15)	Waste time on social media		
Previously, I never participated in any school activities—no volunteering, no extracurriculars, nothing. I never bothered to look up what was on offer. It wasn't until recently that I discovered our university runs a crochet group—just people with a shared interest getting together and teaching each other. I decided to join and found it quite enjoyable. (C#10_0:03)	Behavioural change on social activities	Social Connection (SC)	Internal factors for behavioural change
I think it illustrates that something can seem terrifying if you've never done it before. But once you've done it, you realise…that it's not so bad. (C#7_1:19); Also, I realised that if you don't face something you're afraid of, it will keep haunting you. (C#7_1:36)	Overcome inner fear	Safety Concerns (SC)	
When I look at this picture (*a photo of forest*), I recall how, after arriving in Australia, I've really wanted to get out and explore. Australia has many places I like because, compared to China, they're more pristine and less affected by human intervention. I love that feeling, so I often drive to places like that. This reflects a change in my lifestyle from when I lived in China to now living abroad. (C#3_00:03:34)	Natural environements		
Once you reduce your time on social media, you'll find you have more opportunities to connect with nature and adopt a new lifestyle. (C#1_00:20:00)		Emotional Drivers (ED)	
I'm now willing to go out and explore these places. Even though I live in a city, just as I'm willing to visit a zoo that might be located far away or in a remote area, I'm also willing to visit farm stays or these types of places. Now that I'm in Melbourne, even during holidays, I'm happy to travel somewhere with forests. (C#4_1:30)			
(if) back in the countryside, the main work is farming. If I were to go back and farm, I wouldn't know how to do it. The countryside can't offer me the same job opportunities. Plus, all my daily life and entertainment are city-based. I've stayed in the village for a short period—maybe a day or two—but not long term. Life definitely revolves around the city for me. I find that places too small and too quiet are a bit dull. (C#5_1:35)	Preferred lifestyle	Self Perception (SP)	
Previously, I studied IT, and I used to think programmers were in high demand and coding would be fun. But once I actually started studying it, I felt like I was stuck—it was much harder than I imagined. (C#6_0:06)...It's completely different from what I imagined. (C#6_0:28)	Conflict betwen anticipation and actual situation		
If we're just talking about this random jumble of code, then I'd say it's not great. But seeing this gibberish reminds me of those happy times in my childhood when I was exploring computers, so in that sense, it's good. (C#8_0:16)	Chilhood experiences		

Figure 4.3. Screenshot of the constructivist grounded theory coding process

4.3. Participants recruitment

4.3.1. Recruitment strategy and ethics

Participant selection in this research was purposive instead of random, and the reasoning is stated here before the recruitment procedure is described.

Participatory design requires participants who hold two things at once, namely direct experience of the problem under investigation and the standing to propose alternatives to it. Sampling for statistical representativeness would satisfy neither requirement, since it would dilute the experiential specificity on which co-design depends.

The formal inclusion criteria approved under project 42308 were two, including affiliation with an international student cohort and use of driving as the primary mode of transport to the Clayton campus. Three properties follow from those criteria and explain why this group suits a participatory design enquiry. The first is direct experience of the problem, in that each participant drove to campus and could therefore speak to the decision the design seeks to influence instead of to an opinion about it. Since participants had formed their local travel patterns within the preceding few years and could still recall the reasoning behind them, which a long-settled commuter generally cannot. The third is a capacity to compare, in that each participant had used a different transport system before arriving in Melbourne and could therefore judge the Clayton arrangement against an alternative they had lived within instead of against an abstraction. The explanatory statement provided to participants records the same reasoning, describing them as people who navigate new environments and transport systems and who can therefore contribute firsthand knowledge of the user experience.

Ten participants took part across two workshops and five follow-up interviews. In participatory design the relevant standard is depth and continuity of engagement instead of sample size, since the evidence consists of what participants make, revise, and contest across successive sessions instead of responses aggregated across individuals. Participants in this study met the design proposition three times, at problem framing, at prototyping and at evaluation, which allowed positions to be tested and, in several cases, revised. What this sampling logic cannot support is any claim to representativeness, and Section 9.5 sets out where the findings do and do not transfer.

The participants were recruited through the advertisement flyers posted on the university's intranet for students (Moodle page of the Monash RED program, Research, Experimentation, and Discovery) and the researcher's Facebook, Instagram, and Reddit. Along with the online method, flyers were displayed on notice boards inside the Monash University Clayton and Caulfield campuses, including the campus centre, teaching buildings, parking lots, cafes, and public places. Additionally, the researcher delivered recruitment presentations to undergraduates during their classes. The study was approved by the Human Research Ethics Committee, Monash University (approval number: #42308). The explanatory statement and consent form of the participatory design investigation are detailed in *Appendices D & E,* respectively.

4.3.2. Participant demographics and mobility patterns

Finally, 10 participants took part in the study; details are provided in Table 4.1. The breakdown in each workshop was Workshop 1 Caulfield N = 3; Workshop 1 Clayton N = 7; Workshop 2 Clayton N = 7. The sample included 2 females and 8 males. They were all between the ages of 18 and 24 years and enrolled as full-time students at Monash University during the research period.

Regarding the mobility patterns, nine of the ten participants used single-occupancy private cars as the primary option to access the Clayton campus; one of the participants used hybrid modes, including private cars, cycling, and train.

Table 4.1. Demographic and commuting characteristics of workshop participants

Participant (ID Code)	Gender	Faculty	Frequency of driving to Clayton campus (per week, during formal teaching semesters)	Travelling alternative to the Clayton campus
C1	M	IT	3-4	Cycling
C2	M	IT	3-4	*N/A*
C3	M	Design	1-2	*N/A*
C4	M	Design	1-2	Cycling
C5	M	Design	3-4	Shared cars
C6	M	IT	1-2	Public transport
C7	F	Design	1-2	Public transport
C8	M	IT	3-4	Walking
C9	M	IT	1-2	Walking & Public Transport
C10	F	IT	1-2	Walking & Public Transport

The study was conducted over an eight-month period from August 2024 to March 2025 at Monash University's Clayton and Caulfield campuses. The research project involved a total of ten international student drivers, spanning a range of academic disciplines and levels of study. The research aimed to investigate the sociocultural, economic, and infrastructural factors that might influence their transport choices and to develop design-led solutions that could facilitate a transition away from private car dependency.

4.4. Workshop 1 on envisioning future mobility scenarios

4.4.1. Introduction of the workshop

Workshop 1 was the first primary practice-based investigation in this research endeavour, designed to engage international student drivers from the Monash Clayton campus in envisioning alternative futures for sustainable mobility. This workshop, informed by prior mapping of the mobility landscape and insights from the literature and case

review, presented the adoption of participatory futures-oriented design methodologies to transition from documenting current problems to envisioning potential futures for sustainable mobility. The objective was to capture an understanding of international student participants· daily commute experiences and, more specifically, enable them to envision, question, and design scenarios that may transform their mobility practices towards more sustainable styles.

The workshop addressed two primary objectives. First, it provided an empirical setting for gathering extensive qualitative data on the limitations and facilitators of international student mobility. Second, the workshop aimed to build a creative environment where participants could be designated as co-creators of future mobility services and systems. The session design followed the "say-do-make" approach, which systematically prompted participants to express, externalise, and materialise their mobility narratives. In this context, futures-oriented design methodologies have arisen as a crucial component for navigating through current experiences and envisioning alternative futures.

4.4.2. Workshop objectives and structure

Workshop 1 aimed to engage recruited international student participants from Monash University·s Clayton campus in discussions about their routine commuter behaviours, challenges, needs, and imaginations regarding future MaaS scenarios. These conversations were facilitated using design toolkits, which included postcards, rough sketches, Lego blocks, collages, and designed props. The participants were involved in a series of planned activities. Workshop 1 consisted of three parts, including a break between the second and third parts, during which refreshments were provided.

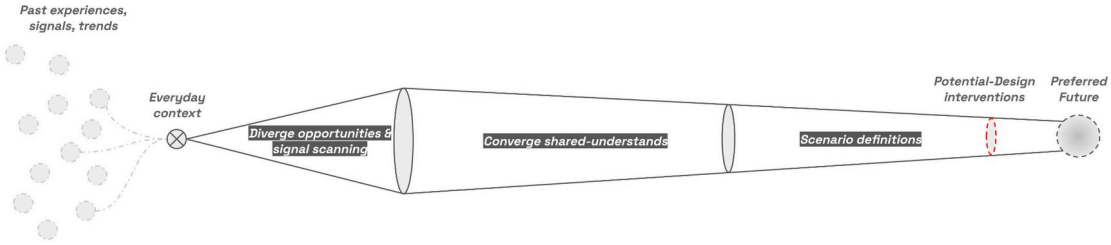


Figure 4.4. The trajectory of Workshop 1, tracing how the design toolkits, postcards, sketches, Lego blocks, collages and printed props, carried participants across the four sequential sessions

The following subsections delineate the four sequential stages of sessions that structured Workshop 1. Each phase was intentionally designed to address the workshop goals of eliciting participants· knowledge, creativity, and contextual experiences as international student drivers from the Clayton campus. A series of sessions were conducted during the workshop aimed at highlighting the participants· talent, understood as personal skills but more essentially as their ability to generate insights, envision alternatives, and collaboratively develop design possibilities when provided with suitable prompts and tools. Instead of focusing solely on retrospective verbal accounts of mobility practices, the workshop design aimed to engage participants through a multimodal sequence of activities that encourage reflection, enactment, and creation.

To capture this range of contribution, the stages were structured according to the say-do-make framework (Sanders, 2016), which provides a structure for transitioning from verbal articulation to practical or enacted demonstration and finally to creative construction. In this study, the initial "say" phase prioritised storytelling and reflective dialogue to elicit personal experiences. The "do" phase transitioned to embodied and visual tasks, such as journey mapping. The "make" phase enabled the collaborative development of envisioned scenarios for future service solutions related to MaaS-based travel and further discovered latent aspirations and values not accessed through dialogue or observation (Brandt et al., 2012). A final step in this sequence was synthesising participants· contributions, both verbally and physically, into design insights that guide the subsequent refinement of the MaaS prototypes.

The research aimed to create a cumulative arc by arranging the workshop into different phases, including the articulation of current challenges in daily commutes, progressing through the externalisation of practice, and concluding with the imagining of alternate or preferred futures (refer to Figure 4.4). This structured progression aimed to provide substantial qualitative data for analysis while also enabling participants to contribute as active co-creators in the study process. The four stages of workshop 1 represent a methodological choice and a generative strategy for accessing the implicit knowledge and creative potential of international student participants.

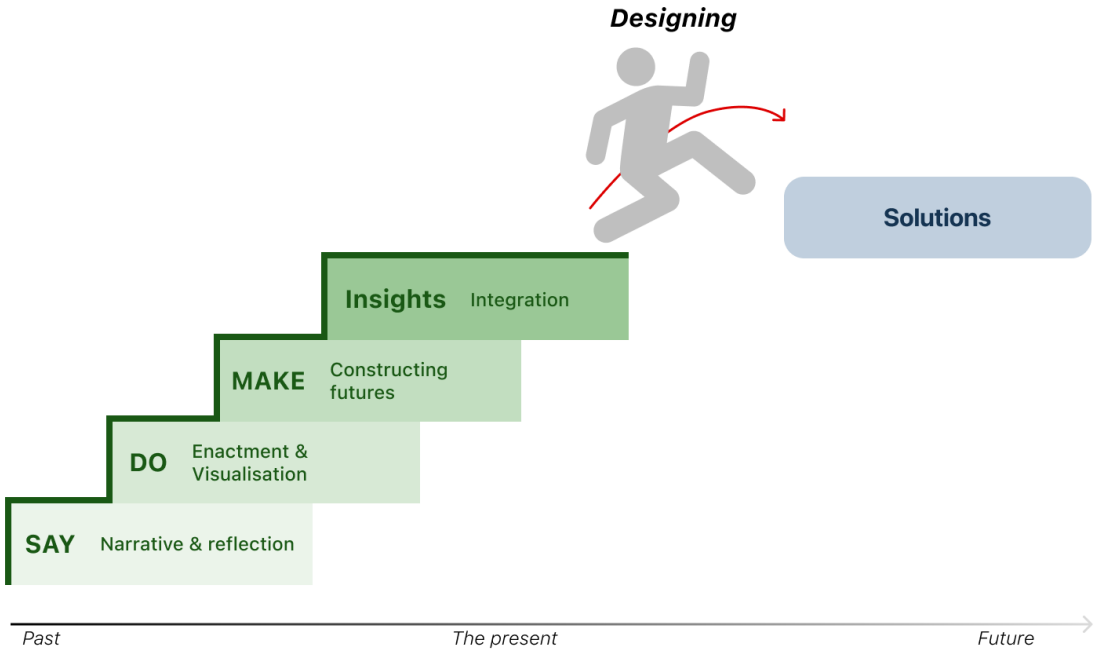


Figure 4.5. Structured progression of Workshop 1 through the say-do-make framework, inspired by Sanders (2016)

4.4.2.1. Say, Do, Make

The participatory workshop in this research facilitated generative and collaborative methods to interrogate underlying assumptions, uncover beliefs, and reveal the perspectives of participants engaging with initial MaaS interface development. Sanders (2016) articulates the techniques by drawing on the model of say, do, and make (see Figure 4.5). Instead of relying solely on verbal articulation, participants were encouraged to express their thoughts and emotions through interactive storytelling and playful prototyping, aligning with the approach advocated by Royalty and Roth (2016). Building on the framework developed by Sanders et al. (2010), the workshops were structured to guide participants through three interconnected modes of engagement (refer to Figure 4.6):

- **Saying:** through structured discussions, participants articulated and reflected upon their mobility experiences, facilitating the co-construction of narratives that contextualised their interactions with the proposed interventions.
- **Doing:** the performance and playful investigation enabled exploratory interaction with future mobility scenarios, allowing participants to prototype and access new service interventions in a dynamic and interactive way (Sanders, 2016).
- **Making:** the act of making facilitated the production of tangible artefacts, enabling participants to manifest and materialise their ideas, externalise latent knowledge and foster a shared understanding of mobility-related challenges and opportunities.



Figure 4.6. Methods that investigated what participants say, do, and make, (redrawn from Sanders & Stappers, 2012: 67)

The following subsections provide a detailed explanation of the four phases of Workshop 1, illustrating how each phase fits within the *say-do-make* paradigm.



4.4.2.2. Workshop procedure

Phase I: Postcard Storytelling

Workshop 1 commenced with a random postcard picking and storytelling session (see Figure 4.7), where participants selected a postcard that evoked a personal experience or emotion, prompting them to reflect on a past moment of change in their lives (refer to Figure 4.8). The participants were encouraged to provide brief narratives on the postcard they picked, including the motivations for the change, the factors that facilitate or hinder it, and its impact on their sense of routine. The oral narratives were audio-recorded, accompanied by reflective notes, and further subjected to thematic data analysis.



Figure 4.7. The introduction slide of kick-off activity during the workshop

accompanied by reflective notes, and further subjected to thematic data analysis.

Each participant shared the story behind their choice of postcard, elucidating the motivations, emotional aspects, and consequences of the change they had made in their past living experience (see Figure 4.9). This narrative-sharing process was based on the theoretical premise that storytelling functions as a reflective practice and a meaning-making activity (Bruner, 1991). The emphasis on motivation, emotions, and outcomes corresponds with the transtheoretical model of behavioural change, which reflects the intricate nature of personal transformational processes (Prochaska & DiClemente, 1983). The activity enables participants to reflect on their emotional dimensions of past experiences of change, recognising the significant influence of affect on behavioural change, as emphasised in recent studies on emotional regulation and the adoption of sustainable behaviours (Bamberg, 2013).

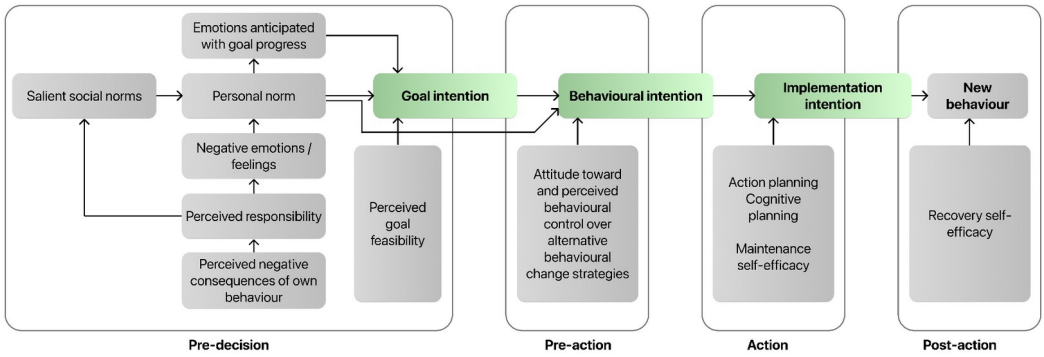


Figure 4.8. The stage model of self-regulated behavioural change, redrawn from (Bamberg, 2013)



Figure 4.9. Participants shared past stories on "change" in their life



Phase II: Mobility journey mapping

The second phase of workshop 1 expanded upon the initial postcard storytelling activity by employing mobility journey mapping to gain a comprehensive and contextual understanding of international students' daily commuting practices. This phase aimed to externalise participants' tacit knowledge of their everyday travelling experiences and to document or capture the challenges, emotional responses, and contextual limitations that influence their mobility decisions. Mobility journey mapping is extensively utilised in transportation research and design anthropology as a visual and participatory instrument to emphasise the experiential dimensions of daily commuting beyond quantitative metrics of time, cost, or distance (Büscher et al., 2010; Jensen, 2013b; Pink, 2012b). This activity adapted the technique to focus on five key stages of commuting, including pre-trip, first-mile, on-the-way, drop-off or connection ports, and last-mile, to align with the daily travelling routines of international students from the Clayton campus. Through structuring the activity across these stages, participants could collaboratively reflect on temporal, spatial, and emotional aspects of their routine travelling experiences while also recognising infrastructural deficiencies and behavioural adaptations.

Each participant was provided with a radar map template (refer to Figure 4.10), which is segmented into the five

stages of everyday journey from home to the Clayton campus. The radar mapping sheet functioned as one of the design props for detective wall building, facilitating and guiding participants' reviewing/re-thinking/re-framing their routine journey from residential locations to the Clayton and Caulfield campuses by driving cars or using multimodal patterns. Participants were instructed to assess the quality or overall experience of their commuting on a five-point scale (0, 10, 40, 70, and 100), considering factors such as reliability, convenience, comfort, and safety. After this personal reflection, participants collectively assembled a "detective wall" by affixing tangible artefacts, including strings, coloured pins, sticky notes, postcards, and images, to visually represent the rationale for their ratings (refer to following subsection). The radar mapping activity produced nuanced insights into the experience of commuting as a multi-faceted practice instead of an act of travel. Participants emphasised persistent challenges during the first-mile stage of journey, such as insufficient pedestrian infrastructure and restricted feeder local bus services, along with concerns at transfer points where modal shifts are susceptible to delays and congestion.

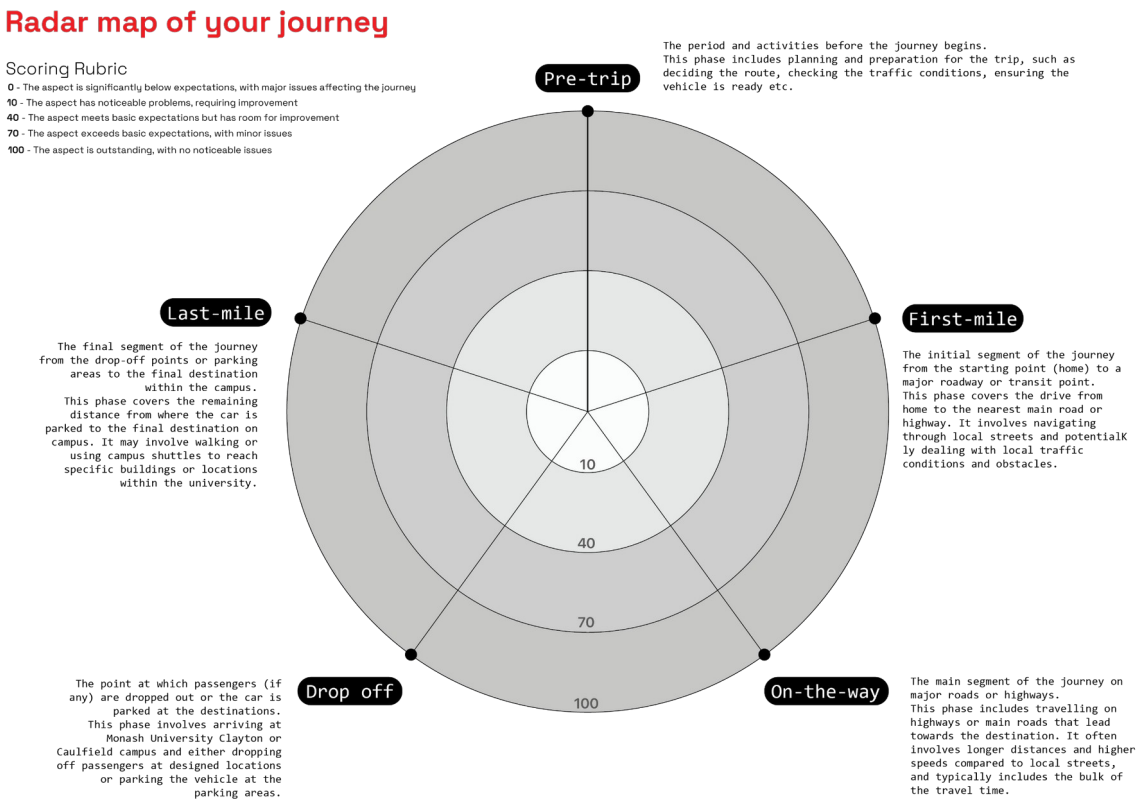


Figure 4.10. The radar mapping sheet, segmented into the five stages of the home-to-campus journey, used as a design prop to prompt participants to re-frame their routine commute

The radar mapping activity produced both individual and collective insights into the commuting experiences of international student participants. Figure 4.11 depicts the composite radar map layers produced from the evaluations of each participant. Each coloured line denotes a single participant's scores throughout the five commuting phases. The dispersion of the lines illustrates the heterogeneity of daily commuting experiences: while some participants provided relatively positive evaluations during the *on-the-way* stage, others assessed the same stage as highly problematic, highlighting the variability in perceived quality across workshop participants.

Moreover, Figure 4.12 presents the aggregated results from all participants, emphasising overarching trends of satisfaction and dissatisfaction. The highest ratings emerged in the *on-the-way* stage (mean score = 74), suggesting that once the journey commenced, participants frequently engaged in activities such as listening to music, using mobile devices, or socialising with peers, which mitigated negative perceptions of time and distance. In contrast, the drop-off and connection ports garnered the lowest overall evaluation (mean score = 45), suggesting that modal transfers and final interchange points, as participants approached the Clayton campus, were regarded as considerable stressors. These frequently involved uncertainties about the unreliability of buses or trains, challenges in coordinating different modes of transport services, and congestion of car parks during peak times.

The *first-mile* stage (mean score = 65) identified persistent problems, including infrequent feeder bus services and inadequately designed pedestrian and cycling routes connecting residential communities to primary transport hubs such as closest bus or train stations. Although not rated as negatively as the *drop-off* stage, these challenges identified by the workshop participants were still highlighted as systemic barriers to encouraging sustainable travel without reliance on private cars. The *pre-trip* (mean score = 61) and *last-mile* (mean score = 61) evaluations represented moderate results, indicating that planning uncertainty and the final stage of arriving at campus facilities necessitate design interventions.

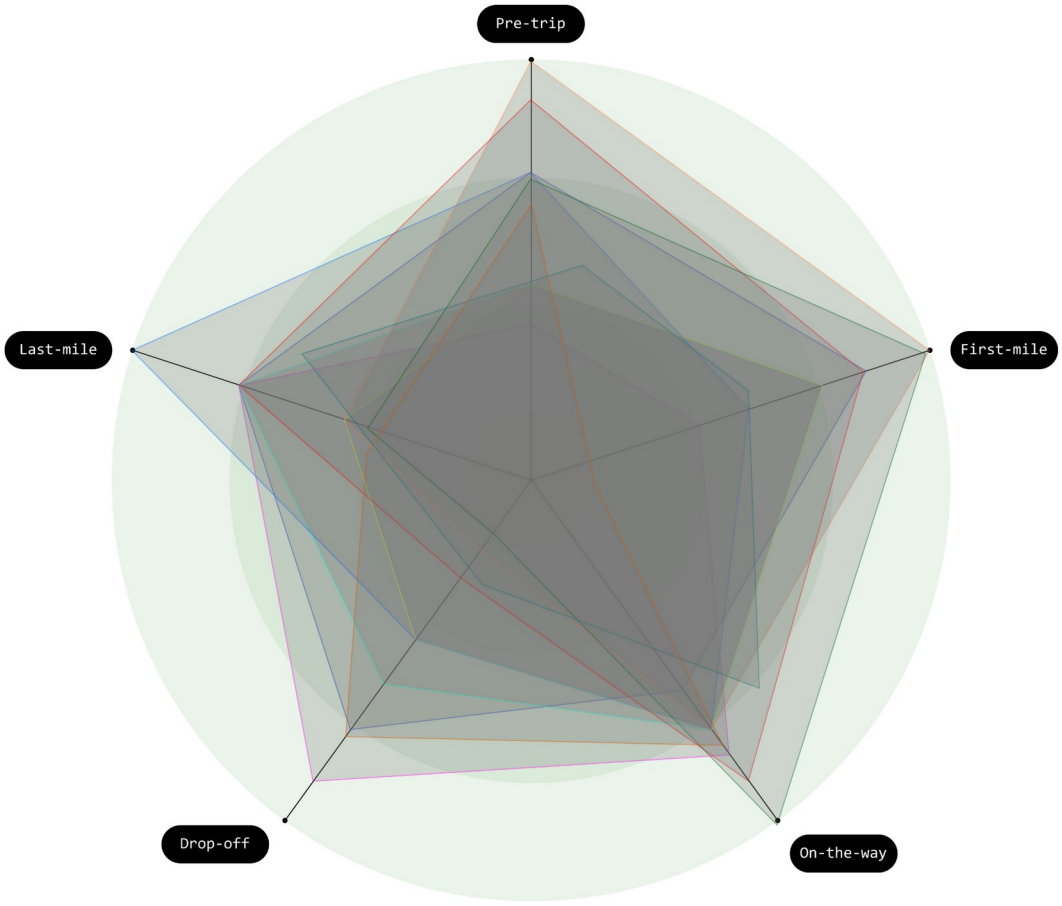


Figure 4.11. Individual radar maps of participants' evaluations of commuting experiences across five stages

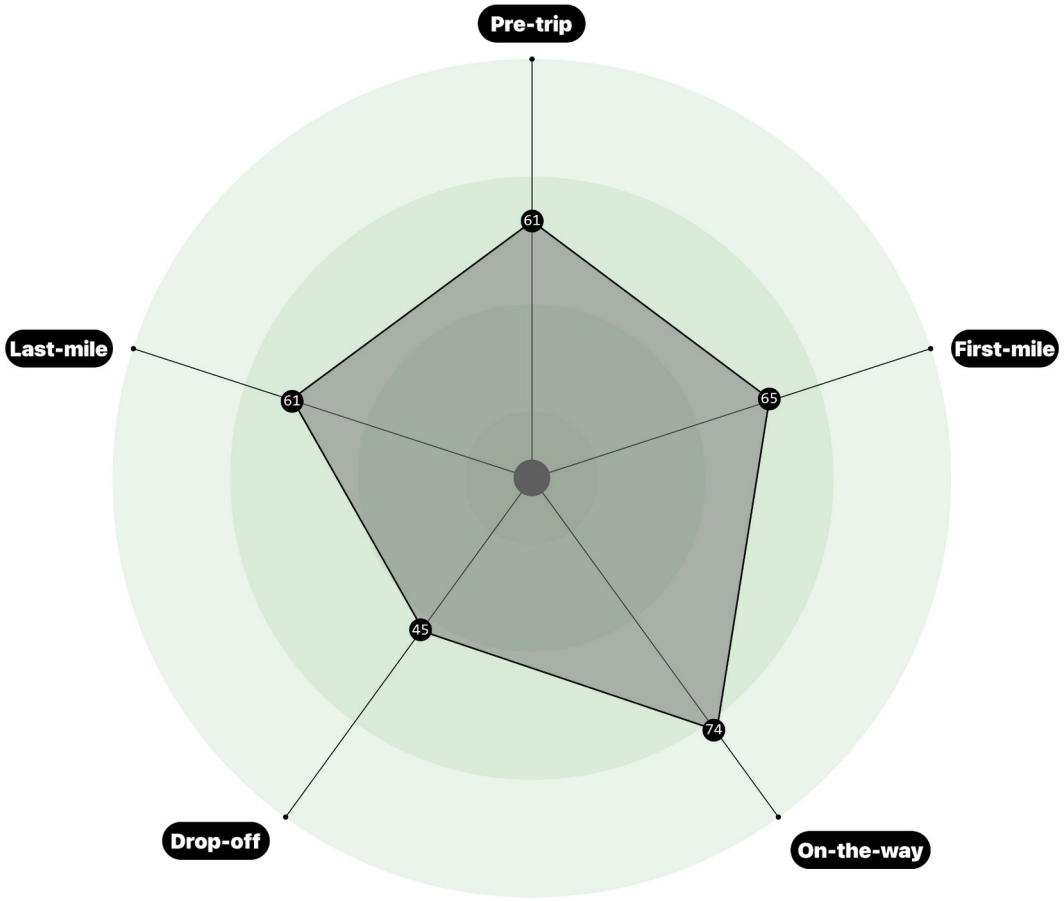


Figure 4.12. Average radar maps of commuting experiences across all participants' evaluations

The radar mapping indicates that the most significant friction points in international student participants' commuting experiences arise at the transitions between transportation modes, at the stage of first mile and drop-off or connection ports, instead of during the main travel itself. This corroborates previous studies that recognised multimodal coordination and transfer reliability as one of the most essential factors in the adoption of sustainable mobility (Cass & Faulconbridge, 2016; Lyons et al., 2019).

To conclude, the mobility journey mapping activity during workshop 1 achieved two objectives, including producing a systematic dataset of evaluative rankings for participant comparison and creating a comprehensive visual and materialised artefact of commuting challenges and adaptive strategies. Collectively, these outputs formed the empirical basis for the subsequent scenario-building activities in Phase III, during which participants were encouraged to envision alternative commuting scenarios and prospective design interventions for a sustainable MaaS platform.



Phase III: Creative conceptualisation and future mobility scenarios

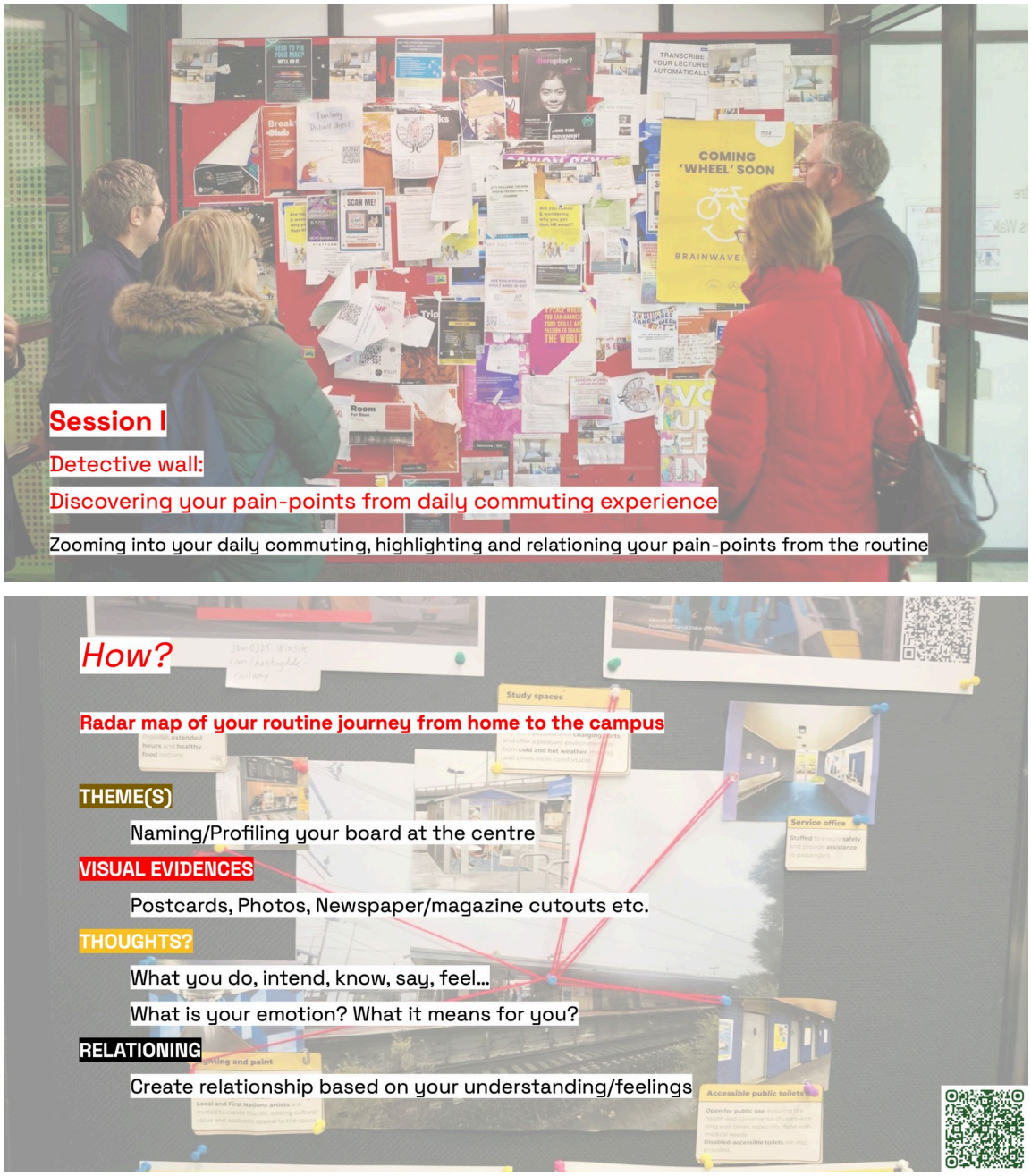


Figure 4.13. The introduction slide of detective wall activity during the workshop

Building on the previous phase, radar mapping on everyday commuting experiences currently from home to the Clayton campus, the third phase involved the collaborative building of a detective wall (refer to Figure 4.13), a design research process used to construct a visualised system mapping display on identifying pain points, behavioural workarounds, and barriers in participants' daily commuting experiences. The phase enabled the participants to externalise or materialise their insights or reflections on the wall into the varieties of infrastructural, emotional, and logistical challenges they encountered by using sticky notes, threads, symbols, and markers (see Figure 4.14).



Figure 4.14. Participants constructing their "detective wall" based on their personal radar map sheets

The detective wall-building activity was integrated with a creative ideation exercise named "Crazy 4's" (refer to Figure 4.15). This activity encouraged participants to transition from analytically identifying barriers to creatively exploring potential futures based on their reflections from the radar maps. Participants were invited to reframe the challenges occurring during their commutes as opportunities for creative ideation in sustainable mobility design, instead of concentrating exclusively on the problems (see Figure 4.16). This activity served as a bridging stage, linking the identification of problems with the exploration of potential design interventions. It provides a transitional section within workshop 1, guiding participants from diagnosing current challenges towards envisioning future possibilities. Therefore, this activity prepared participants to engage in the final phase of the workshop, which focused on creating future MaaS-based mobility scenarios (refer to the following subsection). Structured ideation activities are extensively employed in design research to provoke divergent thinking, expand the solution space, and promote engagement with possible futures (Brown, 2019; Sanders & Stappers, 2014).

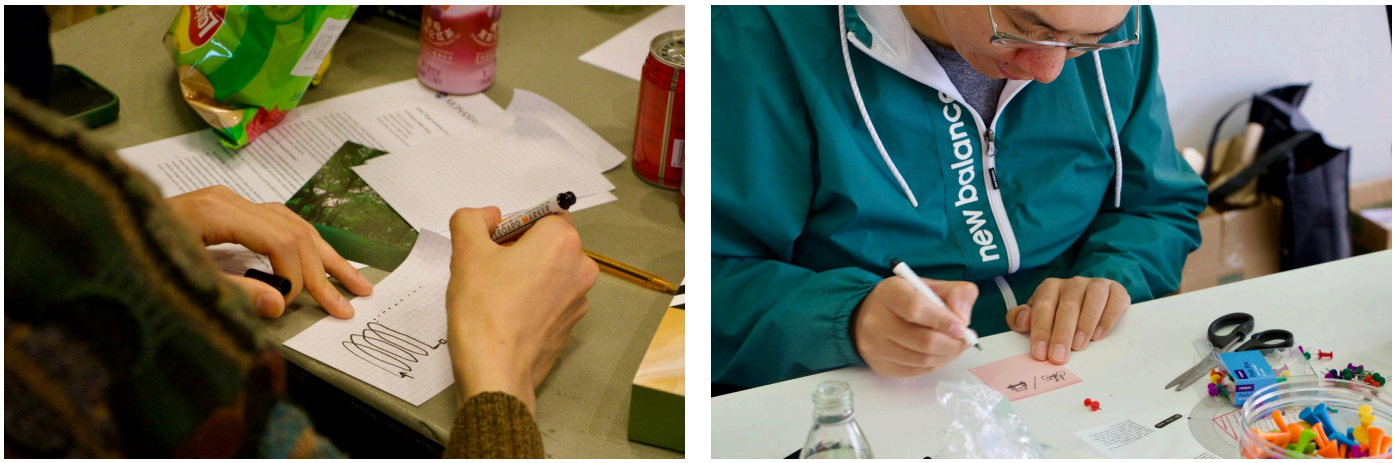


Figure 4.15. Participants engaging in the "Crazy 4's" activity alongside detective wall building

In Crazy 4's, participants expressed their imaginative solutions either visually by quick drawings or textually through brief descriptive statements. The methods of expressions enabled participants with different communication preferences to engage in the ideation process, consistent with participatory design principles that prioritise diverse modes of expression (Bannon et al., 2018). Participants visually represented their imaginative responses to the previously identified challenges through drawing or writing, thereby contributing to a collective repository of design possibilities (Nabuurs et al., 2023; Pykett et al., 2025; Sheikh et al., 2023). These practices were supported by futures-oriented and critical design methodologies, which aim to facilitate critical thinking, open up debate on preferable futures and encourage the exploration of multiple possible futures instead of predicting a single outcome (Dunne & Raby, 2013; Koskela-Huotari et al., 2021; Malpass, 2013).



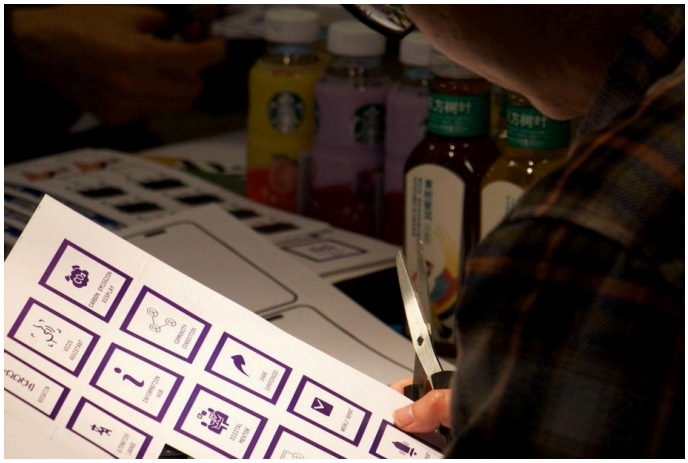
Figure 4.16. Participants worked on their own walls to identify potential design interventions that might engage or facilitate their sustainable mobility choices or behavioural changes



Phase IV: Imagination and future mobility service scenario building

In the concluding phase of Workshop 1, participants engaged in a scenario-building activity aimed at synthesising ideas from previous phases and translating them into tangible proposals for future mobility services (see Figure 4.17). Participants used structured scenario sheets (refer to Figure 4.18) to conceptualise how a MaaS platform may transform their everyday travels, specifically addressing the barriers and challenges identified earlier in the workshop.

To facilitate this process, design props (refer to Figure 4.19) were incorporated into the activity to stimulate imagination and creativity. These props were intentionally colour-coded and thematically categorised; the informational channel (purple) represented potential functionalities and emerging technologies for embedding into the future MaaS platform, while the daily interactive objectives (blue) illustrate the connection of the proposed MaaS platform with their routine commuting experience. Through interaction with these physical prompts, participants could be motivated to connect their abstract ideas of future mobility service systems that incorporate the tangible aspects of daily routines. This activity enabled participants to map out potential service interactions and functionalities, such as integrated multimodal planning, incentives for sustainable travel, and personalised design features that would more effectively correspond with their dynamic requirements.



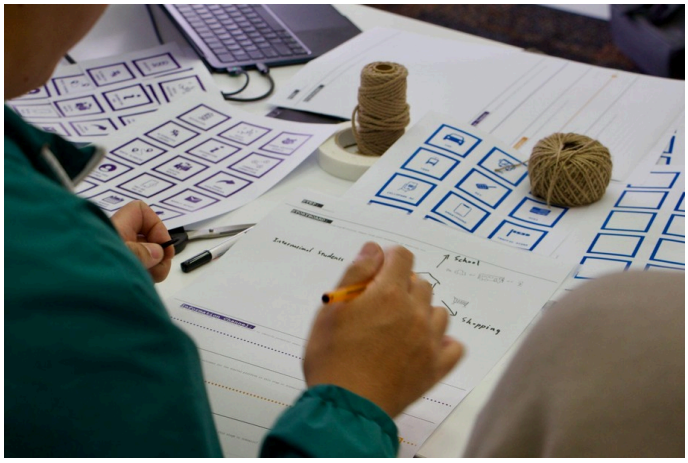
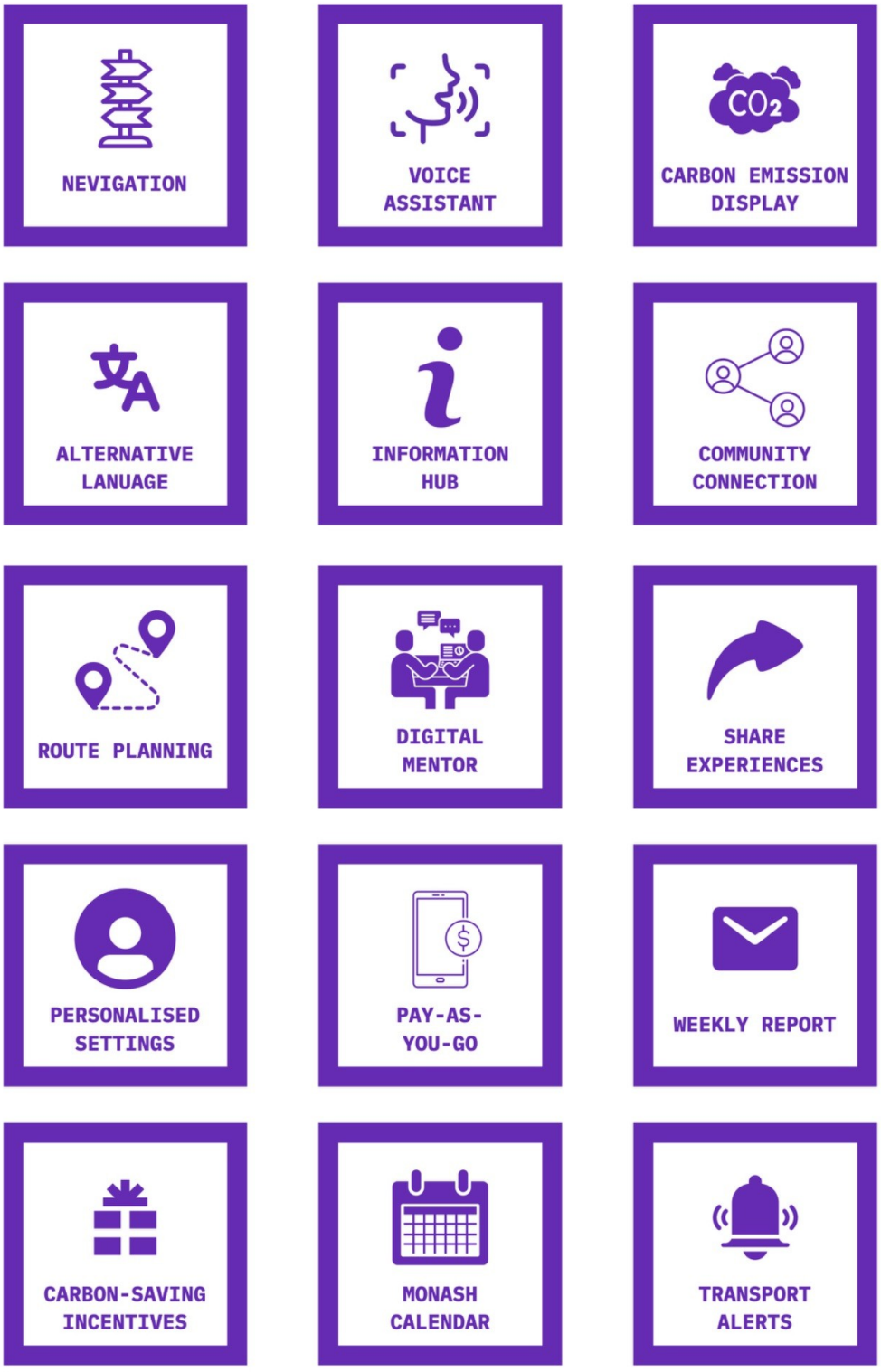
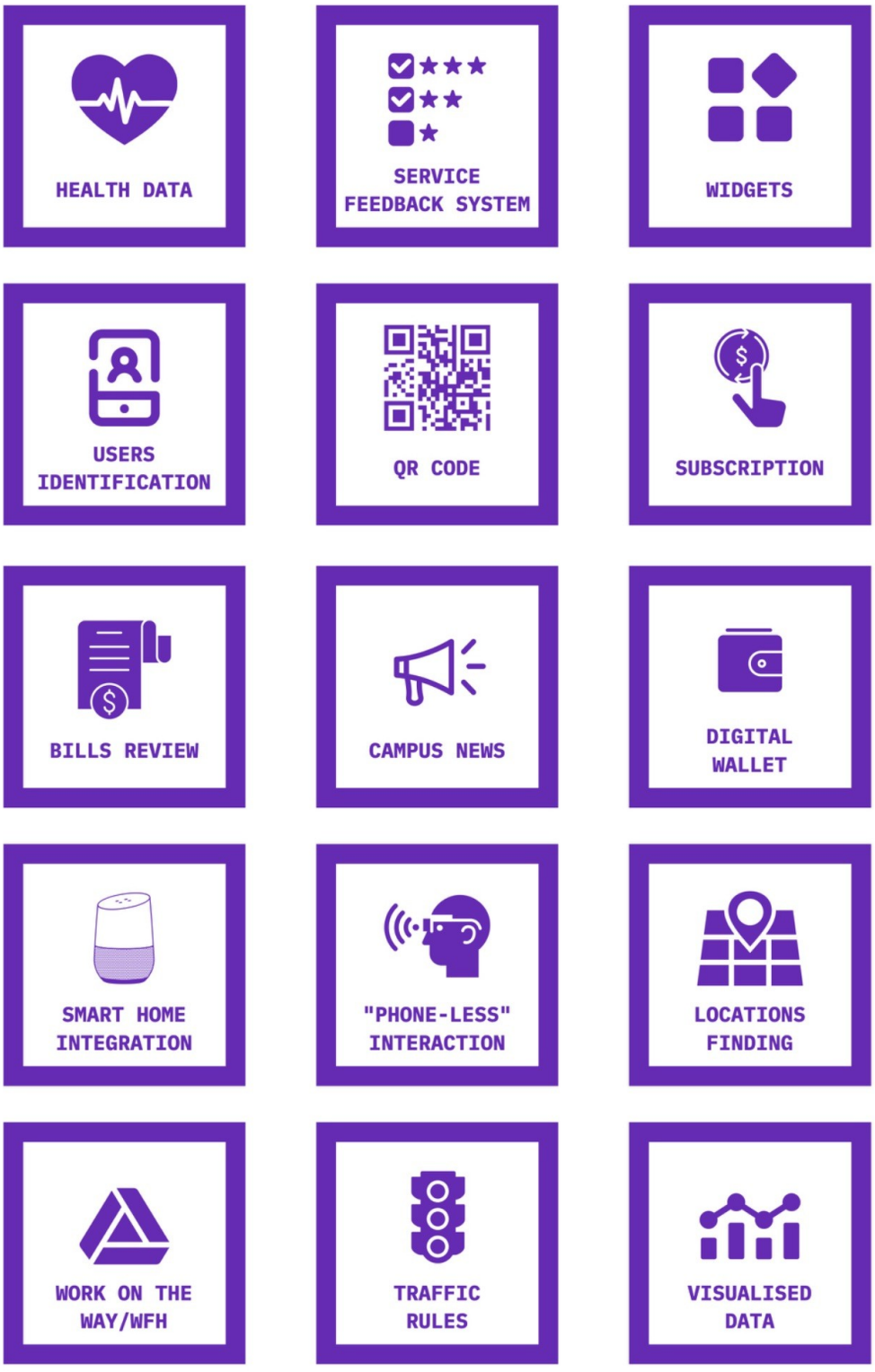


Figure 4.17. Participants framing future mobility scenarios for adopting a digital mobility service platform, facilitated by design props



Figure 4.18. Design sheet illustrating participants envisioned future mobility service scenarios


NEVIGATION
VOICE ASSISTANT
CARBON EMISSION DISPLAY
ALTERNATIVE LANUAGE
INFORMATION HUB
COMMUNITY CONNECTION
ROUTE PLANNING
DIGITAL MENTOR
SHARE EXPERIENCES
PERSONALISED SETTINGS
PAY-AS-YOU-GO
WEEKLY REPORT
CARBON-SAVING INCENTIVES
MONASH CALENDAR
TRANSPORT ALERTS


HEALTH DATA
SERVICE FEEDBACK SYSTEM
WIDGETS
USERS IDENTIFICATION
QR CODE
SUBSCRIPTION
BILLS REVIEW
CAMPUS NEWS
DIGITAL WALLET
SMART HOME INTEGRATION
"PHONE-LESS" INTERACTION
LOCATIONS FINDING
WORK ON THE WAY/WFH
TRAFFIC RULES
VISUALISED DATA


CAR
BUS
METRO TRAINS
TRAM
KEY
MYKI
CELLOPARK AU
SMARTPHONE
TRAFFIC SIGNS
P
BLUE-PERMIT PARKING SPACE
SMARTWATCH
POS MACHINE
BACKPACK
UMBRELLA
LUNCH BOX



Figure 4.19. Design props used to support the creation of future mobility service scenarios during workshop 1

4.5. Findings

4.5.1. Understanding behavioural change

One of the central objectives of the participatory investigation during Workshop 1 was to understand the drivers or factors that influenced international student participants' behavioural change from these lived or encountered memorable mobility experiences, directly informing sub-research question 1: **What behavioural, cultural, informational, and infrastructural barriers and facilitators influence international student drivers' use of alternatives to private-car commuting at the Clayton precinct?** The behavioural change factors identified through participants' lived experiences during the workshop 1 (refer to Figure 4.20), reveal a set of conditions that hinder or enable transitions towards more sustainable mobility patterns. This corresponds with established behavioural research that posits mobility decisions are situated within wider socio-material circumstances instead of isolated individual choices (Shove et al., 2012; Urry, 2007).

Participants' reflections indicated that their behavioural change, particularly regarding everyday commuting option-choices, is an accumulative and relational process influenced by various factors. As shown above, these factors include social, environmental, personal, and technological impacts. The social influences, such as changes in life phases, evolving expectations within peer networks, or cultural norms regarding independence, often altered how

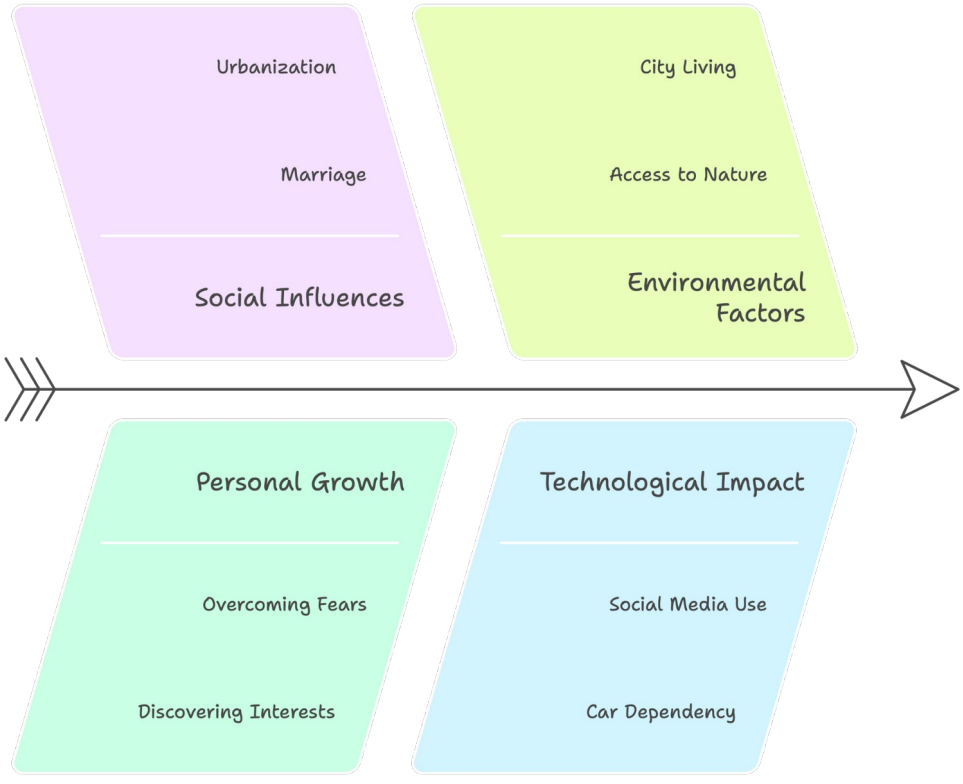


Figure 4.20. Factors shaping behavioural change across social, environmental, personal, and technological domains

participants prioritised their travelling requirements. Environmental factors, including suburban spatial configurations, transportation accessibility and reliability, safety perceptions, and exposure to new mobility ecosystems, delineated the limitations and opportunities of daily travel. The findings indicate that urban design, accessibility, and perceived environmental quality substantially influence modal choice (Banister, 2008d; Cervero et al., 2017).

Personal factors emerged as a significant experiential aspect, wherein confidence enhancement, fear confrontation, and adaptation to unfamiliar environments, including the transportation service systems at the Clayton precinct, contributed to shifts in everyday mobility practice. Behavioural research similarly emphasises adaptability, identity formation, and experiential learning as critical drivers of mobility-related change (Hickman et al., 2018). Technological factors, such as the capabilities and restrictions of digital platforms, like Google Maps and the PTV app, the impact of social media, notably RedNote (a Chinese social media platform), and the perceived reliability of transportation information, served as both facilitators and constraints. These findings corroborate literature on human-technology interaction indicating that trust, usability, and integration are pivotal in shaping the adoption of transport applications (Cottrill, 2020; S. Wright et al., 2020a).

Furthermore, these factors did not operate independently; instead, they engaged in dynamic interaction. For instance, environmental constraints exacerbated technology deficiencies, but personal confidence frequently depended on social or peer-support or previous experience. The participatory investigation methods employed in workshop 1, specifically future mobility service scenario building and reflective design activities, enabled international student participants to express these layered relationships, facilitating the following design development phases.

4.5.2. Key findings on commuting behaviours

The analysis of qualitative data obtained from participatory design workshop 1 identified important insights into the daily commuting behaviour and decision making of international students from Monash University’s Clayton campus. The participants frequently reported reliance on private cars due to perceived convenience, flexibility, and saved total travel time from home to the campus compared to public transport-based alternatives. Figure 4.21 consolidates these accounts into the core parameters shaping international students’ mobility behaviours (Bhattacharjee & Reichard, 2009).

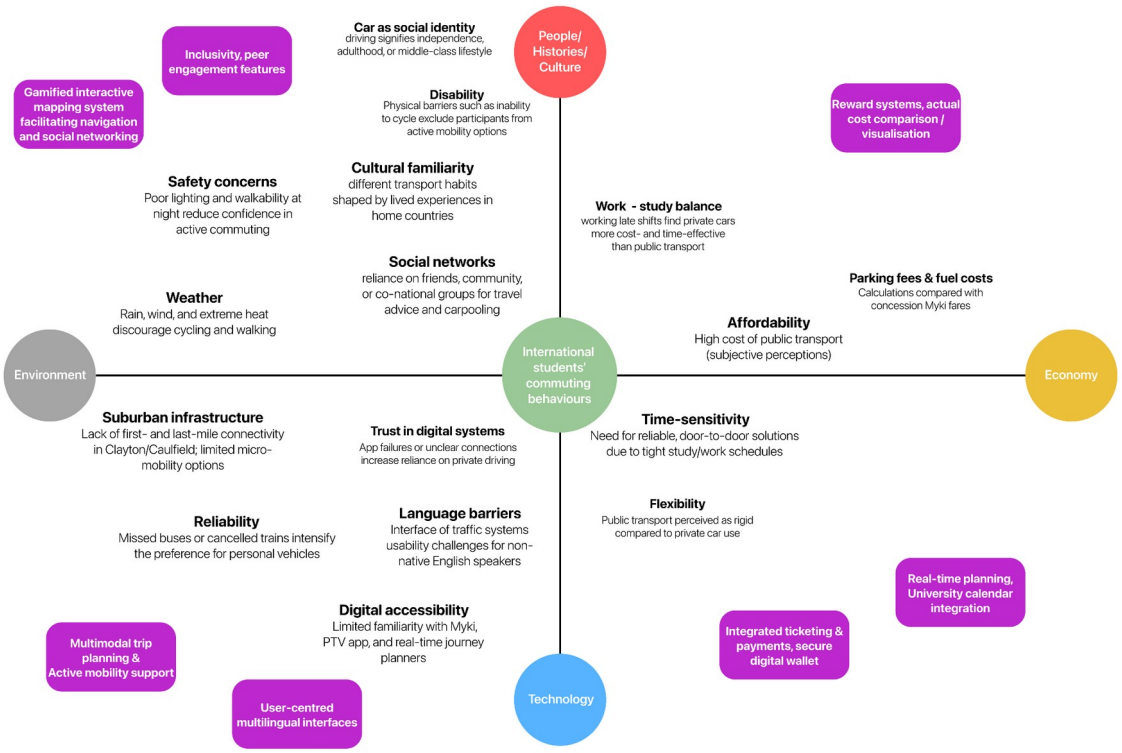


Figure 4.21. Summary of the core parameters that influence international students' mobility behaviours.

A general grounded theme was the complexity and inadequacy of public transportation systems in suburban contexts, particularly concerning irregular bus schedules, limited connectivity between transport modes, and inadequate infrastructure for active mobility, such as cycling and walking. Participants emphasised that their commute choices were deeply influenced by their previous mobility experiences in their home countries, which often featured superior public transport or significantly different urban infrastructure.

4.5.3. Identified barriers to sustainable mobility adoptions

This section presents four key themes derived from the thematic coding of data collected during the "Postcard Storytelling" and "Mobility Journey Mapping" activities in Workshop 1. The findings are organised thematically to highlight participants' past experiences and provide a layered understanding of the behavioural, infrastructural, and cultural factors shaping their daily travel choices around the suburban areas of the Clayton Precinct. To support the interpretation, some verbatim quotations from participants are included throughout, providing contextual evidence and enhancing the situated nature of the research findings.

The findings offer insights into the factors shaping international student drivers' travel behaviours and preferences. Specifically, the analysis uncovers (1) how lifestyle and personal histories influence travel choices in Australian suburban areas; (2) the restrictive role of suburban transport infrastructure in enabling modal shifts; (3) the impact of time sensitivity and the irregularity of suburban public transportation schedules;

and (4) the tension between environmental concerns and practical trade-offs. Collectively, these themes highlight critical barriers to the adoption of more sustainable or multimodal modes of travel behaviour among the participating international students.

Finding #1: lifestyle and personal history shaped travel preferences

Participants' travel modes and mobility preferences were significantly influenced by their lifestyles, personal histories in their home countries, and previous experiences with transportation systems in the suburban areas of Melbourne, Australia. The majority of participants who participated in workshop 1 indicated that their routines, daily schedules, and potentially living environments influenced their selection of certain modes of transportation. This was particularly evident in how participants negotiated the balance between work, study, and social obligations and often emphasised convenience and predictability in their travel decisions.

A significant number of participants expressed that their pre-arrival transport habits influenced their travel behaviours in Australia. Many originated from metropolitan settings where public transportation was affordable, frequent, and well-integrated. Upon arriving in Melbourne's suburbs, specifically around the Clayton campus, participants encountered 'infrastructural shock' due to the comparatively lower service frequency and disjointed transport connections.

"When I got back home (*in China*) I had never thought about buying a car. The metro close to my apartment comes every 5 minutes. But here, after waiting in the cold and missing the bus a few times, I started thinking about getting a second-hand car, like most of the local residents."

(#C4, PC_00:01:57)

"When I first arrived in Australia, during my first month here, I bought a car. Owning a car has had a huge influence on me. Having a car allows me to get closer to nature, so I often drive out to enjoy myself. Before (*pre-arrival*), in China, I sometimes drove as well, but since I was mostly on campus, I didn't really need a car. After coming to Australia, though, I find myself driving almost every day because my campus is in Caulfield, not in Clayton, so I drive to university frequently. On weekends, I drive out to distant places (rural areas)."
(C#3_PC_00:02:29)

Residential circumstance is one of the most essential factors that affect travel inclinations among international students. Most of the participating international students living in shared accommodation or homestays near irregular bus routes were more inclined to use personal vehicles or rely on lifts from peers. Conversely, those residing near train stations or close to the Clayton campus acclimatised more readily to multimodal transportation, including trains, buses, or bicycles. For instance, Participant #C4 resides in the Monash student apartments located at the centre of the Clayton

campus. Previously a private car owner, he has since transitioned to a multimodal commuting pattern following his relocation to the campus. His current travel behaviours incorporate a combination of transport modes, including the campus shuttle bus service, bicycle, mobility scooter, and carpooling with peers. In contrast, Participant #C3 resides in a suburban area located at a considerable distance from the Clayton campus. Due to limited coverage and accessibility of local public transport services in his neighbourhood, he relies on driving his private car to campus daily.

"(*researcher: not owning a car hasn't been a big issue for you?*)Not really, because I live in the city. But my friend lives in Bayswater, a faraway suburb, and she and her boyfriend share their place with two other people. They have three cars between the four of them, but it's still not enough because they all work and have different schedules. Without a car, you can't really get around unless you're near the city or a train line." (#C7_DW_00:04:16)

Furthermore, familiarity with digital navigation tools, such as Google Maps or PTV (Public Transport Victoria: a Victorian transit application), contributed to participants' confidence in exploring unfamiliar routes. They are particularly useful tools for newly arrived international students who need to familiarise themselves with the local transport infrastructure and service schedules. It is also relevant for those navigating the local road network, which frequently undergoes changes due to ongoing construction and route modifications.

"Every day, since the roads near my house are under construction, I never know which road will be closed today or tomorrow. So, every time I head out to uni, I have to rely on GPS. If I don't use navigation, the road I took yesterday might be closed today, and I'd have no way to get around it. That's why I now always use GPS—it's unavoidable. It's not like before when you could take the same route every day without thinking." (#C1_DW_00:00:10)

Although the majority of participants used journey-planning applications on their mobile phones or professional GPS devices, their confidence in these tools was still influenced by lived experiences.

"The main issue is that I have a poor sense of direction, so I always need to check the map before going out…but apart from buses being unreliable, sometimes I can't figure out where the bus stop is. I've gone in the wrong direction five or six times already." (#C10_DW_00:00:17-21)

"Even though I know the route, I'll keep Google Maps on because unexpected issues can arise. For example, last weekend, there was roadwork near Clayton, and without navigation, I wouldn't have known about it." (#C5_DW_00:00:21)

These findings emphasise that for many participating students from the Clayton

campus, transportation habits are shaped by availability or affordability of different modes but were influenced by their previous living experiences, contextual factors and reliability of local transportation infrastructure. The personal history of mobility, together with the perceived trustworthiness and safety of current local options, directly shaped their evolving travel routines in Australia. The consequences indicate that initiatives encouraging or promoting sustainable travel among international students from suburban areas of Australia need to consider these ingrained behaviours and lifestyle circumstances instead of only focusing on infrastructure availability or expenses.

Finding #2: suburban transport infrastructure limits mode shifts

A recurring theme across three rounds of participatory design workshop 1 with ten recruited international students was the constraining effect of suburban transportation infrastructure on participants' ability to shift away from private car use. Most participants expressed a strong willingness to adopt more sustainable travel modes, including public transportation, cycling, or e-scooters, if reliable and accessible options were consistently available around the Clayton precinct. However, the spatial and temporal limitations of the existing suburban transport system surrounding Monash University's Clayton campus significantly constrained these preferences (refer to Chapter 4).

"Driving is much more convenient, especially since I don't live in the city. If I lived in the city, I probably wouldn't have bought a car. But living in the suburbs, driving is far more practical." (#C5_DW_00:03:43)

Participants consistently recognised gaps in service frequency, first- and last-mile connectivity, and the lack of direct routes to campus as significant obstacles. While both campuses are technically accessible by public transport, the route often requires several transfers, long waiting times, or extensive walking from bus stops to destination points.

"That's the worst part (*last-mile*). If you're taking a bus and going somewhere slightly remote, you'll often have to walk a long distance because buses don't stop close to such areas. Bus stops are usually only on main roads, so if you don't have a car, getting to smaller roads can be very difficult." (#C8_DW_00:01:03)

The infrastructural deficiencies were both physical and informational. Some participants indicated challenges in route planning owing to insufficient real-time data, unfamiliarity with the local transport systems, and language barriers in transit signage.

"The parking system here is quite confusing. The distinction between Blue Permits, Red Permits, and Visitor parking isn't clear. Some areas have dots in different colours—red, green,

yellow — but there's no explanation of what they mean." (#C5_DW_00:00:00)

"I primarily use Google Maps or the built-in Apple Maps, and they usually provide accurate navigation. Occasionally, there might be inaccuracies, but they're rare. I've only encountered one or two instances where the destination couldn't be located." (#C1_DW_00:00:05)

Overall, these findings indicate that the suburban transport infrastructure around the Clayton precinct acts as an essential structural barrier to sustainable mobility transition. Even among environmentally motivated or economically constrained student groups, the physical environment and local or institutional transportation offerings do not provide convenient or attractive alternatives to automobile use. Addressing these barriers requires enhancements in public transportation service frequency, improved infrastructure integration, multimodal route assistance, and a culturally responsive informational design to facilitate sustainable travel behaviours or long-term behavioural change.

Finding #3: Time sensitivity and irregular public transportation schedules

Participants expressed substantial concern during Workshop 1 about the mismatch between their time sensitive schedules and inconsistent public transport services in suburban areas. They identified unpredictable public transport schedules as a major barrier that influenced decisions to drive to the Clayton campus instead of relying on buses or trains. This concern was particularly evident among participants balancing academic obligations with part time employment, evening classes, or extracurricular activities.

"Honestly, that (*without or reducing car usage frequency*) would be tough. (*Personal reason*)I can't ride a bike, so cycling or e-scooters aren't really options for me. That means I'm left with either walking, driving, or using public transport. But my accommodation is far from campus—walking takes 40 to 50 minutes, which is too much. Plus, the terrain is uphill…Public transport isn't much better either. I don't need to travel across suburbs or take trains—it's mostly buses, and the service is pretty poor. I have to transfer, wait a long time, and it still ends up taking me around 40 minutes. So even though the total time is about the same, driving gets me there in 10 minutes." (#C2_IV_00:18:51)

In contrast to automobile travel, which provides a sense of control and temporal predictability, public transportation in suburban areas is often characterised as unreliable, particularly during off-peak periods, weekends, or at night. As one participant shared:

"I live in Clayton. However, whenever I plan to go out, I encounter some difficulties. For example, if I need to take a bus to work, catch a train, or visit friends, the buses are often

delayed. And when that happens, I usually have to wait over half an hour for the next one." (#C8_DW_00:00:07)

Finding #4: Environmental concern vs. practical trade-offs

A significant proportion of participants expressed concern about environmental issues and acknowledged the essential nature of a sustainable transportation transition. However, pragmatic considerations related to daily life in a suburban university setting often override these values.

Several participants expressed their commitment to using public or active transport modes in their home countries before arriving in Australia. Nevertheless, after encountering the suburban layout of the Clayton precinct, characterised by dispersed housing, long travel distances, and infrequent public transport services, they

This pattern illustrates what has been described in transport literature as the "value-action gap" (Blake, 1999), the discrepancy between environmental values and actual travel behaviours resulting from contextual limitations. Even some participants who initially tried to use low-carbon transport options due to their previous travelling habits or lifestyle eventually converted to driving when their expectations of reliability, flexibility, and safety were not met in the suburban areas of Melbourne. For instance, some international students from workshop 1 who first commuted by bus or bicycle identified inclement cold weather or tight academic and employment commitments as critical factors for ultimately purchasing a car.

"I usually just walk. But recently, I've been learning to drive. If I'm heading somewhere in the Clayton area, I'll drive myself since I already own a car, though I'm still working on getting my license." (#C8_DW_00:00:40)

"The wind and weather here are extreme—it's often very windy or cold. Driving is just more comfortable. Maybe I will try to cycle to campus during summer." (#C1_DW_00:04:31)

"As soon as you get off (*of the train*), you feel the strong wind, which is uncomfortable—especially for girls with their hair down. The wind blows your hair everywhere, and if you're wearing makeup, it's even worse. Even though the campus is close—just across the road—there's always traffic. You have to keep an eye on cars while dealing with the wind messing up your hair, which is really frustrating." (#C7_DW_00:01:28)

In summary, these findings indicate that environmental concern alone is inadequate to facilitate a transport mode shift towards more sustainable options among participating international student drivers. The interventions designed to promote sustainable travel need to consider more than just awareness-raising and address the tangible trade-offs encountered by international

students. Solutions that integrate flexibility, reliability, and contextual relevance, while visibly aligning with sustainable goals, are more likely to bridge the gap between intention and action in this demographic (W. Liu et al., 2025).

4.5.4. Design opportunities for MaaS platform development

This section synthesises four primary design opportunities identified through thematic analysis of the "Crazy 4's" ideation activity and the "Building Future Mobility Service Scenarios" task conducted with international student participants during Workshop 1. These activities during workshop 1 collectively involve participant students envisioning desirable and feasible features of a future MaaS platform, which reflect on their past and current mobility barriers and aspirations for future sustainable mobility at the Clayton campus. The identified themes suggest practical design interventions that could enhance the adoption and future usage of the MaaS platform among international students.

The design opportunities will be presented in four thematically organised sub-sections, including, specifically (1) integrated real-time, high-resolution localised transport information and multimodal journey planning; (2) incentivising sustainable mode shifts through personalised rewards; (3) personalised onboarding for local transport familiarisation; and (4) integrated social and gamified features.

Opportunity #1: Integrated real-time, high-resolution localised transport information and multimodal journey planning

A prevalent design need that the participating international students expressed during workshop 1 was the demand for integrated, more accurate, and context-specific transportation information to facilitate travel planning within and around the suburban environment of the Clayton precinct. The participants emphasised the necessity of real-time data for public transport schedules and for organising multimodal options, such as walking paths, inner-campus shuttle services, bicycle routes, and carpooling availability within a single digital interface.

Participants described that current transportation apps like Google Maps or the Public Transport Victoria (PTV) app cannot provide the level of detail and dependability they require in their daily commute. As discussed in the previous section, these tools lacked up-to-date information about disruptions, construction detours, or on-campus shuttle routes, which caused delays or travel anxiety during the participants' daily commuting.

High-resolution localisation is essential for building trust and usability in suburban areas, where navigation and transport services have less coverage and are less frequent. Therefore, the proposed MaaS platform needs to provide hyperlocal transport or navigation information that responds dynamically to the user's

conditions, such as real-time alerts about route changes, weather-related impacts on walking or cycling, or the availability of bike racks and shared cars near campus.

"I feel that before arriving on campus, we don't know where we need to go for classes or how big the campus is. There's no real plan. That's why I think this app should help by telling me how to get from where I live to campus." (#C4_SC_00:00:01)

In addition to accurate mapping and navigation information, participants also desired journey planning to seamlessly integrate different modes of transportation so that they could compare different route options based on time, cost, emissions, and convenience. As discussed in the previous subsection (research findings #1 and #2), several participants expressed their frequent usage of Google Maps to plan and navigate their routine journey from home to the Clayton campus. However, they envisioned that future MaaS platforms would be able to visualise and plan their commute before departing in an easier way. For instance, participant #C4 described a function of multimodal planning for the potential future MaaS platform (see Figure 4.22).

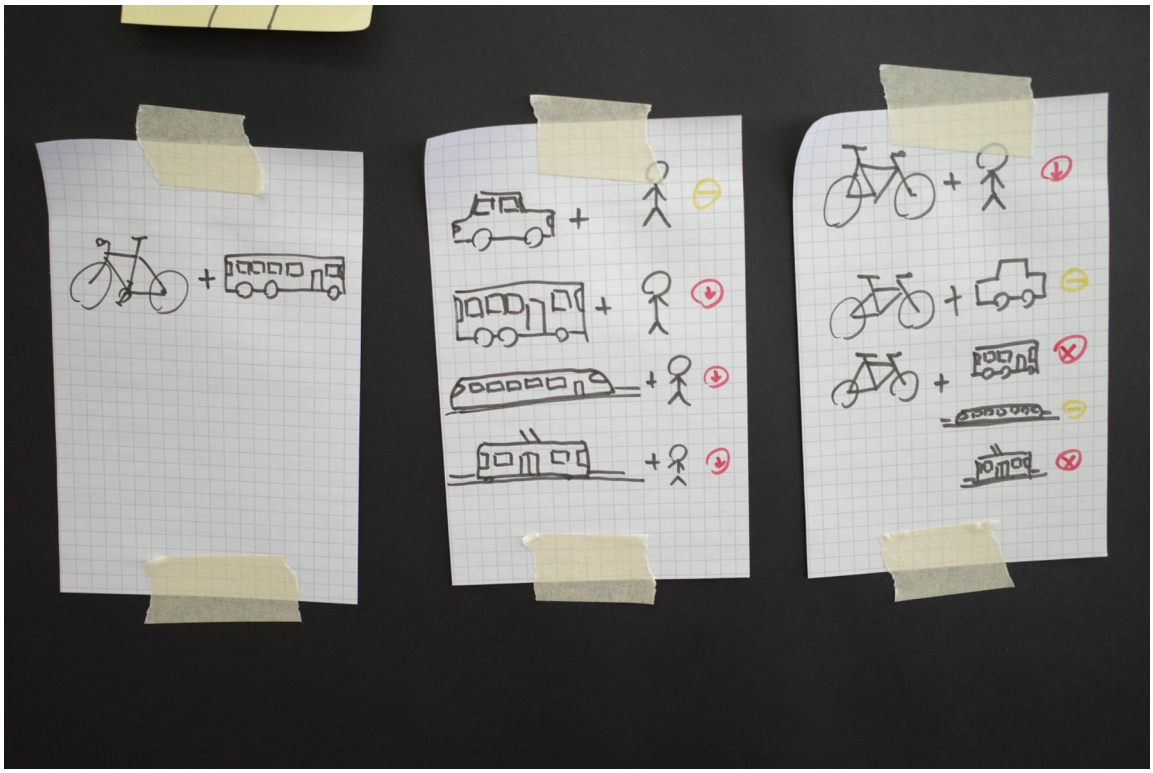


Figure 4.22. Draft sketches of one participant who described future multimodal planning function of the MaaS platform

"So, if this system could integrate all available transport options into one app, it would be great. For example, short trips could be solved with a scooter, while longer journeys could combine a car and a scooter. These options are currently separate, but it would be ideal if they were all accessible and payable through one app." (#C1_SC_00:00:34)

This insight points to the need for a planning tool or function embedded in the future MaaS platform that focuses on the user and provides them information as well as gives them the power to make decisions by letting them compare options and set their own filters or preferences for dynamic travelling demands, such as "low carbon", "shortest walking distance", and "avoid traffic". These design features would help international students navigating unfamiliar local transport systems to more confidently choose eco-friendly options that align with their time, safety, and accessibility needs.

"I want this app to help me quickly develop similar strategies here (*around the Clayton precinct*)…it would offer some assistance at first (*early period of arriving in Australia*). Over time, I'd learn how to use the app and understand local transportation options." (#C4_SC_00:04:31-34)

Designing for integrated, localised transport intelligence is therefore a foundational opportunity for encouraging sustainable behaviour change. The future MaaS platform can become a trusted travel companion and planning tool (C.-F. Chen & Chen, 2023; Molla et al., 2022a) that international students use every day by meeting their cognitive and logistical needs with real-time, multimodal journey support. This might lead to less reliance on private cars and a more connected campus mobility culture (Hensher et al., 2021; Sochor et al., 2015c).

Opportunity #2: Incentivise sustainable mode shifts through rewards

As discussed in Chapter 2, the rewards-based system is one of the most essential facilitators that enable sustainable transport behavioural change. The thematic coding evidence from workshop 1 with international students also highlights the importance of integrating tangible- or intangible-reward systems in the MaaS platform that facilitates sustainable mobility. Many international student participants indicated that, while they recognised the environmental and financial advantages of using public or active transportation options, external incentives could significantly influence the mitigation of perceived inconvenience, unreliability, or discomfort associated with non-driving modes.

"First, there's the idea of rewards for low-carbon travel, whether they're financial or psychological…you (*the future MaaS digital platform*) need(*s*) a mix of incentives. I wrote down the idea of a "digital wallet," a centralised credit system. This wallet could collect credits that can be

redeemed for tangible rewards or other benefits." (#C2_SC_00:00:06)

"The rewards could come in many forms: digital credits, e-vouchers, or discounts usable within the university. If this project is rooted in a university setting, the rewards could encourage campus spending, further promoting the app…This would encourage more walking (*active mobility*)" (#C3_SC_00:01:51)

As the participant mentioned above, the idea of receiving tangible or gamified rewards, such as discounts, vouchers, campus credits, or digital badges, might support international students' sustainable travel decision-making. Furthermore, thoroughly offering extrinsic incentives for sustainable or multimodal travelling through the MaaS platform would facilitate the students developing new travel habits, particularly during transitional periods like the first teaching semester of arrival.

Participants talked about the importance of matching incentives with their actual needs and interests. For example, suggestions included free food or coffee on campus, coupons for car parking, or a permit to reserve a parking lot if they have to drive a car. Additionally, some participants indicated the opportunity to combine the reward system with business promotions or credits for nearby retail stores frequently used by students. These contextually relevant incentives were seen as more significant and attractive than generic prize draws or abstract sustainability messages.

These findings align with behavioural economic studies, indicating that small, immediate, and personalised incentives may significantly influence motivation for repeated actions (Gneezy et al., 2011; Thaler & Sunstein, 2021; X. Zhu et al., 2020a). The majority of participants expressed a willingness to continue engaging with the digital platform when it offers monetary incentives. However, several participants articulated a preference against direct monetary rewards, noting that such incentives may encourage them to withdraw the funds to their personal bank accounts, thereby reducing their attraction to ongoing engagement with the platform. Instead, these participants favoured a system of in-app reward points that could be redeemed for tangible benefits related to campus services or transportation costs, such as PTV travel passes, or used to offset other essential living expenses.

"For me, monetary rewards would be ideal. For instance, if driving emits a certain amount of carbon, and using this platform reduces that, I'd want a cash reward for the carbon savings." (#C1_SC_00:00:34)

Implementing a reward-based feature within the MaaS platform has a substantial potential to foster continued engagement and mitigate the psychological burden associated with transitioning from car-centric travel. Nevertheless, provided it is carefully integrated and aligned with users' real-life challenges, the reward-based nudging mechanisms may convert sustainable

mobility into a more fulfilling and socially valued practice. This is especially important for individuals who are unfamiliar with the transportation landscape and need immediate reinforcement to modify their behaviour.

Opportunity #3: Personalised onboarding for local transport familiarisation

All participants in Workshop 1 recalled encountering challenges when first interacting with Melbourne's public and shared transport services, especially in the suburban regions surrounding Monash University's Clayton campus. A predominant portion of participants characterised their first transit experience as perplexing or daunting in Melbourne, particularly during the early months of their arrival. The student participants initially relied on informal social networks, such as friends or housemates, to navigate their routes from home to the Clayton campus. Due to the limited familiarity with local transportation services and the inconvenience of accessing nearby bus stops or train stations from their residences, many participants reported relying on private automobiles, even though this was not their preferred mode of transport. In addition, a number of participants indicated that their inadequate understanding of the Myki fare system, local bus routes, or the process of transferring between modes led to their feelings of being "lost" or "unsure" while planning their first journey.

"For me, the two most important aspects of travel are convenience and speed. If there's a method other than driving that can get me to my destination, I'd be happy to use it—as long as it's convenient and reasonably comfortable…So, if this system could integrate all available transport options into one app, it would be great. For example, short trips could be solved with a scooter, while longer journeys could combine a car and a scooter. These options are currently separate, but it would be ideal if they were all accessible and payable through one app." (#C1_SC_00:00:07-34)

As discussed in research finding #1, most participants use smartphone applications, such as Google Maps or the PTV app, to plan and navigate their journeys. Nonetheless, these tools were usually described as incomplete, difficult to interpret among the participants, and not tailored to the context of the Clayton precinct. For example, there is a lack of detailed information about cycling paths both around and within the Clayton campus, as well as isolated transportation details and inadequate navigation functions inside the teaching buildings. These challenges are commonly encountered by newly arrived international students and reflect a broader pattern of informational gaps that hindered the adoption of sustainable modes and resulted in feelings of uncertainty or risk.

Regarding these challenges, participants emphatically suggested the concept of a structured and tailored onboarding feature integrated into a MaaS platform. This feature would ideally include sequential instructions for using local public transport services such as public buses, trains, or campus shuttle services, tailored route recommendations or

guidance based on personal mobility preferences from students' living locations to the Clayton campus, and daily destinations. More specifically, some participants believed that visual guidance and tutorials, such as instructions for tapping on/off a Myki card or locating a campus shuttle stop are essential components of a MaaS platform for newly arrived international students to familiarise themselves with local transport systems. Others suggested implementing multilingual support or onboarding pathways customised for distinct user categories, such as first-year undergraduates, part-time employees, or students living off-campus. As one participant said, "The app (MaaS platform) should offer alternative language options for people who don't speak English and cater to the needs of distinct user groups." (#C1_SC_00:02:22)

"I think it could add personalised recommendations. For instance, if I often choose to bike or use public transport, it could prioritise suggesting those options…(*researcher: so, more personalised recommendations?*) Yes, but tailored to individual preferences and conditions like the weather. For example, if it's likely to rain, the app could recommend I take public transport instead of biking. Also, for local students, there are concessions like half-price fares, but international students might not be aware of these benefits." (#C6_SC_00:00:32-42)

In conclusion, the integration of a personalised onboarding design feature within a MaaS platform represents substantial potential to facilitate the mobility transition or familiarisation of local transport networks for international students during their early period of arrival in the Clayton Precinct. By filling in gaps in local transport-related information, alleviating potential negative emotions, and supporting decision-making, such a design feature might promote a transition to sustainable habits prior to automobile reliance being the norm. This design opportunity presents the platform as a responsive and caring solution tailored to the unique experiences of international students from a suburban university precinct in Australia.

Opportunity #4: Integrated social and gamified features

A fourth opportunity emerged less as an explicit request than as a pattern running through the Workshop 1 accounts, participants' mobility decisions were consistently mediated by other people. As reported in research finding #1, several participants relied on lifts from peers or carpooling arrangements where local services were inadequate, and Participant #C4's shift to a multimodal pattern following relocation to campus included carpooling among the modes he combined. Similarly, the onboarding difficulties described above were most often resolved informally, with participants turning to friends and housemates instead of to any transport information source to learn how to reach campus. Social relationships were therefore already performing the work of route discovery, reassurance, and mode

coordination, but were doing so invisibly and unevenly, depending on whom a student happened to know.

This suggests a design opportunity in making those peer relationships visible and usable within the platform, instead of leaving them to chance. Features raised or implied during the ideation activities include peer-based journey coordination for students travelling similar routes at similar times, visibility of the modes and routes used by others in the same residential area, and the ability to share a route or a planned journey with a peer. For newly arrived students, seeing that a route is routinely taken by others carries an assurance that timetable data alone does not provide.

The gamified dimension of this opportunity is closely coupled to the reward mechanism discussed in Opportunity #2 instead of separable from it. Participants proposed non-monetary recognition alongside tangible incentives, including digital badges and credit accumulation, indicating that the motivational value of the reward system lies partly in progress and recognition instead of in financial return alone. This points to a gamified layer built on top of the incentive structure, which might include progress tracking, milestones, and group or cohort-level challenges, comparing to a separate game mechanic competing for attention with the platform's core planning function.

These directions were carried into Workshop 2 and the follow-up interviews, where participants responded to concrete representations of social and gamified features; the refinements arising from that testing are reported in Chapter 8.3.

4.6. Chapter conclusion

This chapter presents a detailed procedure of the Participatory Design Workshop 1, which engaged international student drivers from Monash University's Clayton campus in co-reflecting on their everyday mobility patterns and envisioning more sustainable commuting practices through creative activities to narrate a series of potential interactions with the MaaS platform. Through the adoption of participatory design methodologies and creative techniques, including postcard storytelling, radar mapping, detective wall building, and future mobility scenario structuring, the chapter revealed the specific mobility needs, challenges, and aspirations from the perspective of this frequently neglected user group in the previous transport-related investigation.

The findings indicate that international students' mobility choices are influenced by personal preferences, which may be shaped by their past commuting experiences from their home countries or during the initial period of their arrival in Australia. In addition, the local environmental realities also are important in shaping their mobility patterns in a suburban university precinct, which is intricately embedded within broader sociocultural and infrastructural contexts. To further explain, the reliance on private cars among the international students was shaped by multiple interacting

factors, including prior urban mobility experiences in their countries of origin, deficiencies in Melbourne's suburban transportation infrastructure, perceived barriers to accessing and understanding local public transport systems, and the conflict between time-sensitive daily routines and the irregularity of transit schedules.

Methodologically, the workshop demonstrated the essential role that participation and partnership in service design practice can play in revealing these contextual complications. During the workshop sessions, participants can express their dynamic mobility needs and barriers to adapting to more sustainable travel styles, but more importantly, they can envision potential alternative future commuting scenarios, resulting in MaaS physical and digital prototypes. The design opportunities of the future MaaS digital platform, synthesised from the research findings from Workshop #1 with international students include (a) real-time and high-resolution multimodal transport integration; (b) rewards-based incentive systems customised for international student lifestyles; (c) personalised onboarding processes that accommodate linguistic, cultural, and experiential differences; and (d) university context-aware planning tools that balance convenience with carbon emissions.

In summary, this chapter provides the empirical basis for the subsequent design phases outlined in the following chapters. The design insights generated through Workshop #1 guided the development of physical and digital diegetic prototypes, which facilitated the procedure of Workshop #2 and follow-up interviews. The following sessions of this research project align with the human-centred design (HCD) approach and make international students the co-creators of a future MaaS digital platform.

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5. A co-prototyping investigation into future MaaS-based commuting experiences

CHAPTER OVERVIEW

This chapter will step into the design practice phases of the research endeavour after the preceding chapters have elucidated the contextual foundations of the Clayton campus (refer to Chapter 2) and presented findings from the first participatory design workshop (refer to Chapter 4). The same group of participants who engaged in Workshop #1 were invited to continue with Workshop #2, ensuring continuity of insights and allowing them to build on their earlier reflections. This phase shifted from understanding international students' mobility patterns to collaboratively imagining and further refining the features of a designed MaaS digital platform that might support sustainable commuting or decision-making. Workshop #2 involved near-future contextual scenario exploration, physical prototyping, and feedback on the platform's flowchart. The workshop enabled participants to co-develop and reimagine potential features, such as personalised trip planning, gamified incentives, and carbon tracking. Following Workshop #2, some selected participants were interviewed through in-person interaction with the designed digital prototype. The chapter demonstrates how design practice serves as a medium of enquiry, translating ideas into tangible and actionable design concepts through interactive and participatory processes.

5.1. Introduction

This chapter details the interactive design development process undertaken during the second phase of the research project with the same group of international student participants. Building on the pre-design insights and design opportunities identified in Chapters 2 and 4, respectively, the design practice phase aims to co-develop and refine a series of user interfaces for future MaaS platforms with international student drivers to potentially enhance their sustainable or multimodal journey planning and decision-making. This phase included a series of interactive activities, such as participatory design workshop #2 and follow-up semi-structured interviews, aimed at evaluating, critiquing, and improving the user experience of the early-stage prototypes through direct contributions from participants.

Following the participatory design workshop #1, workshop #2 provided a collaborative environment in which participants interacted with low- and mid-fidelity physical prototypes, contributing to the ideation and expression of context-specific mobility service solutions. These activities during Workshop #2 were structured to elicit experiential knowledge, preferences, and behavioural patterns related to participants' daily

commutes from home to campus. Furthermore, workshop #2 also enabled the study to evaluate both the design interface usability and the motivational or infrastructural elements that might influence participants' modal choices in the near-future mobility scenarios in the context of a suburban university precinct.

A series of design feedback interviews with digital prototyping sessions were conducted with selected participants following Workshop #2. These sessions enabled an in-depth exploration of personal reflections on the usability, relevance, and adoptability of the designed MaaS digital platform. These iterative design feedback loops were crucial in uncovering hidden user needs and directing the ongoing enhancement of the interaction logic, informational architecture, and incentive mechanisms of the designed MaaS platform.

The chapter is structured to detail the methodological framework, design activities, and findings from each phase (see Figure 5.1). It concludes by reflecting on how participatory design methodologies influenced the development of a final digital mobility service prototype that is grounded in the past experiences and aspirations of international students. This practice-led enquiry demonstrates how collaboratively engaging users in iterative design and prototyping processes may provide actionable insights for the development of an inclusive and sustainable digital mobility service platform in a suburban university precinct context.

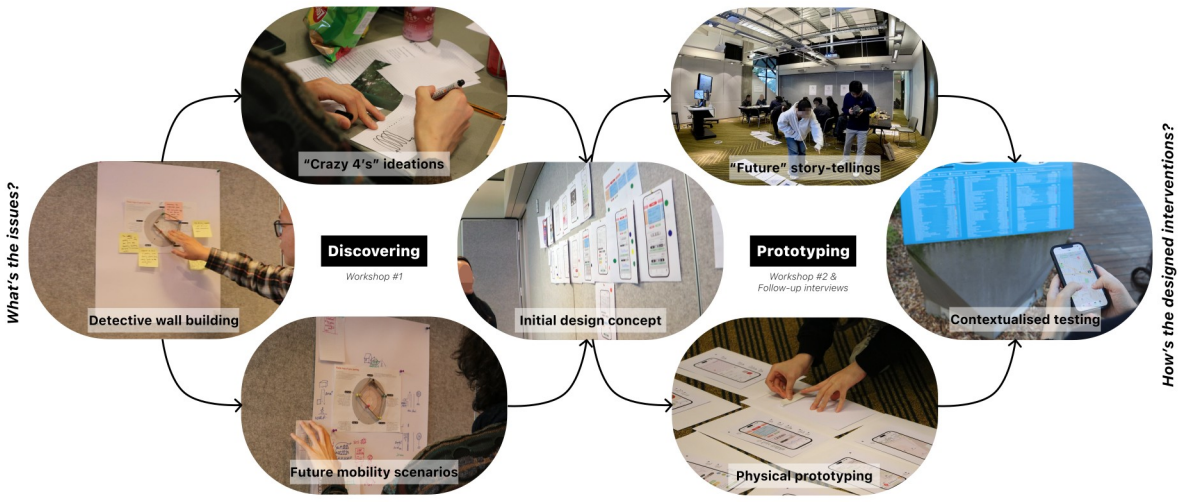


Figure 5.1. Design framework illustrates how this practice-led investigation with international student drivers from discovering their daily commuting challenges (left) to the development of a designed MaaS digital platform through iterative prototyping (right).

5.2. Workshop 2 on narrating the adoption of a future mobility service platform

5.2.1. Workshop objectives and structure

The second participatory design workshop was designed as a pivotal phase in the co-development of sustainable mobility services for international students. Situated within a broader participatory enquiry framework (refer to Chapter 3), Workshop #2 aimed to transition from initial issue discovery and ideation (Workshop #1) to the contextualisation and evaluation of preliminary design interventions. Specifically, one of the most essential objectives of workshop 2 was to investigate how a future mobility service digital platform could be made tangible through interactive prototyping activities and structured user feedback. Therefore, this stage of action investigation addressed the primary design question and research sub-questions:

DR: How might we design a campus community-based and user-centred MaaS platform that addresses the mobility needs and preferences of international students?

RQ3: How can participant-informed design requirements be translated into and evaluated through a campus-based MaaS interface prototype and service blueprint?

The workshop framework was guided by the essential principles of participatory design methodology, which actively engage users as informants and co-designers (Qi & Yu, 2025; Simonsen & Robertson, 2012). Participatory design workshops are structured to actively involve stakeholders, especially end users, throughout the design process. The approach is characterised by collaboration and co-creation (Nofal, 2023; Scariot et al., 2012), an iterative feedback loop (ibid.), and empowerment of participants (Arcia et al., 2024; Ferguson & Candy, 2014; Jalowski, 2020).

Workshop 2 also focused on the interaction between divergent and convergent design thinking (see Figure 5.2). Following the convergence session of the previous workshop 1, where participants collaboratively constructed future mobility service scenarios, student participants were invited to engage directly with the proposed MaaS platform interfaces. The subsequent divergent phase of Workshop 2 aimed to elicit contextualised feedback by encouraging participants to interact with and critically evaluate the physical prototypes, organising them in relation to their everyday mobility practice and past experiences. This was followed by a convergent phase, where design ideas were critically synthesised and assessed using activities where participants used a set of physical prototypes to visualise and tell the story of a future sustainable commuting experience from their

personal perspective and living context facilitated by the proposed MaaS platform. The iterative process of ideation and evaluation was crucial for aligning design interventions with the everyday realities and potential future needs of the international students.

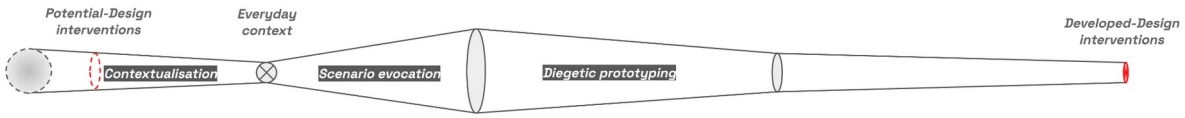


Figure 5.2. The Workshop 2 framework, alternating divergent and convergent sessions so that participants moved from the future scenarios built in Workshop 1 to direct critique of the MaaS interfaces

Crucially, workshop 2 also incorporated a back-casting approach to extend the temporal and reflective aspects of the participatory investigation process. This was implemented through a series of follow-up semi-structured interviews (O'Reilly, 2011), conducted one-on-one with selected participants from the previous workshops. The post-workshop interviews encouraged participants to reflect on the whole procedure of the participatory investigation sessions and engage directly with the interactive digital prototype developed from previous workshop insights. Participants, recruited from the workshop 1, were asked to provide in-depth evaluative feedback on interface design, navigation logic, contextual relevance, and motivational features, including reward systems or social networking functionalities, which might contribute to a potential sustainable commuting behavioural change in the future. Significantly, these interview sessions facilitated a conclusive design decision-making process for this research. Participants were invited to articulate their preferences and identify which design features should be prioritised in the final iteration of the MaaS platform so they could engage in their future sustainable mobility practices around the Clayton precinct.

Through integrating collaborative workshop activities with individual reflective interviews, the design process captured collective, dynamic, and personalised perspectives essential to comprehensive design research (Sanders & Stappers, 2008). The implementation of diegetic prototyping, a technique that embeds design concepts within narrative contexts (Harwood et al., 2020; Kirby, 2010a; Stepanovic & Ferraro, 2024), enabled participants to evaluate proposed design interventions through the perspectives of their lived experiences on commuting from suburban university communities, and imagined sustainable travel futures.

5.2.2. Workshop procedure

5.2.2.1. Pre-workshop

During the planning phase for Workshop 2, several physical and digital prototypes were developed to represent imagined future scenarios for a sustainable MaaS platform. These prototypes can be considered a means to transition from abstract or initial design ideas to tangible,

fathomable forms of representation that facilitate further development and testing (Ferraro & Testa, 2023). The prototypes may manifest in either physical or digital form and, while not fully functional, are realistic enough to represent the final experience or concept. As Hare et al. (2009) propose, effective prototypes occupy a spectrum of functionality that balances both *active physicality*, referring to how the prototype and its software respond to user interaction, and *passive physicality*, which concerns the prototype's form, materiality, and aesthetic qualities when not in active use. This dual consideration underscores the importance of integrating interactive behaviour and tangible presence in prototype development. Beaudouin-Lafon and Mackay (2007) emphasise that prototypes serve as "explicit representations that help designers, engineers and users' reason about the system being built", regardless of their level of completeness.

Mid-fidelity prototypes were selected for participants during the Workshop 2 to evaluate recognisable interface structures, information hierarchies, interaction sequences, and proposed service features while these designed elements remained open to substantial revision. Low-fidelity sketches would not have provided sufficient visual and interaction detail for participants to assess navigation, usefulness, or cognitive load consistently. Conversely, a high-fidelity or full functional prototype could have implied that the design was already resolved, directing attention towards visual polish and technical performance instead of encouraging participants to rearrange, question, and revise its underlying concepts. The mid-fidelity prototype therefore balanced realism with openness, supporting contextual storytelling, comparative evaluation, and collaborative design modification before investment in a more refined interactive prototype.

In the design practice phase of this research, the design direction for these user interfaces of the MaaS platform was directly informed by insights derived from the previous participatory investigation with the international student drivers (see Chapter 4). Specifically, barriers and design opportunities were synthesised into the design criteria, including poor last-mile connectivity, lack of real-time local transport information, the psychological stress of navigation in unfamiliar environments, and preferences for peer route recommendations. These criteria guided the iterative development of physical prototype cards (see Figure 5.4), modular UI mock-ups, and scenario journey maps that address existing user frustrations and aspirational functions for future mobility service systems.



Figure 5.3. Participants interacted with the physical prototypes during the Workshop 2

The implementation of interactive prototypes during the design practice procedure of this research facilitated the collaborative development of near-future-oriented MaaS service blueprints. The interactive physical and digital prototype testing with end-users, grounded in their lived experiences, validated the possibilities of the design strategies that could support sustainable travel decision-making at the Clayton precinct.

5.2.2.2. Workshop sessions

i) Contextualised evaluation and future storytelling

In the first part of the workshop, participants were provided with a full set of printed interface design cards (see Figure 5.4), each illustrating distinct screens and designed features of the proposed MaaS platform. Furthermore, the participants were also provided primary flowcharts of the prototypes (see Figure 5.5), which provide an interaction guide of the designed platform for participants. Participants were invited to construct a future narrative facilitated by rearranging and organising the physical prototype cards, specifically, a commuting scenario based on their lived experiences or future imagination. This card-based interaction activity was designed to facilitate a scenario-based storytelling exercise, enabling participants to construct a personalised narrative of how they might engage with the platform in their future everyday commuting.

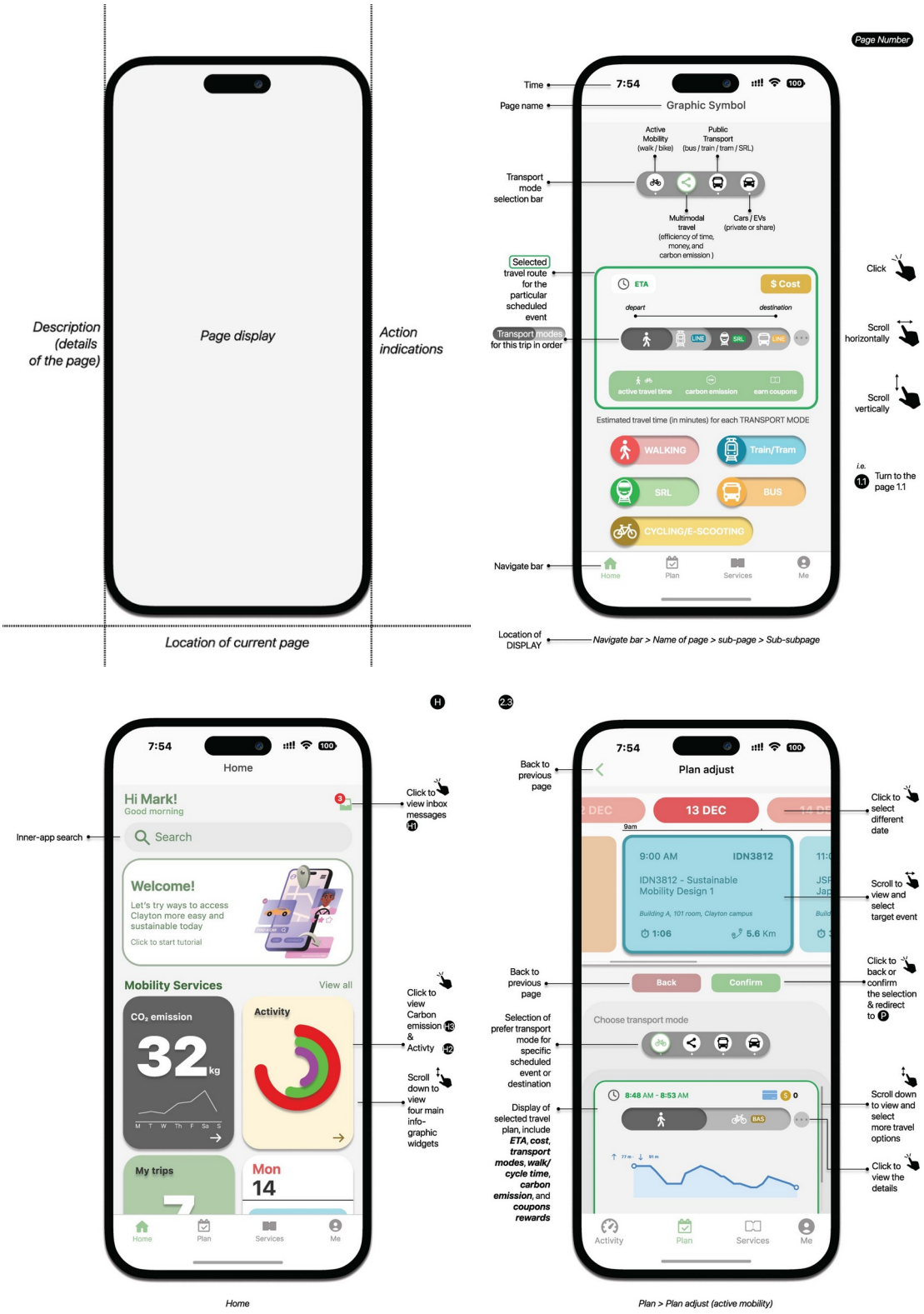
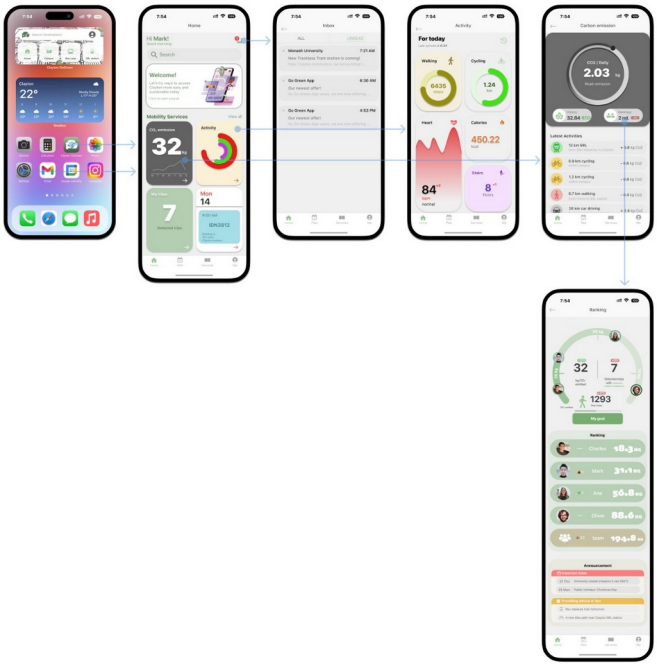


Figure 5.4. The printed interface design card set given to participants, each card presenting one screen or feature of the proposed MaaS platform as a tangible object for ranking and critique

Home



Evaluation Criteria

Usability
- **Ease of Navigation**: How easy is it to navigate through the app? Are the menus and options intuitive?
- **User Flow**: Does the design support a smooth user journey from start to finish? Are the steps logical and straightforward?
- **Clarity of Instructions**: Are the instructions and prompts clear and easy to understand?

Visual Aesthetics
- **Design Consistency**: Is the visual design consistent across different screens? Do the colours, fonts, and icons align with the overall theme?
- **Visual Appeal**: How visually attractive is the design? Does it create a positive first impression?
- **Clarity of Layout**: Is the layout well-organised and easy on the eyes? Are the elements placed logically?

Functionality
- **Feature Accessibility**: Are key features and functions easily accessible? Can users find what they need quickly?
- **Interactive Elements**: Do buttons, links, and other interactive elements respond appropriately? Is the interaction smooth?
- **Performance Perception**: Does the design convey a sense of efficiency and speed in app operations?

Content and Information
- **Information Clarity**: Is the information presented in a clear and concise manner? Is it easy to understand the content?
- **Relevance of Content**: Is the content relevant to the user's needs? Does it provide the necessary information at the right time?
- **Content Hierarchy**: Is the most important information prioritised and easy to find?

Accessibility
- **Inclusivity**: Does the design accommodate diverse user needs, including those with disabilities? Are there accessible features like text size adjustment, colour contrast, etc.?
- **Language Options**: Is the app available in multiple languages? Is the language selection process straightforward?
- **Compatibility**: Is the design responsive across different devices and screen sizes? Does it work well on both mobile phones and tablets?

User Engagement
- **Personalisation**: Does the design allow for personalised experiences? Can users customise settings according to their preferences?
- **Engagement Elements**: Are there features that encourage users to interact with the app regularly? For example, notifications, reminders, or gamification elements.
- **Feedback Mechanism**: Does the design provide a way for users to give feedback easily? Are there clear channels for support and help?

Innovativeness
- **Creative Design Solutions**: Does the design offer innovative solutions to common problems? Does it introduce new, useful features?
- **Forward-Thinking Design**: Is the design future-proof and adaptable to emerging trends in mobility services?
- **Unique Selling Points**: Does the interface have any distinctive features that set it apart from competitors?

Trust & Security
- **Data Security**: Does the design communicate a sense of security and trustworthiness? Are security features (e.g., login, payment) clearly indicated?
- **Transparency**: Are terms of service, privacy policies, and data usage clearly communicated?
- **Brand Trust**: Does the design reflect the project's values and build user trust?

Plan

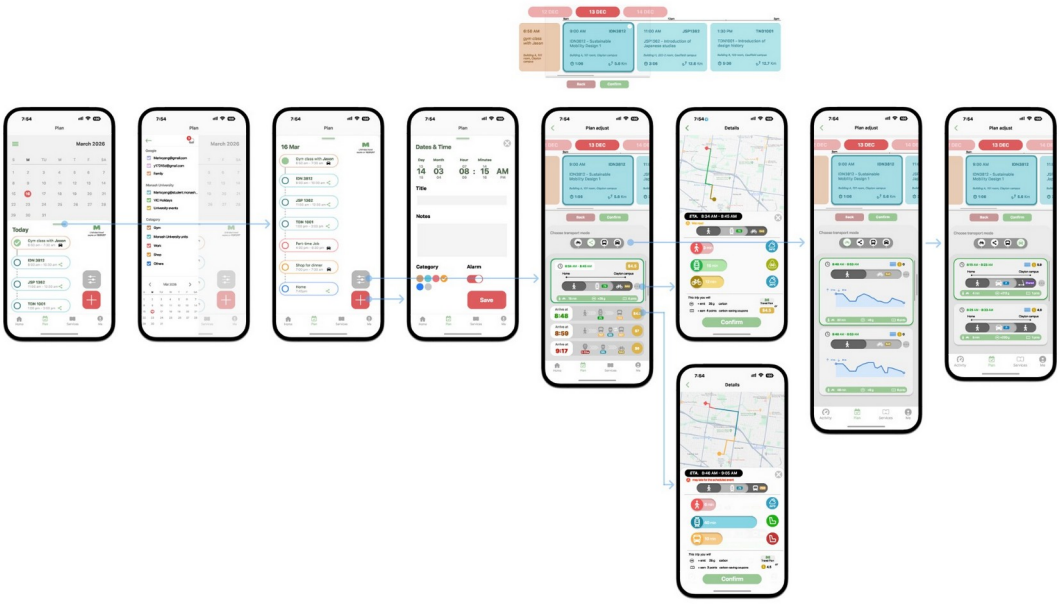




Figure 5.5. Flowcharts of the physical prototype, supplied alongside the card set to show participants how the designed screens connect into a complete interaction sequence

The subsequent visualised storyboards and open discussions demonstrated functional expectations and emotional connections with the future MaaS

platform-based mobility service, including user trust in the platform's services, convenience or ease of use, and alignment of social identities (refer to Figure 5.6 and Figure 5.7). For instance, some participants positioned reward features at the beginning of their future journey to indicate motivation, while others positioned these cards as cumulative outcomes to enhance a sense of progress.

The adaptability of the physical prototyping-based narrative structure facilitated critical user interaction feedback, and evaluation of the strategic design elements, with the primary objective of reducing the frequency of driving private cars, particularly in the context of digital and early-stage design interventions.



Figure 5.6. Participants constructed future mobility scenarios involving the adoption of a digital mobility service platform, facilitated through the process of sorting and organising the physical prototype cards



Figure 5.7. Participants articulated their envisioned future commuting experiences through the reconfiguration of the designed physical prototype of the MaaS platform during Workshop 2

This activity corresponds with methodologies in experience prototyping (Buchenau & Suri, 2000; Keane et al., 2012; Nissinen, 2015; Yasar, 2007) and narrative design fiction (Coulton et al., 2017; Kirby, 2010b), where provided prompts, such as a set of physical prototype cards in this study, functioned as conversational and reflective probes. The tactile interaction with tangible prototypes enabled participants to articulate latent needs, values, and intentions that may not have emerged through direct interface critique alone (Dhaundiyal & Sharma, 2022; Karanian & Kress, 2010). Numerous participants envisioned future commuting scenarios in which the MaaS platform actively influenced their decision-making and motivation for sustainable mode choices or acted as a daily planning assistant

intricately linked to their academic and personal calendars.

This activity generated rich and in-depth qualitative data on user expectations, evaluations of interface design, and strategic insights into behavioural transitions towards more sustainable travel practices and decision-making processes, grounded in the potential integration of the proposed MaaS platform into participants' envisioned future commuting scenarios. Furthermore, this phase of Workshop 2 provided methodological insights into the integration of visual storytelling and physical prototyping to support contextual and reflective evaluation within participatory design processes, particularly when engaging transitional or newly arrived user groups such as international students.

ii) Co-ranking on the user interface design and flowcharts

The second phase of Workshop 2 employed a co-ranking activity to evaluate participants' perceptions of the proposed MaaS platform interfaces. This method was designed to provide collaborative analysis and prioritise interface components, enabling participants to express positive evaluations and constructive feedback in a visual and accessible format. The full set of the interface physical prototypes and flowchart sequences was displayed on the wall in operational order (see Figure 5.8), illustrating the user experience from homepage access to trip planning, service engagement, reward tracking, and personal settings.

During the activity, participants were given red, green, and blue dot stickers to annotate their responses directly onto the printed interface screens (see Figure 5.9). Red dots signified positive impressions, representing the designed interfaces that participants found clear, useful, or visually appealing. Conversely, green and blue dots indicated interface pages that participants thought required more refinement, due to perplexing layout, inadequate context hierarchy, or lack of perceived relevance. This tactile interactive rating method fostered a shared space of design dialogue (Heiss & Kokshagina, 2021; Sadek et al., 2023), facilitating personal expression while promoting collective reflection on shared or group-level usability challenges and value congruence (Knowles et al., 2021; Van Mechelen et al., 2017).

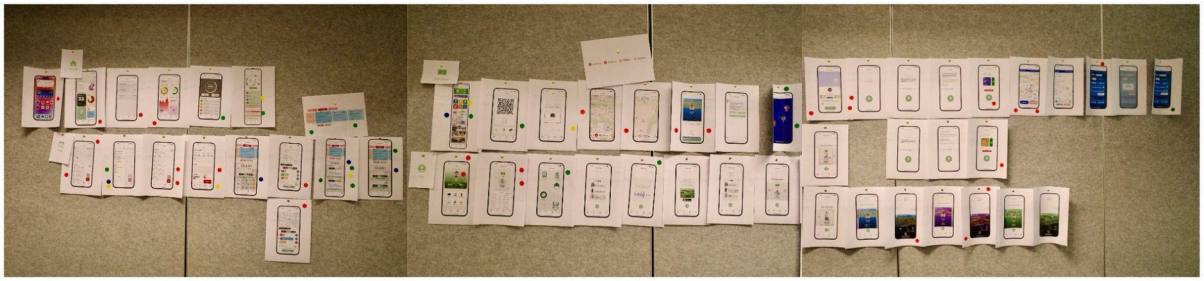


Figure 5.8. The flow map of the proposed digital platform on the wall



Figure 5.9. Participants co-ranked the interface pages they liked by placing the red-dot stickers, and they thought they could be improved further by placing the green or blue stickers on the relevant pages

iii) Re-Radar mapping

In the final phase of Workshop 2, participants engaged in a re-radar mapping activity as a comparative tool to reflect on how their commuting experiences might change through the adoption of the proposed MaaS platform. Building on the Radar Mapping activity from Workshop 1 (refer to Chapter 4 & Figure 5.10), participants charted their current commuting experiences across five phases of the journey, including pre-trip, first mile, on-the-way, drop-off/connection ports, and last mile. At the conclusion of Workshop 2, participants were invited to evaluate their envisioned MaaS-facilitated commuting experience using the same radar mapping format. This second iteration of the activity (see Figure 5.11) enabled participants to articulate their anticipated experiential shift across the same five phases of the routine journey.

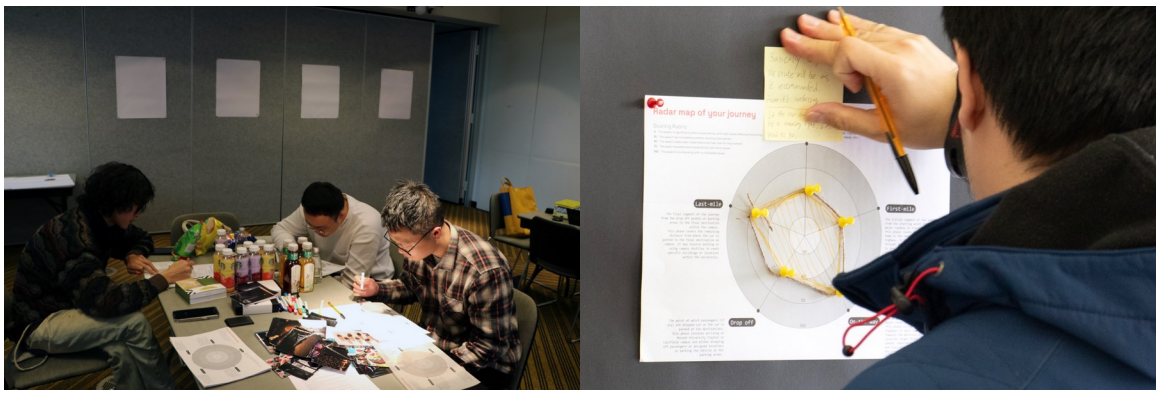


Figure 5.10. Participants evaluated their everyday commuting experience on the first sheet of the Radar Map during Workshop 1



Figure 5.11. Participants were invited to redraw their future MaaS-based commuting experiences at the end of Workshop 2

5.2.3. Findings

"User experience (UX) design is the process of creating products and services that are easy to use and enjoyable for people. UX designers focus on the entire user journey, from the moment they first encounter a product to the moment they finish using it."

(Philippe H, 2023)

5.2.3.1. Overview

The outcomes of the two radar mapping sessions indicate that the proposed MaaS platform may enhance sustainable commuting and improve the overall user experience of daily commuting. The radar mapping comparison was conducted at two key timepoints: at the commencement of workshop 1 and the conclusion of workshop 2. In both sessions, participants were asked to evaluate their current and future MaaS-based commuting experience across five main phases, including pre-trip, first mile, on-the-way, drop-off/connection port, and last mile. The comparison findings indicate significant improvements in user-perceived satisfaction and efficiency across these phases of commuting, demonstrating the MaaS platform's ability to mitigate current challenges or problems in the commuting experience through user-centred design interventions.

However, the improvements were predicated on participants' envisioned future experiences, instead of direct engagements with a fully functional digital platform in their real-world, daily commuting contexts. Therefore, these evaluations represent expected advantages instead of experimentally substantiated results. Nevertheless, the results provide essential insight into how a user-centred MaaS platform might facilitate more sustainable travel habits and decision-making, especially tailored to the demands and routines of a varied university context.

The following subsections further explain how the proposed MaaS platform enhances the overall commuting experience for international student participants. These findings, summarised from the second participatory workshop, were crucial to the iterative design practices and refinement of the MaaS platform. The results can be categorised into two primary areas, including (i) ***contextualised storytelling for articulation of user values and future mobility narratives*** and (ii) ***evaluation***

and prioritisation of user interface components. These findings enabled understanding of how international student users envision and interact with a future university-based MaaS platform. Several verbatim quotations from the workshop participants are included throughout the following subsections to provide contextual evidence and enhance the situated nature of the design practice outcomes.

5.2.3.2. Contextualised storytelling for the presentation of user values and future mobility service narratives

The contextualised storytelling session during Workshop 2 provided a critical opportunity for participants to articulate their everyday mobility practices, express personal aspirations, and reflect on the functional and potentially emotional values of the proposed MaaS platform. Through interactive engagements with physical prototypes and organised narrative-building activities, some crucial design insights into how international students envision future sustainable mobility services based on their lived experiences were revealed. These findings include (a) sustainable aspirations mediated by pragmatic constraints, (b) temporal and situational flexibility as essential to adoption, (c) the value of integration with academic and social identities, and (d) the tangibility of behaviour change through embedded reward systems.

a. Sustainable travel willingness mediated by pragmatic constraints

A central finding from contextualised storytelling in Workshop 2 was the significant congruence between participants' sustainability beliefs and their mobility desires or demands. Many international student participants expressed a readiness and willingness to decrease dependence on private cars and adopt more sustainable commuting practices, including walking, cycling, and using local public transportation services. However, the structural, physical, and experiential limitations encountered in the Clayton precinct and surrounding suburban areas often mitigated or compromised this intent.

For instance, participant #2 noted that real-time carbon emission monitoring and leaderboard functionalities (see Figure 5.3) of the developed MaaS physical prototype were particularly impactful, fostering a "sense of accomplishment" that motivated the exploration of alternatives to driving. This finding aligns with the existing literature on eco-feedback technologies, which indicates that visualising one's environmental influence might enhance pro-environmental behaviour by increasing self-efficacy and awareness (Froehlich, 2011; Pierce et al., 2008; Steg & Vlek, 2009). Recent academic research suggests that eco-feedback systems that enhance emotional connections with users are significantly effective in promoting sustainable behaviours (Berney et al., 2024). Furthermore, the mechanism through which visualisation enhances and encourages behaviour change may be mediated by increased self-efficacy and environmental awareness (Qin et al., 2024). In addition, participants who develop a sense of agency through environmental action

frequently report greater confidence in their ability to contribute meaningfully to sustainability efforts (Acquadro Maran et al., 2023).

Participant #2 further stated that, if the proposed MaaS platform is integrated into future everyday commutes, functions such as multimodal planning with real-time emissions data visualisation may decrease car usage by a total of 30 to 40%. However, the expected behavioural change ability was constrained by a lack of trust in the local public transport systems, particularly due to the unpredictability of bus arrival times and inadequate schedules. The tension between behavioural change intention and infrastructure feasibility reflects what (Anable, 2005) referred to as the "value-action gap" in sustainable mobility, whereby the personal values do not necessarily result in behavioural change owing to contextual impediments (refer to Chapter 4).

"It's somewhat helpful because it shows my emissions, encouraging me to take public transport or walk instead of driving. (*researcher: Does it motivate you to change your behaviour?*) Yes, it makes me feel a (positive) sense of accomplishment, especially when I walk or use public transport." (#C2_CT_00:04:15-49)



Figure 5.12. User interfaces of real-time transport-related carbon emission and leaderboard

Similarly, participant #10 conveyed ambivalence, indicating a preferred behavioural change from relying on the high cost of driving or public transport services to more active options, such as walking or cycling, to save daily costs and enhance personal health benefits. This intentional behavioural change in her transportation mode choice, influenced by the financial transparency and comparison provided by the proposed MaaS platform, highlights the significance of economic incentives and costs of each transport option (see Figure 5.13). Some research indicates that cost-effective and personalised fare structures may significantly affect travel mode choices, especially among students and low-income demographics (Beirão & Sarsfield Cabral, 2007; Rosenblatt & DeLuca, 2012; Shafi et al., 2019).

"What if it offered flexible plans, like cheaper bundles for just buses or other modes? (because) Myki is expensive, especially for short trips where one stop costs the same as a longer journey across zones." (#C10_CT_0:03:18-38)



Figure 5.13. Initial design concepts on multimodal selection based on university calendar with the visualisation of time, costs, active moving and reward points for each transport option

Critically, participants did not exclude sustainable transportation alternatives on ideological bases. Their narratives indicated an in-depth concern with the usability and dependability of available alternatives to private cars around the suburban university precinct. The limited availability of real-time public transport data, unpredictability in route planning, and insufficient infrastructure for active transport modes, such as cycling or walking, were mentioned by the student participants as the contextualised barriers when they narrated the potential implementation of the proposed MaaS platform into their everyday life (see Figure 5.14).

More specifically, the concept of "forced car ownership" (FCO) was proposed by Jones (1985) and Banister (1994), who use it to refer to the UK semi-rural areas where inadequate public transport infrastructure necessitated private car ownership even among low-income families. The demographic group from semi-rural areas was compelled to own and maintain private vehicles to access employment, education, healthcare, and

other essential services, despite facing economic constraints. Infrastructure limitations, not personal preferences, shaped this involuntary transport-related decision (ibid.). The concept of FCO is central to understanding transportation disadvantages in a suburban context where travelling alternatives to private cars are underdeveloped or inaccessible (Currie et al., 2009; C. Liu & Bardaka, 2021; Mattioli, 2017).

The foundational idea of FCO was reinvigorated by Currie & Senbergs (2007) in their exploration of the issue of car dependence in Melbourne, Australia. They extended the term to urban fringe and suburban settings and illustrated how spatial planning and transportation infrastructure could reflect rural transport deficient patterns in metropolitan regions. Their study demonstrated that in low-density suburban areas, which especially lack effective public transportation options, car ownership emerged as a necessity instead of a lifestyle choice (ibid.). (Currie et al., 2009) subsequently highlighted that these circumstances formed a cycle of "transport poverty" (Gleeson & Randolph, 2002), whereby families faced an inequitable burden from car ownership costs without equivalent enhancements in accessibility or mobility outcomes.

In the context of international students living in suburban areas of Melbourne, Australia, the concept of FCO provides a significant analytical perspective. Most of the research participants reside in the suburban areas due to affordability concerns or considerations of travelling time if they mainly attended the classes at the Clayton campus. At the same time, they encounter infrastructural restrictions or have limited information on accessing essential mobility services, including local public transport, university-operated transport services, or active modes. Although they prefer sustainable or cost-effective modes of transport, the lack of connection of multimodal options or real-time informational guidance forced some participants to own a car. For instance, participant #4 relied on driving when living in a suburban area distant from the Clayton campus, primarily due to poor connectivity within the local public transport system. However, after relocating to the student apartments situated at the centre of the Clayton campus, he sold his car and adopted a range of multimodal travel options, including walking, cycling, public buses, and on-campus shuttle services.



Figure 5.14. A participant described how the proposed MaaS platform could engage future sustainable commuting practices

To sum up, an essential finding from Workshop 2 highlights that a future MaaS platform should facilitate multimodal access while simultaneously addressing infrastructure and mobility service gaps to better meet the dynamic demands of users in suburban areas. The efficacy of the future MaaS platform is dependent on its ability to bridge the gap between personal behavioural intentions, such as choosing more sustainable travel options, and infrastructural realities in suburban regions, including limited transit service coverage and a lack of first- and last-mile connectivity. Therefore, the future MaaS platform design features may need to encompass (refer to Table 5.1):

- **Real time multimodal data visualisation** presents available transport options, including public transport, ride sharing, micromobility, and active mobility, through a user interface that is updated continuously.

- **Context-sensitive and personalised route suggestions or route planning** that adapts to the user's profile, multiple travelling preferences, and realities of infrastructural constraints.

- **Adaptive feedback mechanisms** that respond to real user experiences and constraints, continued learning from usage data, and providing responsive updates or auto-adjustments to mobility services and suggestions.

Table 5.1. Summary of design directions from Workshop 2

Design direction	Purpose	Design implementations	Benefits
Real-time multimodal visualisation	Improve informational transparency and decision-making in dynamic settings	Live data feeds, GPS-based information sharing	Reduce uncertainty, support multimodal travelling

Design direction	Purpose	Design implementations	Benefits
Context-sensitive routing	Align routing with multiple users travelling demands and social/contextualised realities	Integration of academic calendar, navigation systems, interactive mapping platform	Enhances usability,
Adaptive feedback mechanisms	Learn from user travel behaviour to evolve and enhance service experience	Gamification components, reward systems,	Enhance relevance, foster user trust, and encourage sustained usage

b. Temporal and situational flexibility is essential to adoption

A significant observation from the contextualised storytelling in workshop 2 was the crucial role of temporal and situational flexibility in affecting international students' willingness to adopt a digital mobility service platform in the future. Participants described their commuting behaviours as dynamic, frequently dependent on changing academic timetables, part-time employment demands, personal energy levels, weather conditions, and infrastructure dependability. These factors resulted in nonlinear mobility patterns that require mobility service solutions to adapt to high levels of personalisation and spontaneity. Consequently, the capacity of a future proposed MaaS platform to support adaptive, context-aware, and multimodal travel planning emerged as essential for sustainable mobility behavioural change.

Participant 4 described a preference for planning trips "randomly" according to wake up time, emotional state, and daily obligations (see Figure 5.15). Travel choices were shaped by personal conditions, including mood and energy levels, and external conditions, including weather or disruptions to local public transport. The participant emphasised the value of live feedback and the capacity to adjust a journey while underway, which could improve the flexibility and reliability of a future MaaS platform. Mobility scholarship similarly suggests that travel may shift from fixed and habitual patterns towards more dynamic and temporally contingent practices, particularly among younger populations such as international students (Cresswell, 2010; Temenos et al., 2017). Research also links digital technologies and changing lifestyles with the emergence of "liquid mobility", characterised by live decision making, multimodal journey planning, and adaptive routing (Bissell, 2018; Kaufmann et al., 2004; Urry & Grieco, 2012). Studies of international students further suggest that temporary residence, financial pressures, and willingness to adopt digitally mediated transport may contribute to mobility flexibility (Beech, 2019; J. Lee & Waters, 2024; Yin, 2023).



Figure 5.15. Participant #4 described his future commuting experience based on the proposed MaaS platform

To conclude, digital mobility service tools have emerged as critical enablers for the group of international students, providing spatial and temporal flexibility that aligns with their academic and social travel demands (Sochor et al., 2018). Compared to the local residents, international students have a stronger willingness to use shared and digitally coordinated transport systems due to their portability, cost-effectiveness, and reduced need for ownership responsibilities (Dowling & Kent, 2015; Matyas & Kamargianni, 2019).

c. Value of integration with academic and social identities

Another notable and conceptually substantial finding from the contextualised storytelling sessions in Workshop 2 was the perceived value of matching the proposed MaaS platform's functionalities with international students' institutional, academic, and social identities (Ashforth & Mael, 1989). Several participants expressed that the symbolic affiliation with Monash University, combined with personalised features reflecting their academic patterns and student routines, significantly enhanced their sense of trust, relevance, and willingness to adopt and continue to use the platform. This indicates that, in addition to the practical value, the emotional, and institutional aspects of identification are crucial in user engagement with the mobility service platform.

For instance, participant #7 emphasised that the Monash University branding, through visual language, colour palette, and associated on-campus services such as student IDs (M-Pass) or shuttle bus services, and integrating university calendars, fostered a feeling of "belonging". She described how the institutional identities shown in the proposed MaaS platform can validate or legitimise the mobility services and foster a stronger emotional attachment. This finding is aligned with prior research

indicating that organisational identification, which represents the psychological connection between people and their related institutions, can significantly affect technological adoption and continued engagement (Cao & Yang, 2022; Dutton et al., 1994; Polites & Karahanna, 2012).

"The app feels distinctly Monash-focused. For instance, integrating your student pass into your wallet or Apple Pay feels personal and useful…like reminders about upcoming bus schedules or new routes. It's also nice if it integrates with Monash systems, like linking to school emails or course schedules." (C#7_CT_00:01:55-00:02:44)

Bushell et al. (2022) recently highlighted the importance of social and institutional factors in user acceptance, particularly among students, who may be highly sensitive to institutional affiliation and peer influence. Contemporary studies have also identified social influence and institutional facilitating conditions as critical factors in MaaS adoption. Users' affiliation with organisations that promote or provide MaaS services substantially affects adoption (Arias-Molinares & García-Palomares, 2020b; Pangbourne et al., 2020b).

Integrating institutional systems, including MyMonash, academic calendars, course schedules, and parking services, may align mobility support with the temporal and spatial organisation of student life. Participants proposed that mobility recommendations incorporate lecture schedules, campus events, and changing class locations. These proposals suggest that transport services embedded in university communities should respond to the academic routines that shape students' everyday activities (Hensher, 2017; Ho et al., 2018; Jittrapirom, Caiati, Feneri, Ebrahimigharehbaghi, González, et al., 2017; Maas, 2022). Such alignment may improve the usability of the proposed MaaS platform and foster perceptions of institutional care and responsiveness among students encouraged to adopt sustainable travel practices.

Critically, the platform's capacity to facilitate identity-based interactions was reflected in some participants' nuanced perspectives on social features. Although most of the participants expressed the positive influence of embedding institutional integration within the proposed MaaS platform, some expressed reservations about the peer-to-peer functionalities (see Figure 5.16). These interfaces enable users to connect with others in nearby living locations and access their commuting routes to the Clayton campus, facilitating opportunities for shared travel and community-building among student users. However, participants #7 and #9 expressed their concerns about privacy and unsolicited interactions, particularly from the perspective of female users (see Figure 5.17). Consequently, some participants proposed that integrating Monash-only authentication systems as a protective boundary can foster trusted interactions of the platform.

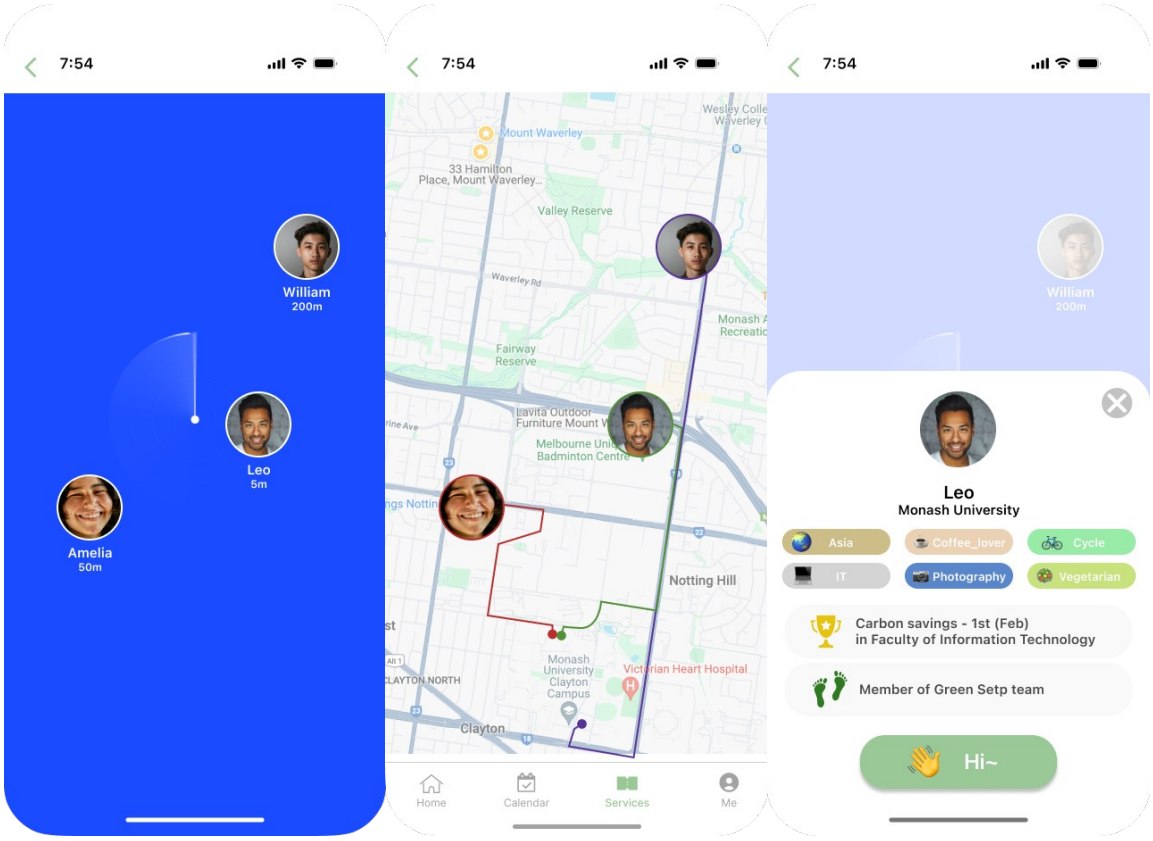


Figure 5.16. An early design concept of the interactive social mapping page of the MaaS platform features functionalities such as user search (left), pairing, and social networking (right)



Figure 5.17. Participant #7 expressed her concerns on privacy and safety issues of social connection functions of the proposed MaaS platform

This finding highlights that designing for identity congruence, where the service reflects and strengthens the users' self-concept and institutional affiliation, can significantly enhance perceived value, adoption, and continued use (Gerstenberg et al., 2023; M et al., 2023; Warren & Sukumar, 2013; Yu et al., 2020). As

Leung (2011) argues, identity-affirming technologies are more likely to be accepted, especially among young adults navigating changes in educational and cultural environments. For international university students in suburban areas, where physical and cultural dislocation may be commonly encountered, the digital platforms that enhance their academic and social connection may serve as stabilising anchors (see Figure 5.9). The *Home page* (left) offers users a visualised welcoming environment, featuring a friendly greeting and transport-related notifications displayed prominently at the top of the screen area. The *Daily Carbon Emissions page* (middle) enables users to easily track their transport-related emissions, allowing for personal monitoring and comparison with their own historical data as well as with peers in carbon-saving cohorts. The *Carbon-Savings Community page* (right) fosters a sense of engagement and motivation by enabling users to compare their performance and compete with friends within the university community.

In summary, the collaborative design process in Workshop 2 indicates that the proposed MaaS platform's perceived validity and continued appeal depend on more than functional or multimodal planning capabilities. They are also shaped by integration with students' academic and social identities. The design responds by using Monash University's institutional identity, connecting academic calendars, and providing student-specific features such as MyPass and campus mobility services. These interventions may enhance

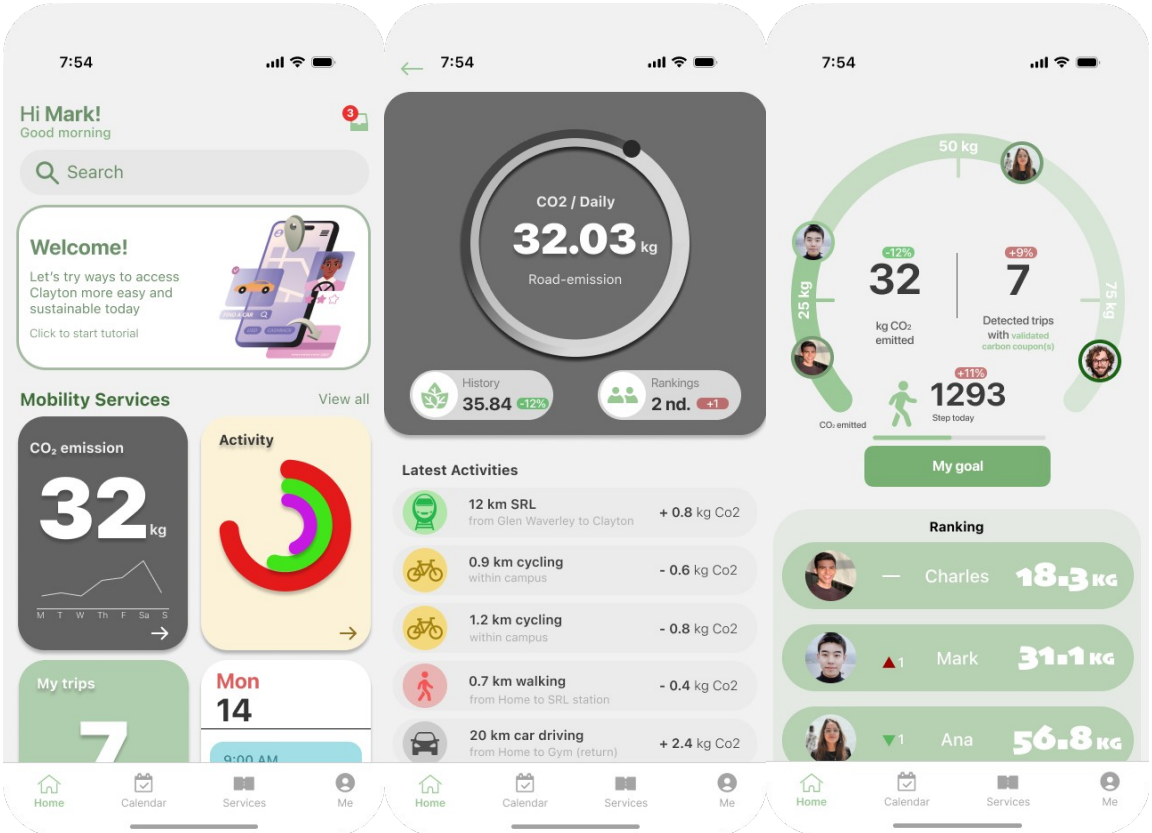


Figure 5.18. Designed user interfaces of the MaaS platform which highlight the integration of student users' academic and social identities

usability and strengthen students' identification with the platform. By connecting the service with the institution and supporting a sense of belonging, the platform may operate as both a transport tool and an identity-affirming service that addresses everyday requirements while supporting sustainable travel behaviour.

d. Behaviour changes through reward systems

The integration of reward mechanisms into the design strategies of the MaaS platform was identified as a crucial driver of both initial adoption and long-term behavioural engagement with sustainable mobility practices (refer to Chapter 2). This finding can also be supported by the participants' narratives from the contextualised story-telling sessions in Workshop 2. In many narratives of future MaaS platform-based commuting, participants expressed that tangible or symbolic incentives, such as cashback, loyalty reward points, environmental impact visualisations, or comparison ranking within the communities or cities, could substantially encourage decision-making in everyday commuting practice, especially the transition from habitual car usage. Based on these insights, a reward store was developed and embedded in the MaaS platform where users can review available offers and activate rewards upon completing specific sustainable travel activities (see Figure 5.10).

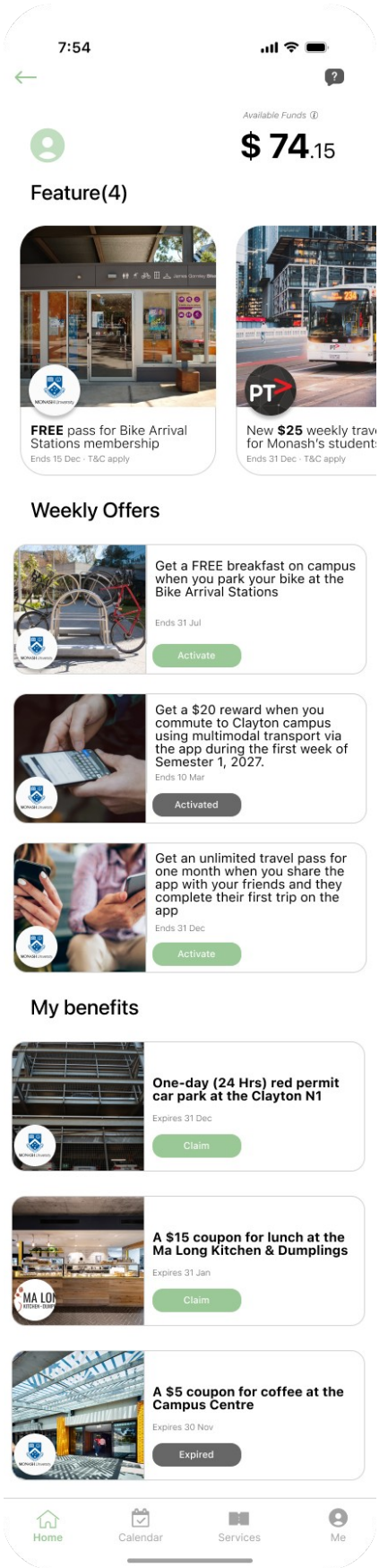


Figure 5.19. Homepage of the reward store, translating participants' accounts of point-based incentives into a visible exchange between sustainable trips and tangible rewards

For instance, participants #2, #4, and #10 expressed that point-based incentive systems embedded within the proposed MaaS platform could encourage more frequent use of public transport or active-modes-based multimodal travelling, as well as contain gamification design elements which make sustainable travel practice more engaging and socially impactful. Participant #4 further proposed that these carbon-saving gains from engaging multimodal commuting could be redeemed for tangible benefits, such as discounted public transport fares, or ride-share subsidies during inclement weather or other personal reasons. This would establish an interactive feedback loop between sustainable commuting behaviours and tailored, context-aware incentives. This reflects existing empirical evidence in behavioural science, indicating that incentive-based interventions might improve the adoption of pro-environmental behaviours when they are timely, relevant, and socially visible (Abrahamse et al., 2005; Arian et al., 2018; Hamari et al., 2014).

However, the attractiveness of these reward schemes extended beyond just cash or financial incentives. Some participants noted that environmental feedback, such as comparisons of carbon emissions between driving and multimodal travelling modes, could elicit a sense of moral gratification and symbolic accomplishment. Participant #2 described a "sense of achievement" upon seeing reduced emissions and being evaluated in comparison to others. Participant #9 further elaborated on this strategic design concept, suggesting that it could incorporate travel budget-saving or personal health goal-setting features (see following direct quotation). Research on eco-feedback technologies indicates that supplying users with information regarding their environmental performance can foster enduring behavioural changes by enhancing personal agency and reinforcing identity-consistent actions.

> "Another feature could involve setting goals, like calorie burns or carbon emissions. For instance, I could aim to burn 100 calories, and the app could suggest walking between stops instead of driving or taking the bus…and a budget feature would also be helpful. For example, if I need to go to Malvern, I could specify a $10 or $20 budget, and the app could recommend routes like public transport, walking, or even Uber within that budget." (C#9_CT_00:02:32)

Therefore, the incorporation of tailored reward systems into the proposed MaaS platform can serve as an action motivator as well as a significant strategic design feature that can drive behavioural transitions, enhance engagement, and align users' actions with collective sustainability objectives in a suburban university context.

5.2.3.3. Evaluation and prioritisation of user interface-designed components

The following subsection outlines the evaluative phase of Workshop 2, in which participants engaged in a structured co-ranking activity to provide specific feedback on the proposed MaaS platform

interface components. Compared to the previous session of Workshop 2, which explored users' needs and identified potential strategic design drivers to support behavioural transition and sustained engagement, this activity concentrated specifically on the interface design features of the MaaS platform's physical prototype.

During the session, participants were invited to evaluate, rank, and annotate the design elements of a flowchart-style interface wall, including homepage layout, academic calendar-based trip planning, on-campus mobility services, and gamified reward features, based on perceived usefulness, function or interface design clarity, and relevance to their routine mobility. This activity produced nuanced design insights into the further refinement of the platform's information architecture, interaction logic, and visual hierarchy. The findings are summarised in three primary themes, including customisability, simplicity in interface structure, and low cognitive load.

- **Customisability**

Participants' feedback from Workshop 2 highlights a significant requirement for customisability in the user interface design of the proposed MaaS platform, which could enhance overall user experience through shaping user satisfaction and long-term engagement. Compared to adopting a rigid, one-size-fits-all interface structure, participants #8 and #9 both expressed a clear preference for an adaptable interface that could respond to their dynamic mobility routine, personal preferences, and contexts of use. Their suggestion indicated that the capacity to adjust the layout, feature visibility, and information hierarchy might reduce unnecessary cognitive load and enhance perceived usefulness.

This design insight emphasises the necessity for modular and reconfigurable interface components, enabling users to customise their dashboards by prioritising essential functions, including trip planning, emission tracking, or payment options based on personal preferences. For instance, participant #9 suggested a configuration procedure to allow users to pre-select modules shown on the homepage. Furthermore, participant #8 emphasised that frequently used tools, such as Monash-specific wayfinding and real-time bus timetables, should be more visible and easily accessible. The HCI (Human Computer Interaction) literature suggests customisability at the interface layer as a vital aspect of user-centred design, especially in multifunctional mobile applications (Gulati et al., 2024; C. Guo & Li, 2024).

Although several Workshop 2 participants supported customisable interface components, others raised concerns about the cognitive and temporal demands of these features. Participant 2 was particularly concerned about the time required to configure the platform before meaningful use. The participant preferred a simple design centred on essential functions, including personalised trip planning, payment integration, and campus navigation, without extensive personalisation (refer to the following quotation). Excessive customisation may

overload the user experience, particularly for people who are unfamiliar with local transport systems or use the application infrequently. This concern reflects a tension between adaptability and immediacy because greater user control may also contribute to choice fatigue or impede onboarding (Bassett, 2023; Carrera-Rivera et al., 2024; Gullà et al., 2015; Norman, 2013).

"I think personalisation has its pros and cons. Some people might find it better to have things personalised. But for me, if I had to personalise something, I feel like I'd have to spend a lot of time just learning how to use it. I'd probably just stick to the basic functions — like checking how to navigate or how to select a trip. I honestly don't care much about all the personalisation features." (C#2_CR_00:00:22)

To address this concern, the interface design of the MaaS platform may benefit from adopting a progressive disclosure strategy (Tidwell, 2005), whereby essential features or functions can be directly accessible upon initial use, while more advanced customisation options are presented only when relevant or contextually appropriate. This approach recognises that while flexibility is advantageous, not all users need or require considerable customisation components of their experience. Consequently, the designed interfaces need to balance between configurability and clarity, providing a functional default experience while permitting customisation over time. In this way, the design serves for both beginners and experienced users of local transport services, ensuring that customisability enhances instead of hinders the platform's core mobility functionalities (refer to Figure 5.20). These initial designed interface pages include *the Homepage for first-time login (left), which* provides new users with access to a tutorial or introductory walkthrough, supporting onboarding and platform orientation. The *Homepage for the experienced users* (middle) allows for personalisation by replacing the welcome module with real-time displays of carbon emissions or carbon-saving points or discovering new incentives via the linked button to the reward store. The *My Services customised page* (right) enables users to tailor their homepage layout and feature of the digital platform according to their preferences, enhancing usability and engagement through a personalised interface experience.

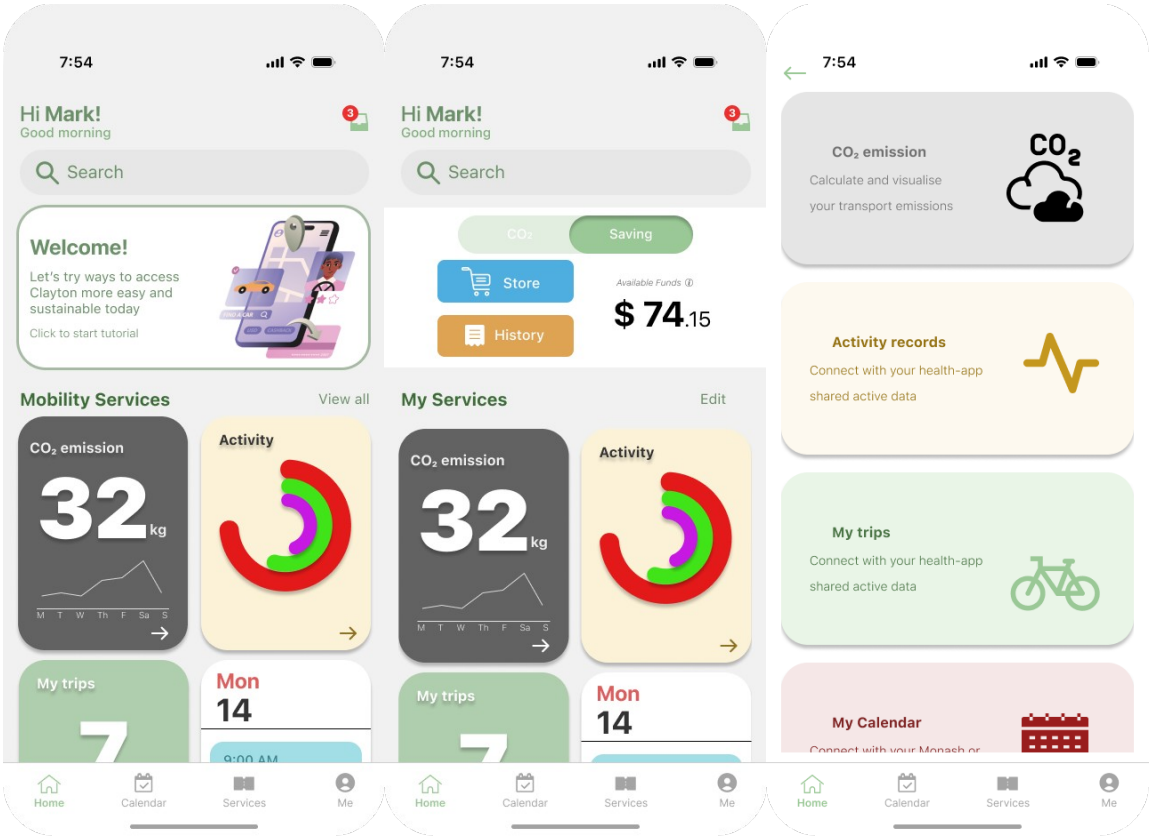


Figure 5.20. Initial homepage interfaces, applying progressive disclosure so that essential commuting functions are immediately available while advanced customisation is deferred until contextually relevant

- **Simplicity in interface structure**

Another significant design insight from the activity was the participants' desire for a straightforward, clearly structured interface that emphasises accessibility to essential functionalities. Following several co-ranking and future storytelling sessions, participants consistently emphasised the needs for a clear layout, straightforward navigation journey within the platform, and the reduction or elimination of unnecessary features. For instance, participants #8 and #10 indicated a preference for a digital platform experience like the traffic apps they were already familiar with, such as Google Maps or PTV, which presented essential travel-related features or real-time information on the homepage without necessitating deep menu exploration. For these participants, simplicity was an aesthetic matter, but a functional and experiential necessity, particularly when navigating time-sensitive or unfamiliar commuting scenarios.

Krug (2014) argues that users typically scan interfaces instead of reading them sequentially, particularly under cognitive or time constraints. This observation highlights the value of minimising clicks and providing clear visual hierarchies and predictable interaction flows. Choi and Lee (2012) similarly suggest that simplified task structures, coherent information hierarchies, and carefully designed visual displays may improve satisfaction with smartphone applications. Research on adaptive interfaces further indicates that simplified layouts may support cognitive processing by reducing the mental resources required for navigation and orientation (Choi & Lee,

2012; Fujiwara & Matsumoto, 2024; Q.-X. Qu et al., 2017; Romano Bergstrom & Schall, 2014).

In response to these design insights, the MaaS platform design was further refined to foreground core modules, such as "plan trip", "mobility service", and "payment", on a homepage structured according to visual hierarchy and task immediacy. The design features and functions were structured into clearly defined, customisable modules on the homepage, such as "plan your journey", "your eco impact", and "green community", to enhance user navigation and support personalised engagement with the platform (refer to Chapter 6). The visual structure of the MaaS platform was also simplified using consistent iconography, negative space, and logical grouping of related functions, enabling quick scanning and user-friendly navigation. For instance, compared with the initial design concepts of the interface pages of homepage and trip planning (refer to Figure 5.21), the refined pages (refer to Figure 5.22) provided a simpler layout and prioritised display of essential daily tasks based on participants' demands and feedback during the design workshops.

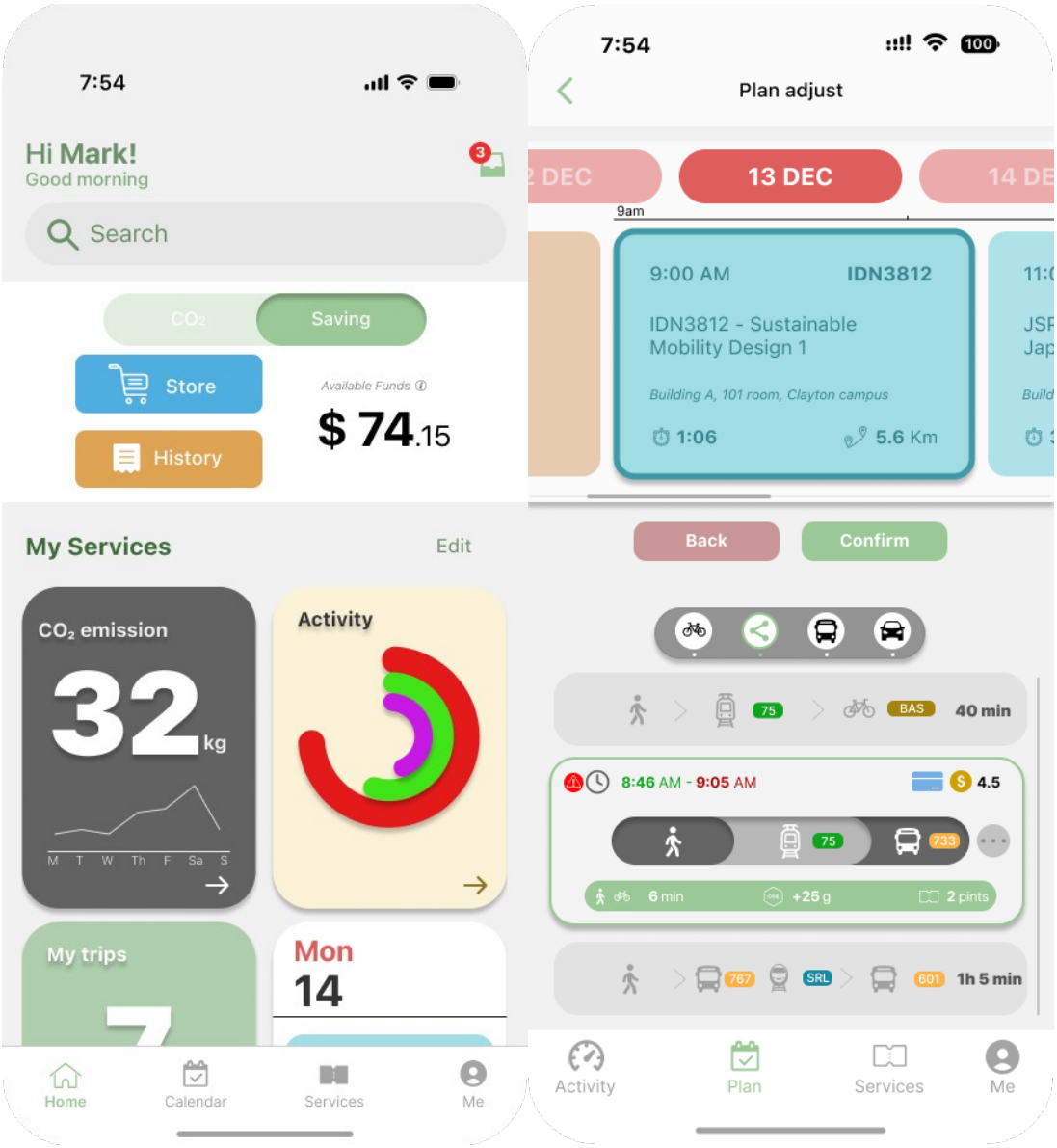


Figure 5.21. Early design concept of the Homepage & trip planning page of the MaaS platform

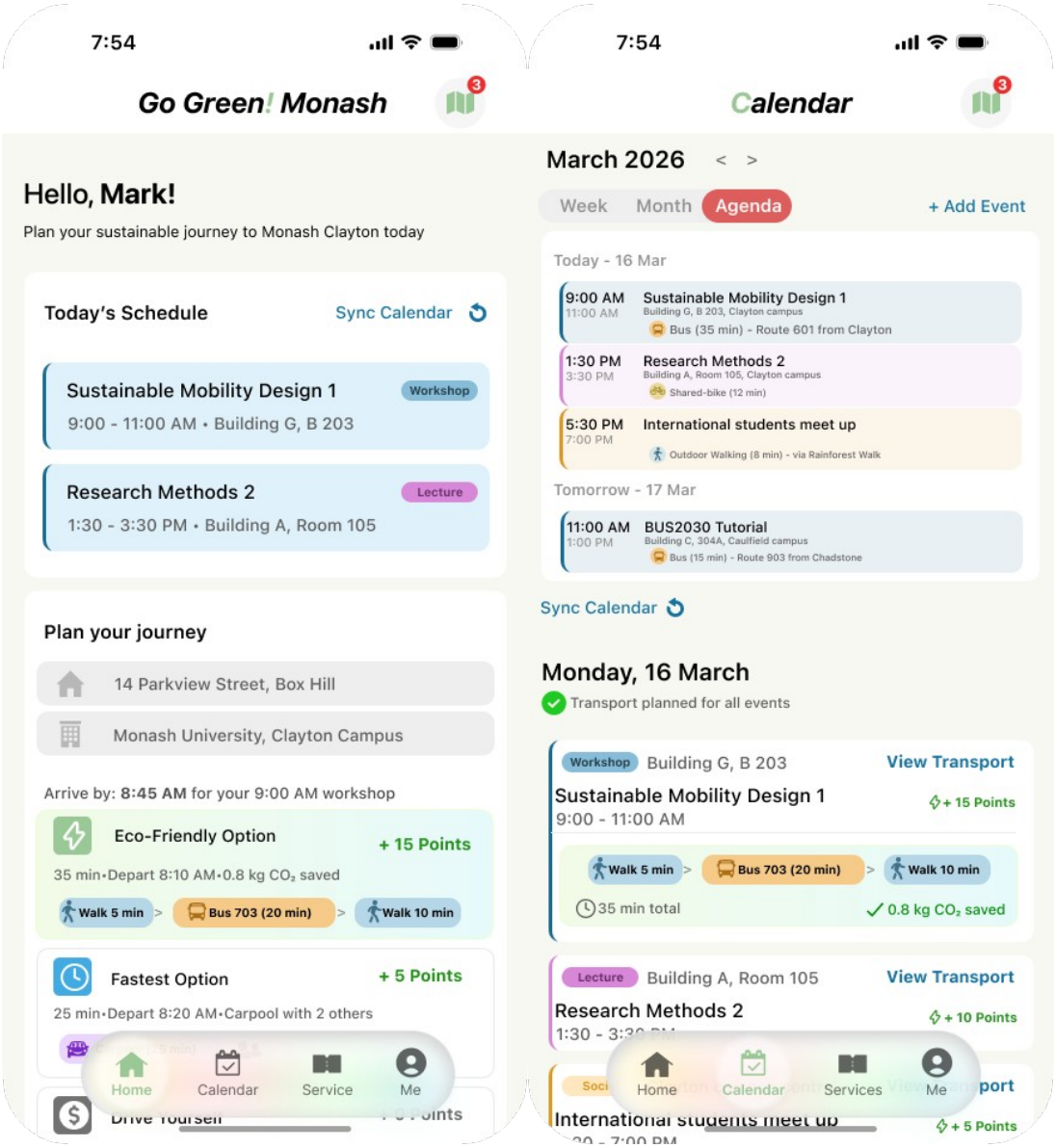


Figure 5.22. Refined design concept of the Homepage & trip planning page of the MaaS platform

Critically, simplicity of the design structure and application of iconographical design features can also enhance accessibility for international students who may be navigating in a second language or adapting to unfamiliar transportation networks. Through reducing potential textual density and simplifying interactions, the interface may become more accessible and support a broader range of users and enhance adoption across diverse user segments at the Clayton precinct.

"For new international students, their English might not be that good, and then the platform's made so complicated — with all these functions and interactions, and it's all in English — so it might not actually be very usable for them. I think if there was a multilingual interface, it could be much more acceptable or welcoming for new international students. At the moment, the design just feels too hard to get started with. If it's difficult to find the services or functions you need, it really discourages people from

using it regularly." (C#7_CR_00:02:56-03:06)

In short, participants' emphasis on simplified interaction and clear organisation of tasks or information within the interface structure played a crucial role in guiding the iterative refinement of the MaaS platform. Participants' feedback revealed that the effectiveness of the proposed MaaS platform lies not in the quantity of features offered, but in the delivery of appropriate functions and services through an accessible and user-centred interface.

- **Cognitive load**

The reduction in cognitive load emerged as a central theme in participant responses to the interface design of the MaaS platform, especially regarding interpretation, navigation, and transport decision-making. International students usually encountered issues of unfamiliar transportation systems, language barriers, and digital tools during the early stages of arrival. Therefore, the international student participants expressed a clear preference for interfaces of the proposed MaaS platform that facilitate seamless decision-making, particularly in time-sensitive commuting scenarios.

This design insight corresponds to the fundamental cognitive load theory (Sweller, 1988) and the HCI principle that minimising extraneous cognitive load can enhance interaction efficacy, especially in time-sensitive and mobile environments (Faudzi et al., 2024; Sevcenko et al., 2023). To address this finding, the MaaS platform was iteratively refined to diminish visual complexity, optimise selection menus, and streamline interaction flows (refer to Chapter 6). These adjustments were informed by usability heuristics and a comprehensive user experience (UX) framework, notably that of Hassenzahl and Tractinsky (2006), who posit that UX is influenced by instrumental and non-instrumental design elements, including experiential aspects, users' emotions, and effectiveness (see Figure 5.23). The facets of user experience explain that UX emerges at the intersection of instrumental function, experiential temporality, and affective meaning.

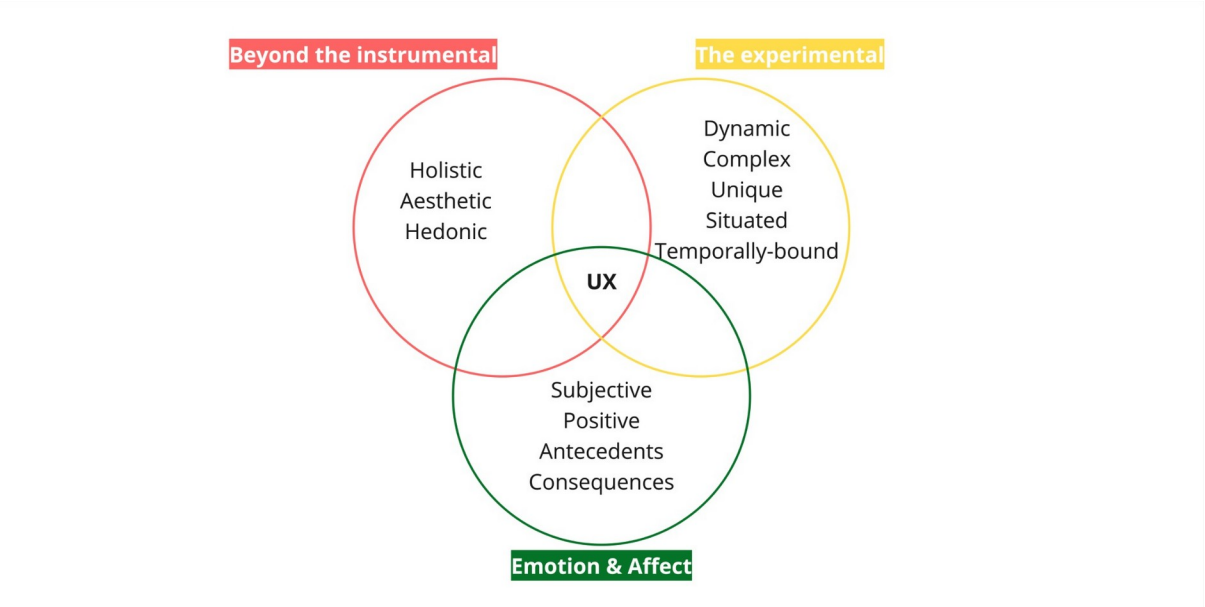


Figure 5.23. The facets of user experience, adapted from (Hassenzahl & Tractinsky, 2006)

Within the theoretical framework of user experience design, reduced cognitive load is not merely a form of interface simplification but a critical mediating factor that facilitates positive affective responses, enhances user trust formation, and enables situated ease of use.

Furthermore, this conception positions cognitive load reduction as an outcome variable and a causal mechanism that influences the broader phenomenological experience of human-computer interaction (refer to Figure 5.24).

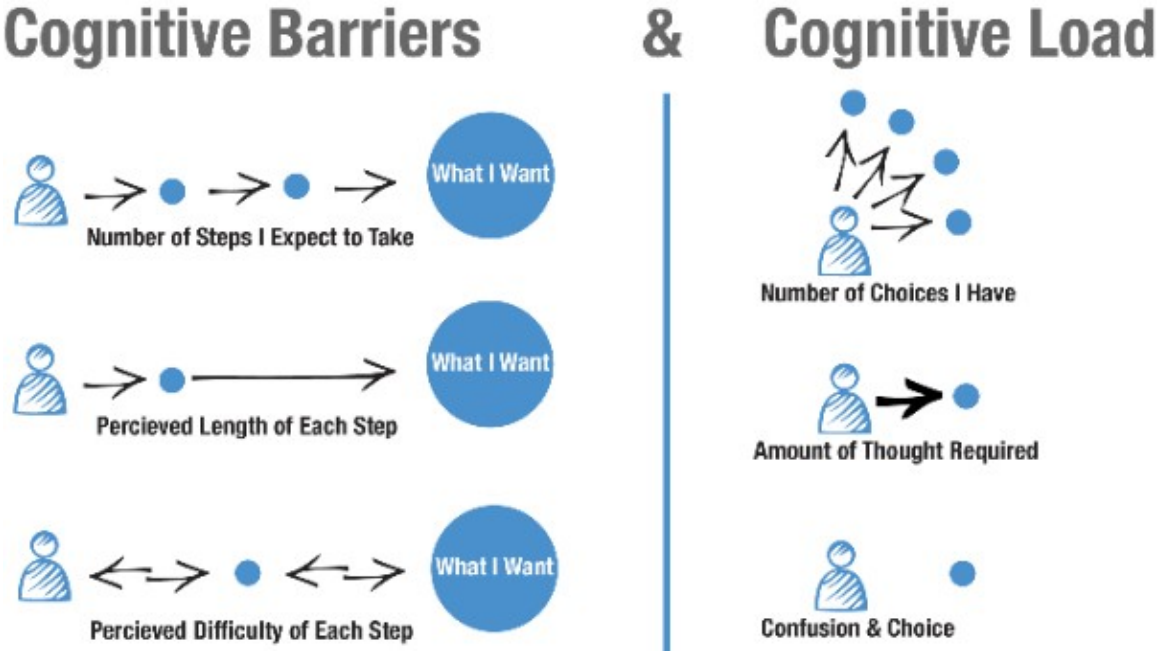


Figure 5.24. Cognitive barriers and cognitive load in interface design, (source: Julien. 2012)

The design features of dynamic customisability and simplified interface layouts collectively contribute to minimising cognitive load, which emerged as a critical requirement for the usability and long-term adoption of the proposed MaaS platform. Participants' open discussions during the co-ranking activity

in Workshop 2 provided this design insight.

During the co-ranking session of Workshop 2, participants #8 and #9 both expressed concerns about excessive feature layering, unclear information hierarchies, and the cognitive effort required to interpret multifunctional pages. They highlighted the necessity of prioritising clarity, consistency, and seamless interaction patterns to enhance navigation efficiency within the platform design (see Figure 5.25). Additionally, participant #7 expressed concern regarding the difficulty of navigating the platform when overloaded with information and functions. She noted that such complexity may increase the time required to learn how to use the platform and potentially diminish her willingness for long-term usage.

> "I feel like I wouldn't be able to use this app, because there are too many features being shown that, for me, just aren't necessary. It actually increases the effort I need to put in to learn how to use it, and it might even reduce my willingness to keep using it over time." (C#7_CR_00:00:47)

5.3. Chapter conclusion

This chapter has elucidated the design practice phase of the study, which is in the development and early delivery phases of the Double Diamond research process (refer to Chapter 3). This phase builds upon the Discover and Define phases, which established the contextual analysis of everyday mobility practice and pre-design opportunities.



Figure 5.25. Open discussion among participants during the co-ranking session of the Workshop 2

During participatory design workshop 2, participants engaged in contextual storytelling, co-ranking on design interfaces, and re-radar mapping activities, positioning the design interventions within their lived and envisioned commuting experiences. These interactions reveal the potential to enhance a sustainable future commute experience through multimodal accessibility, real-time feedback, and alignment with institutional and social identities while also addressing infrastructural and behavioural constraints that influence adoption among international students.

The subsequent follow-up semi-structured interviews with five selected participants provided in-depth evaluative feedback on a refined interactive digital prototype of the proposed MaaS platform. This stage sits within the early delivery phase of the Double Diamond research process and consolidated three strategic design directions:

- **Reward mechanisms will encourage** low-carbon or multimodal travel choices and reduce reliance on single-occupancy cars.
- **Gamification design elements aim to** enhance ongoing user engagement and encourage behavioural change by embedding interactive design features.
- **Social networking features** to foster digital community building and a sense of belonging among international students from the Clayton campus.

Drawing on these insights, the design practice phase culminated in the articulation of a design brief that framed the central objectives of the design project (refer to Figure 5.26). The brief established a specific direction for the project through framing the primary challenge, which is to design a MaaS platform that reduces reliance on private cars among international student drivers by providing accessible, reliable, and engaging alternatives. This framework is shaped by the identified barriers, including time constraints, safety concerns, cost, weather conditions, and suburban infrastructural gaps. The international student participants also identified enablers of digital solutions from the previous workshop sessions, such as incentive structures, digital community building, and campus service integration.

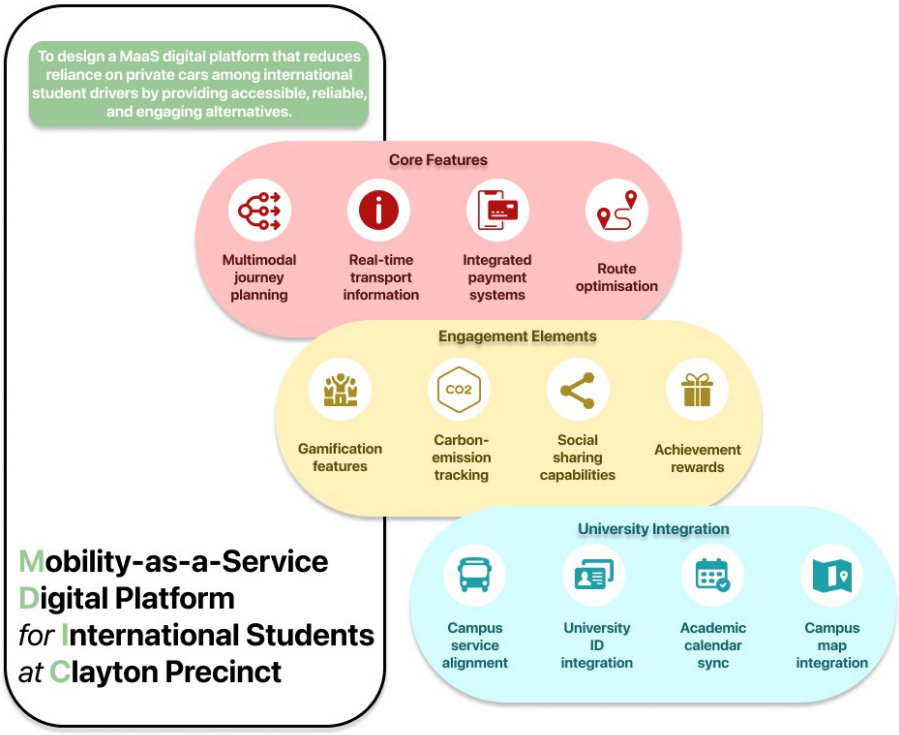


Figure 5.26. The design brief for the MaaS platform, consolidating the workshop findings into a single statement of the challenge, the target users and the three feature domains carried into Chapter 6

The design brief delineates three interconnected domains of the proposed MaaS platform. The primary features of the MaaS platform include multimodal journey planning, real-time transportation information displays, integrated payment systems, and route optimisation. Second, engagement components are integrated to mitigate resistance to behavioural change, incorporating gamification aspects, carbon emission monitoring, social sharing functionalities, and reward systems for personal carbon-saving achievements. Finally, university integration is emphasised to enhance contextual coherence with students' daily lives, encompassing service alignment with campus amenities, synchronisation with academic calendars, integration with university identification systems, and an additional navigation layer based on the digital campus mapping system.

In sum, the design brief identifies the MaaS platform as a sociotechnical designed intervention that addresses the past mobility experiences and pain points of international students instead of purely focusing on a technological solution, like most of the other MaaS-related research projects. This approach addresses critical issues, for instance, the "yes, but no" contradiction, the suburban connectivity crisis, and the vulnerability of international students, while facilitating more sustainable, inclusive, and user-centred mobility practices at the Clayton precinct. This brief provides the foundation for the subsequent chapter, which elucidates the final design outcomes and their implications for sustainable mobility transitions.

6. Developing the design from research findings to core interventions

CHAPTER OVERVIEW

This chapter presents the refined design outcomes of the research, articulating the finalised, or "frozen", version of a prospective MaaS platform, tailored to the commuting patterns and near-future-oriented mobility demands of international students from Monash University's Clayton campus. Building upon the design insights from previous participatory design workshops, follow-up interviews, and platform prototyping, the design outcomes illustrate how iterative refinement informed the platform's service features, interface design, and user experience. The proposed MaaS platform integrates reward-based mechanisms, real-time multimodal travel information, and university community-focused elements to encourage a reduction in private car use and facilitate more sustainable transportation choices.

Positioned as the Deliver phase within the Double Diamond framework, this chapter demonstrates the translation of participatory design processes into visible and tangible design interventions. The design outcomes are a practical response to the identified barriers and motivations of international students and serve as a broader design research contribution on sustainable mobility. This study illustrates how design practice may bridge the gap between behavioural intentions and infrastructural realities, emphasising the potential of user-centred MaaS interventions to inform future sustainability transitions in suburban university contexts.

6.1. Introduction

The chapter delineates the final design outcomes of the research, positioning them as a phase of the iterative and participatory design process undertaken in the prior stages. The chapter details the explicit design features of the MaaS platform, specifically developed for international student drivers from Monash University's Clayton campus, following the contextual analysis, participatory design workshops, and iterative prototyping discussed in previous chapters. These outcomes represent the Deliver phase of the Double Diamond research framework, whereby insights from research and design exploration are synthesised into refined interventions that directly address the research objectives and answer the design project question:

How might a user-centred MaaS platform, embedded within the campus community, be designed to promote sustainable mobility practices and reduce car dependency among international students?

The primary objective of this chapter is to illustrate how design practice might respond to the key insights derived from the early participatory research process. This encompasses barriers of external

realities, such as infrastructural deficiencies in active mobility, limited information on multimodal travel guidance, and unreliability or limited coverage of public transport services. Additionally, behavioural dynamics, including the importance of convenience, digital preferences, and attitudes towards sustainability, play a crucial role. These two primary factors represent the external and internal barriers that shape the commuting decisions of international students living in suburban areas. The proposed design intervention presents a near-future MaaS platform that emphasises the critical role of persuasive information architectures (B. J. Fogg, 2003; V. Sunio & Schmöcker, 2017d) in user interface design paradigms. This MaaS platform integrates three essential informational components, including the provision of real-time textual data, mobility data visualisation (Jittrapirom, Caiati, Feneri, Ebrahimigharehbaghi, Alonso-González, et al., 2017; Polydoropoulou et al., 2020), and the development of comprehensive multimodal journey guidance systems (Mulley et al., 2018).

The chapter is structured into two interconnected parts, with a companion chapter following it. The first part (Section 6.2) states the design proposition and derives it from the evidence gathered across the preceding chapters, mapping each design requirement to the finding that warranted it. The second part (Section 6.3) presents the two core designed interventions, campus-situated multimodal commuting decision support, and motivation, feedback, and incentives, showing how each responds to a specific barrier identified with participants instead of as a catalogue of interface screens. Chapter 7 then integrates these interventions into a single end-to-end commuting scenario and service blueprint across five journey stages: pre-trip, first-mile, on the way, drop-off and connection ports, and last-mile. That chapter also defines the service ecosystem on which the platform depends, together with its boundaries and the conditions under which it would operate. Interface-level design documentation, including colour selection, iconography, typographic hierarchy, and the platform’s visual language, is presented in Appendix K. Situated within a practice-led design research paradigm, this tiered structure enables the chapter to explicate the designed artefacts and their functional attributes, as well as the iterative prototyping, reflective processes, and methodological choices that guided their development. As Bredies et al. (2020) emphasised, "The role that artefacts play in a research process is often entirely different: they do not need to function but rather to provide explanatory power and serve as theoretical considerations in their own right." The chapter aims to clarify how each design decision engages with and responds to the primary research objectives, highlighting the generative role of design practice as a method of enquiry.

6.2. From research findings to the design proposition

The design proposition presented in this chapter is an outcome of the investigation instead of a premise of it. Its direction was set by the evidence presented in Table 6.1. The annual travel-survey and manual traffic-count data supplied by BPD, together with the field observations reported in Chapter 2.8, established the structural conditions of commuting at the Clayton precinct. The four barrier findings in Chapter 4.5.3 established why students who expressed environmental commitment nonetheless continued to drive: pre-arrival mobility histories and residential circumstance, the spatial and informational limits of suburban transport infrastructure, the mismatch between time-sensitive schedules and irregular services, and the value-action gap between stated concern and daily trade-offs. The design opportunities in Chapter 4.5.4, which were subsequently tested and revised through Workshop 2 and the follow-up interviews (Chapters 5.2.3 and 8.3), established which responses participants themselves found credible.

Where the evidence did not support a direction, that direction was not carried forward. The clearest instance concerns reward structures: although some participants initially advocated direct monetary rewards, others rejected them on the grounds that withdrawable cash would reduce instead of sustain engagement with the platform, favouring in-app points redeemable against campus services and transport costs instead (Chapter 4.5.4). The incentive mechanism described in Chapter 6.3.2 follows the latter position, and does so because participants argued for it, not because rewards were assumed at the outset.

Three further design decisions respond to evidence from the case review in Chapter 2. Treating continued use as the principal design problem responds to the UbiGo finding that curiosity attracts users while ease of use and cost shape continued participation. It also responds to the novelty effect reported in the gamification literature reviewed in Chapter 2.7.2. Institutional hosting addresses the collapse of Whim, whose reported reductions in car use were achieved under pricing that did not prove commercially sustainable. Designing around first mile and last mile segments responds to the Zume trial in Cambridge, where resolving the last mile affected participants' willingness to relinquish a second car. Table 2.3 in Chapter 2.3.2.3 records these lessons and the limitations of the supporting evidence.

The table below sets out this derivation explicitly, so that each designed intervention described in Chapter 6.3 can be traced to the evidence that warranted it. The mapping is intended to make the reasoning auditable instead of to imply that the process was linear. Several requirements became apparent only after participants had responded to an earlier prototype, and the iterations through which they were refined are documented in Chapter 5.3.

Table 6.1. Mapping of evidence to design requirements and designed interventions

Evidence source	Finding	Design requirement	Where realised
BPD annual travel surveys and manual traffic counts; field observations (Ch. 2.8)	Car mode share and peak-period congestion persist despite available public transport; first- and last-mile connections within the precinct are weak.	The design must address connection gaps inside the precinct without assuming that trunk services are sufficient.	Ch. 7.1.2; Ch. 7.1.4; Ch. 7.1.5
Workshop 1 thematic coding, Finding #1 (Ch. 4.5.3)	Pre-arrival mobility histories and residential circumstance shape mode choice; unfamiliarity with local services produces early reliance on driving.	Support needs to be differentiated by arrival stage and residential location instead of delivering uniformly.	Ch. 6.3.1
Workshop 1, Finding #2 and Opportunity #1 (Ch. 4.5.3; Ch. 4.5.4)	Existing tools lack hyperlocal detail: shuttle routes, disruptions, and detours, cycling paths, and parking permit rules are absent or unclear.	Integrated real-time, high-resolution multimodal journey planning with user-set filters and comparison of options.	Ch. 6.3.1; Ch. 7.1.1
Workshop 1, Finding #3 (Ch. 4.5.3)	Irregular suburban services conflict with time-sensitive study and work schedules; driving is valued for temporal predictability.	Decision support must surface expected duration and service reliability, not route options alone.	Ch. 7.1.1; Ch. 7.1.3
Workshop 1, Finding #4 (Ch. 4.5.3)	Value-action gap: stated environmental concern is overridden by comfort, weather, and time trade-offs.	Awareness messaging alone is insufficient; the design needs to address the trade-offs students encountered in daily commuting journeys.	Ch. 6.3.2
Workshop 1 Opportunity #2, tested and revised in Workshop 2 and follow-up interviews (Ch. 4.5.4; Ch. 5.2.3; Ch. 8.3)	Rewards motivate continued engagement, but direct cash was rejected as self-defeating; in-app points redeemable against campus services and transport costs were preferred.	Incentives must be contextually relevant and retained within the platform economy without being withdrawable.	Ch. 6.3.2
Workshop 1 Opportunity #3 (Ch. 4.5.4)	First-journey confusion around Myki fares, transfers, and campus shuttle stops; no multilingual or user-type-specific guidance.	Structured, personalised onboarding targeted at the arrival period, before car reliance becomes habitual.	Ch. 6.3.1; Ch. 7.1.1
Workshop 1 Opportunity #4 (Ch. 4.5.4), refined in Workshop 2 and follow-up interviews (Ch. 5.2.3; Ch. 8.3)	Mobility decisions were mediated by peers: lifts and carpooling substituted for inadequate services, and route knowledge was acquired informally from friends and housemates. Participants also proposed non-monetary recognition such as digital badges.	Peer coordination and route-sharing should be made visible within the platform, with a gamified recognition layer coupled to the incentive structure instead of separate from it.	Ch. 6.3.2; Ch. 7.1.1

The following subsections delineate the user interface (UI) design of the *Go Green! Monash* digital platform as a series of interconnected design strategies that might influence users' perceptions, understanding, and actions throughout future commuting experiences. This section illustrates the interface system, integrating visual signals, interaction, and functional modules to facilitate daily transportation choices.

6.3. Core designed interventions

6.3.1. Campus-situated multimodal commuting decision support

The platform embeds a gamified interaction mapping interface at the top of each navigation page (refer to Figure 6.1). Its consistent position makes it an ambient layer of interaction instead of an isolated element, enabling users to maintain awareness and reminders of their daily movements and decisions within the dynamic spatial structure of the Clayton precinct. The interface connects personal journeys with shared mobility knowledge, prompting students to perceive their travels as practical commutes as well as contributions to the broader university community network through interaction with the MaaS platform. This design decision is informed by insights from the participatory action research sessions, in which student participants highlighted feelings of alienation and uncertainty in suburban transport environments and their demands for social networking (refer to Chapter 4.5.4). Through emphasising collaborative involvement, the active mapping interface builds a more contextual commuting experience for newly arrived international students, fostering a sense of belonging and shared responsibility. The full set of designed features and their behavioural rationale is catalogued in Appendix K. Design features catalogue.

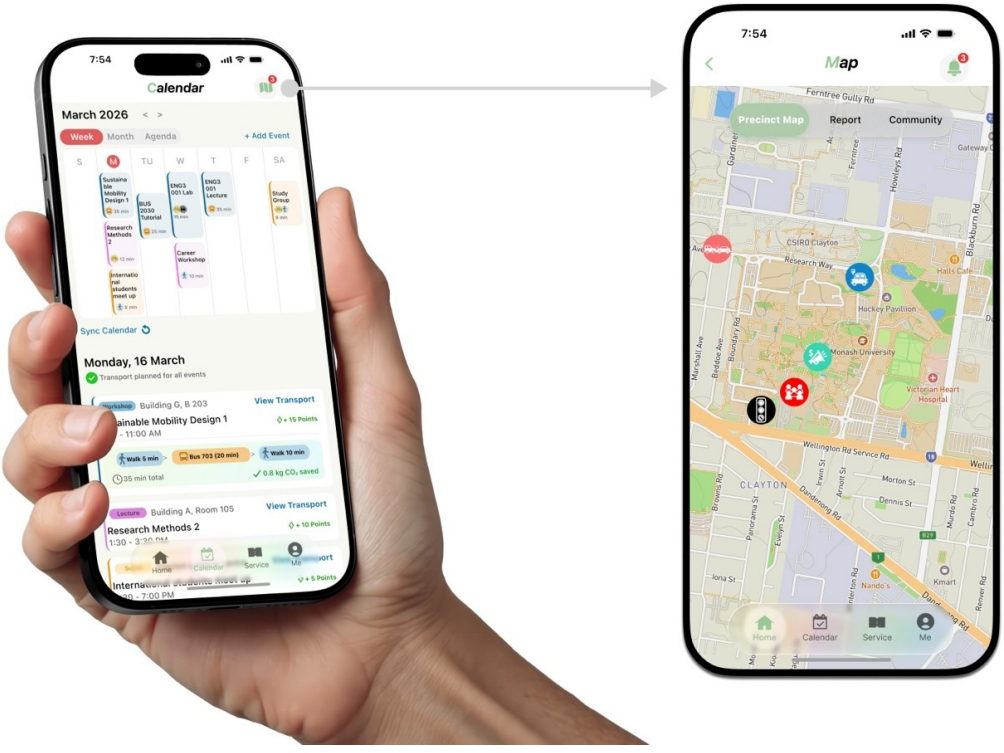


Figure 6.1. The gamified interactive mapping interface, held at the top of every navigation page so that awareness of daily movement becomes an ambient layer instead of a separate task

The interface comprises three primary functions facilitated by a segmented control located at the top of the screen, including *Precinct Map*, *Report*, and

Community. The Precinct Map (see Figure 6.2) provides users with a dynamic and interactive representation of the Clayton precinct, employing a unique visual taxonomy to convey urgency and functionality. The interface uses intuitive iconography to address language barriers for international students. For example, infrastructure disruptions are shown by a red construction-vehicle sign, whereas parking availability is indicated by a blue car-and-parking icon corresponding to the colour-coded student-permit zones on the Clayton campus. This design enables

student users to swiftly identify points or areas of interest or risks within and around the campus. Previous workshop sessions indicated that student participants frequently desire to express problems but lack a platform that is both accessible and communal. The *Precinct Map* function addresses this requirement by enabling users to articulate their voices across the university communities.

The second component, *Report*, concentrates on feedback previously supplied by community members and real-time transport-related data (see Figure 6.3). The "Recent Reports" list converts singular observations into collective intelligence by documenting incidences with time accuracy, such as "10 minutes ago" or "yesterday". Information displayed in the interface

page, such as "Bus 601 is delayed" at the Clayton Bus Loop or "Pothole on Wellington Road", reflect the user's role as a 'campus sensor.' Each report serves two functions: it alerts peers to immediate friction points like "Fallen tree blocking path," while concurrently indicating to service operators the necessity for maintenance. During user digital prototyping sessions, this design

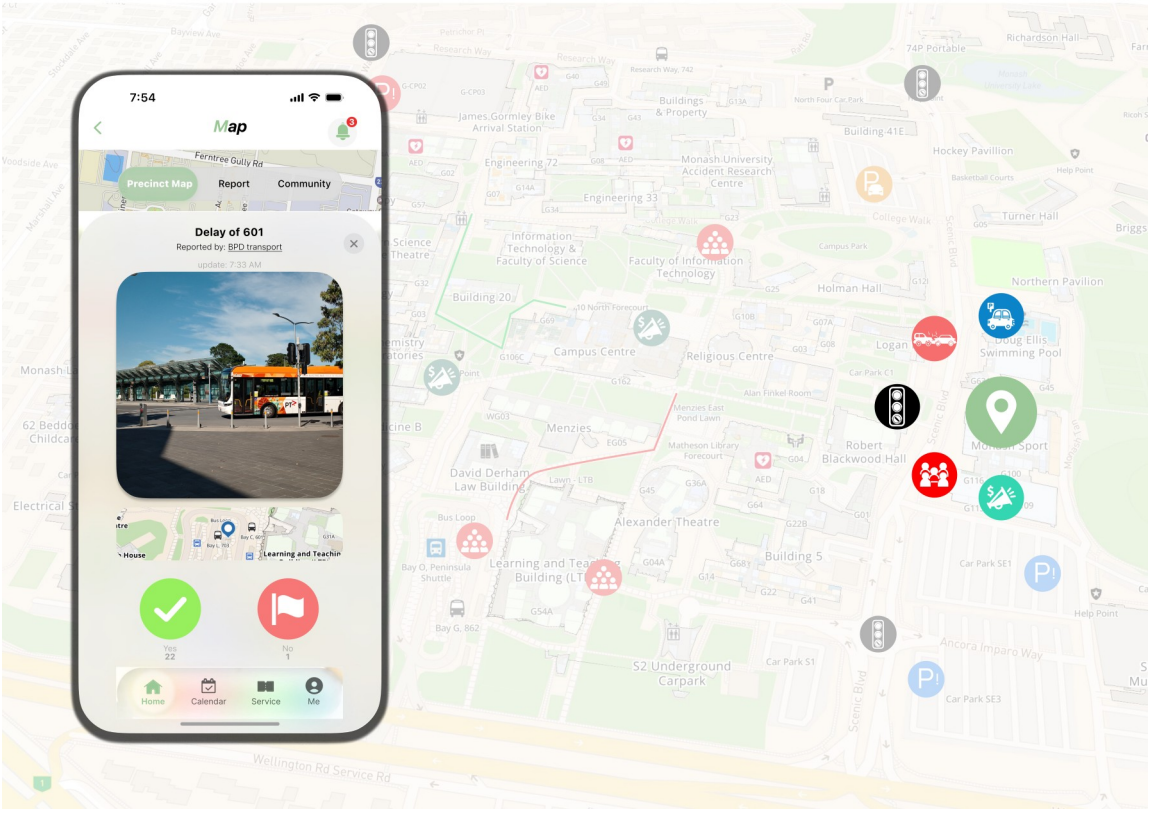


Figure 6.2. The Precinct Map interface, rendering the Clayton precinct as a dynamic representation that makes local mobility options legible to students unfamiliar with the campus

feature of the MaaS platform made participants feel recognised as contributors to a collaborative mobility enhancement initiative.

The third function, *Community*, provides a straightforward platform for users to post short messages or visual content related to their everyday mobility practices (see Figure 6.4). The design promotes social connection through peer-to-peer interaction within the platform community and aims to address the issue of social isolation among new international students. The feed includes pragmatic logistical arrangements, such as student users seeking carpool partners near their living locations, thereby reducing the obstacles to shared transportation.

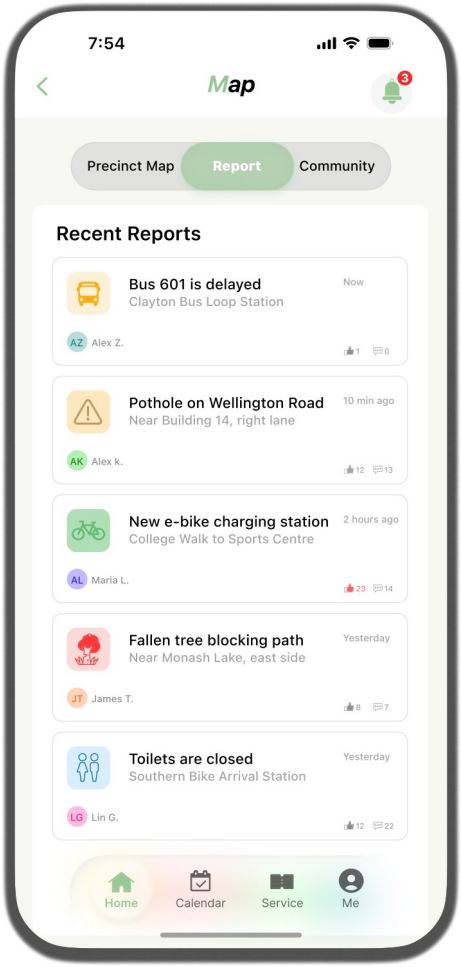


Figure 6.3. The Report interface, converting individual observations and real-time transport data into collective intelligence through time-stamped community reports

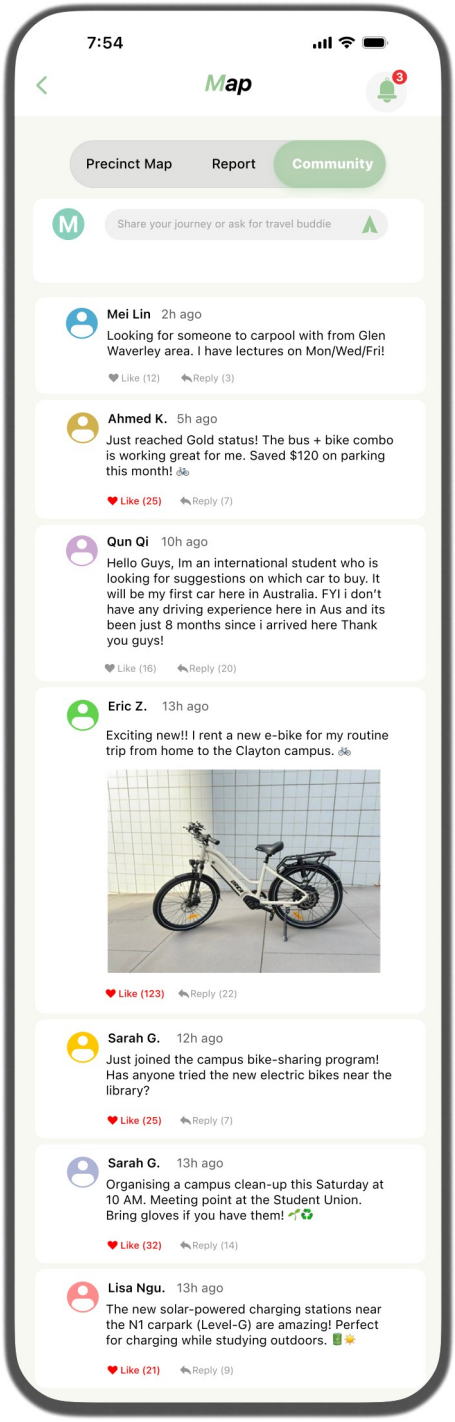


Figure 6.4. The Community interface, enabling peer-to-peer posts about everyday mobility practice to address the social isolation participants associated with solo car commuting

Positioning all three features within a single-entry icon at the top of each page ensures that users remain constantly one click away from interactive engagement with precinct communities, thereby maintaining seamless access to participation, reporting, and spatial information functions across the platform.

6.3.2. Motivation, feedback, and incentives

As discussed in Chapters 2, 4, and 5, the design strategies, including rewarding mechanisms, gamification design elements, and social networking (refer to Figure 6.5), may support encouraging and sustaining the adoption of

environmentally friendly travel choices and continued use by student users. The designed *Go Green! Monash* platform implements the MaaS conceptual model through an integrated, user-centred digital system intended to encourage sustainable transportation choices for international student car drivers. This section delineates the system's functional architecture, structured into four interrelated components, including (1) homepage and navigation framework, (2) trip planning functions, (3) service integration, and (4) user profile and personalisation. Each component reflects the research's theoretical framework for participatory and explorative service design, converting user insights into practical opportunities that facilitate behavioural change. The platform design represents a synthesis of technological systems thinking (F. W. Geels, 2018), human-computer interaction (Norman, 2013) and behavioural design frameworks (B. Fogg, 2009) in alignment with the objectives of facilitating the Monash Net Zero Precinct through daily mobility practices among international students.

A consistent navigation bar appears across all pages within the MaaS platform, enhancing uniformity and aiding user orientation within the system. The navigation bar includes the four primary destinations of the MaaS platform, including *home*, *calendar*, *service*, and *me* (see Figure 6.6). Therefore, the following sections elucidate the four main navigation pages of the *Go Green! Monash* digital platform, including (i) homepage and navigation framework, (ii) trip planning page, (iii) transport service integration, and (iv) user profile and personalisation. Detailing the structure and logic of these pages clarifies how the designed platform operationalises its theoretical and methodological foundation into situated everyday mobility services for the users.



Figure 6.5. The three design strategies carried by the platform, reward mechanisms, gamification elements and social networking, each shown against the motivational barrier it responds to (refer to Chapter 4.5.3)

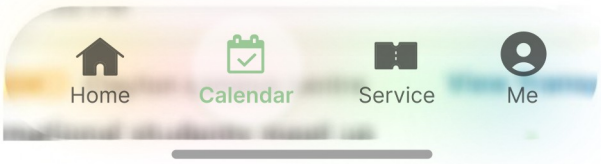


Figure 6.6. The persistent navigation bar carrying the platform's four destinations, home, calendar, service, and me, to maintain user orientation across the system

6.3.2.1. Homepage and navigation framework

The homepage operates as the central entry point to the service platform (see Figure 6.9). It emphasises information that a commuter may require promptly, such as upcoming departures, recommended routes, and updates related to their established routines. This configuration reflects the significance of low-effort information processing in mobility service interfaces, wherein a distinct visual hierarchy and context-relevant prompts facilitate rapid decision-making for users (Verkijika, 2020). For new arrival international students acclimatising to Melbourne's suburban transportation environments, an interface that displays recognisable reference points, such as frequently used routes or campus-focused shortcuts, could provide reassurance and reduce the cognitive burden of trip planning.

Immediately beneath the greeting from the homepage layout, the "Today's schedule" widget amalgamates the student user's academic schedules with transportation planning, providing a "Sync Calendar" feature to connect daily event management and trip planning. The interface explicitly presents course details, such as "Sustainable Mobility Design 1" in "Building G", and the interface prompts the user to "Plan your journey" according to precise arrival deadlines, thus situating travel within the student user's everyday reality.

The central feature of the homepage is the comparative route option card (refer to Figure 6.7), which utilises choice architecture to encourage users to opt for sustainable transportation alternatives. The interface emphasises the "Eco-friendly option," showcasing affirmative reinforcements, such as "0.8 kg CO_2 saved" and gamified incentives like "+ 15 points." This is graphically juxtaposed with the "Drive Yourself" option, which is characterised by disincentives such as "$5 parking fee" and an absence of award accumulation ("+ 0 Point"). This visual hierarchy is designed to question the habit of relying on private cars by making the wider costs of driving feel immediate and easy for users to notice when they make decisions.

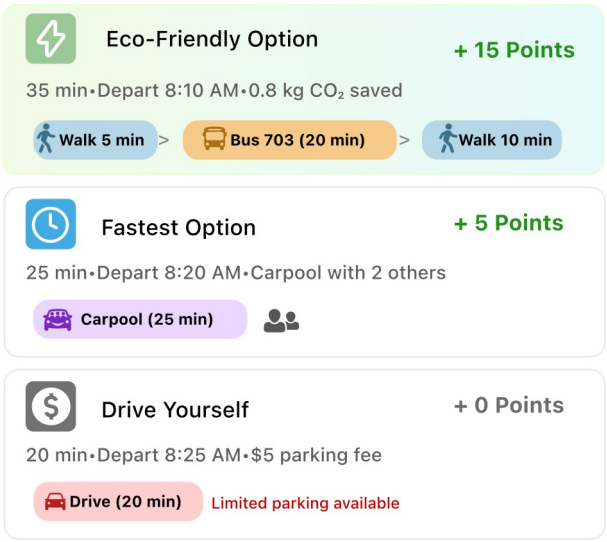


Figure 6.7. The comparative route option card, applying choice architecture by foregrounding the eco-friendly option against the fastest option at the moment of decision

Moreover, the designed layout of the homepage allocates screen space to the "Your Eco Impact" widget and "Available Rewards," (see Figure 6.8) reinforcing the project's gamified design strategy. The design fosters extrinsic motivation for student users to reduce car dependency by monitoring progress towards more sustainable commuting and providing practical incentives, including "Free coffee at Clayton campus centre" or a "One-day PTV unlimited travel card." The "Green Community" feed at the bottom of the scroll employs social networking functionalities through which users can share their daily commuting experiences or report issues on the way.

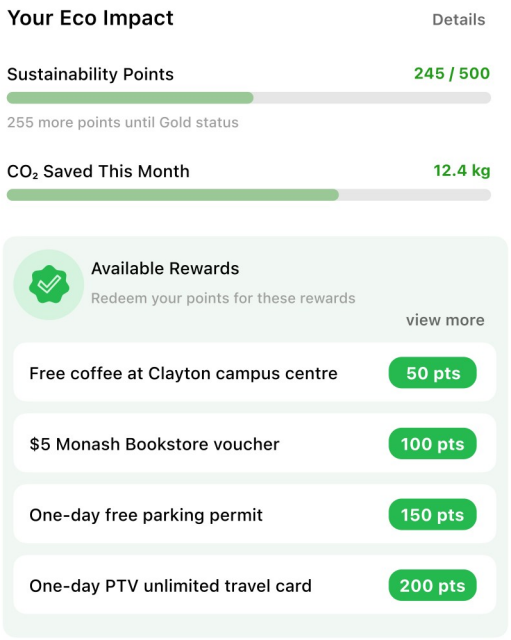


Figure 6.8. The "Your Eco Impact" and "Available Rewards" widgets, giving the gamified strategy permanent screen space so that progress is visible without the user seeking it out

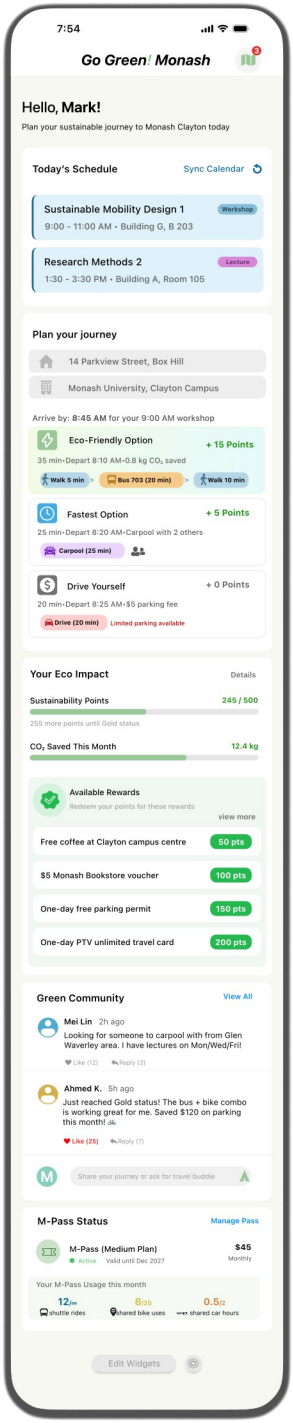


Figure 6.9. The homepage layout, allocating its hierarchy to journey comparison, eco impact and rewards so that sustainable options occupy the most prominent positions

Furthermore, the MaaS platform incorporated a reward store where users can review the offers of sustainable commuting journeys and redeem the relevant benefits (refer to Figure 6.10). The interface is crafted to convert abstract sustainable actions into concrete or tangible values, notably showcasing the user's "Available Funds or Points" at the apex of the hierarchy. This financial quantification provides a prompt response, emphasising the economic benefits of alternate transportation options, and has proven to encourage sustainable commuting decisions among international students (refer to discussion in Chapter 8.3.1).

The layout categorises incentives into several sections, including *Feature*, *Weekly Offers*, and *My Benefits*, to facilitate user interaction and continued engagement with the MaaS platform. The *Feature* and *Weekly Offers* sections function as behavioural nudges, promoting sustainable modal transitions. For instance, the platform offers a "$20 cash reward" to student users who utilise detectable multimodal transit to get to the Clayton campus during the first teaching week of the following semester. Active mobility is incentivised with immediate rewards, such as a "Free breakfast" on campus when users utilise the Bike Arrival Stations for parking their bicycles. The following My Benefits section lists the activated and redeemable offers that users have already earned through their sustainable trips. Distinct status indicators of "activate", "claim", "activated," and "expired", provide essential visibility into system status, enabling users to monitor the validity of their incentives. These rewards encompass pragmatic transportation services, such as "One-day (24 Hours) red permit car park at the Clayton N1," as well as lifestyle benefits such as a "$15 voucher" for lunch at the campus's kitchens.

The incorporation of specific local vendors situates the service into the Clayton campus community, aligning incentive systems with the daily environments of international students. Positioning incentives within identifiable economic and social touchpoints, such as food outlets, cafés, or local vendors, enables the reward system to function as a contextualised provision instead of a generic benefit (Bucchiarone et al., 2023; Galanakis et al., 2024; Hjalmarsson-Jordanius et al., 2017; X. Zhu et al., 2020b). This localisation enhances the perceived significance of behavioural incentives, since student users can readily connect sustainable travel decisions with concrete, location-specific benefits integrated into their routine movements within the precinct. This contextual alignment supports the platform's intention to incorporate sustainability-oriented commuting behaviours into the everyday experiences of campus life.

Finally, the interface of rewards store extends beyond transactional rewards by providing educational context in the *Get more through using the platform* section. This section contextualises personal actions within a broader environmental narrative, enabling users to track their carbon savings or footprints and explicitly align their travel decisions or personal contribution of sustainable commuting practices with Monash University's net-zero initiatives.

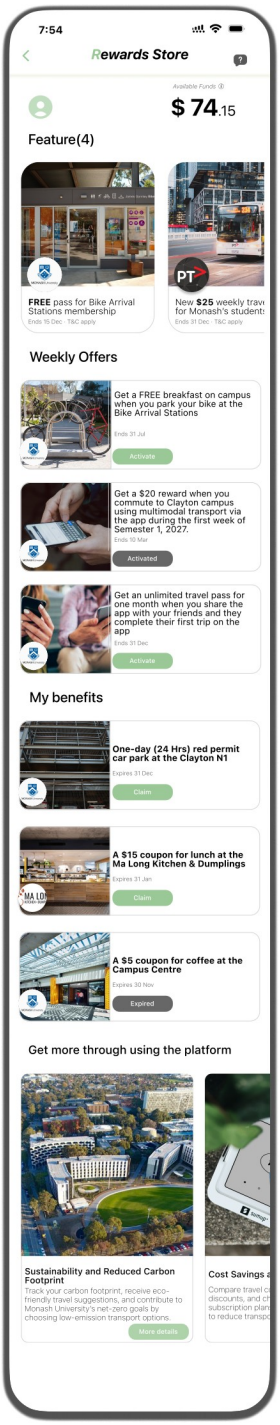


Figure 6.10. The rewards store, extending redemption beyond transaction by situating individual point balances within a wider account of carbon saved

6.3.2.2. Trip planning functions

While the homepage's "Plan your journey" widget addresses the immediate need for mobility decision-making by comparing "Eco-Friendly" and "Fastest" options, the Calendar interface (refer to Figure 6.11) enhances this capability by integrating mobility choices within the temporal structure of the student users' academic schedule. The trip planning page facilitates comprehensive comparisons of mobility options by displaying various routes concurrently. Users can get information of travel times, estimated costs, carbon emissions, and real-time reliability indicators. The incorporation of multimodal comparison demonstrates

established evidence that passengers react favourably when provided the opportunity to evaluate options transparently, instead of through disjointed or sequential searches (Jittrapirom, Caiati, Feneri, Ebrahimigharehbaghi, Alonso-González, et al., 2017; G. Smith, 2020).

To integrate sustainable mobility practice into the everyday routine of students, the platform's Calendar interface combines academic scheduling with transportation logistics. The design provides flexible visualisation options through "Week", "Month", and "Agenda" toggles, enabling users to organise and filter according to

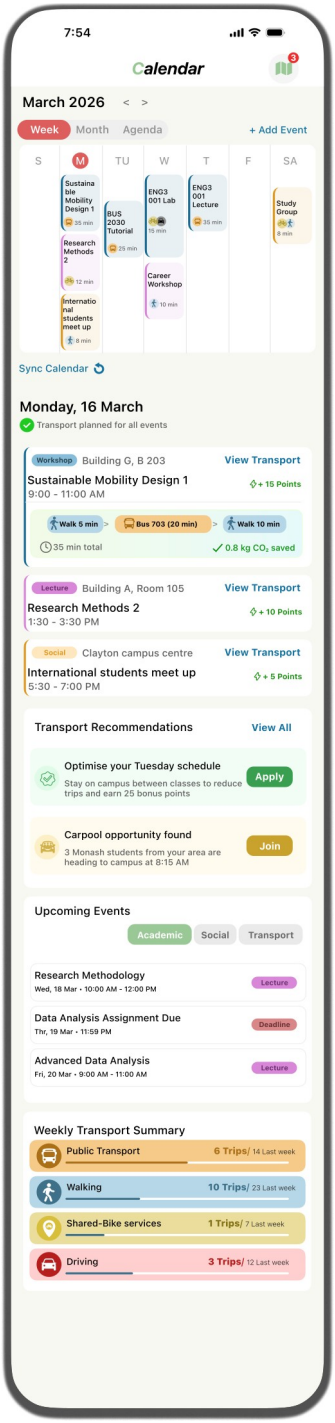


Figure 6.11. The Calendar layout, embedding mobility choices in the temporal structure of the student timetable instead of treating each trip as an isolated decision

their desired time scale (see Figure 6.12). This interface distinctly associates destination events with modes of transportation, for example, a "Sustainable Mobility Design" class is visually connected to a "Bus (35 min)" journey, whereas a "Research methods" seminar features a "Shared bike (12 min)" indicator directly within the schedule block. This visual integration mitigates the cognitive burden linked to multimodal trip chaining. By framing everyday mobility as an intrinsic temporal aspect of the academic event instead of a distinct logistical activity, the interface reconciles the divide between intention and action, a crucial obstacle in the implementation of MaaS systems (Sochor et al., 2018).

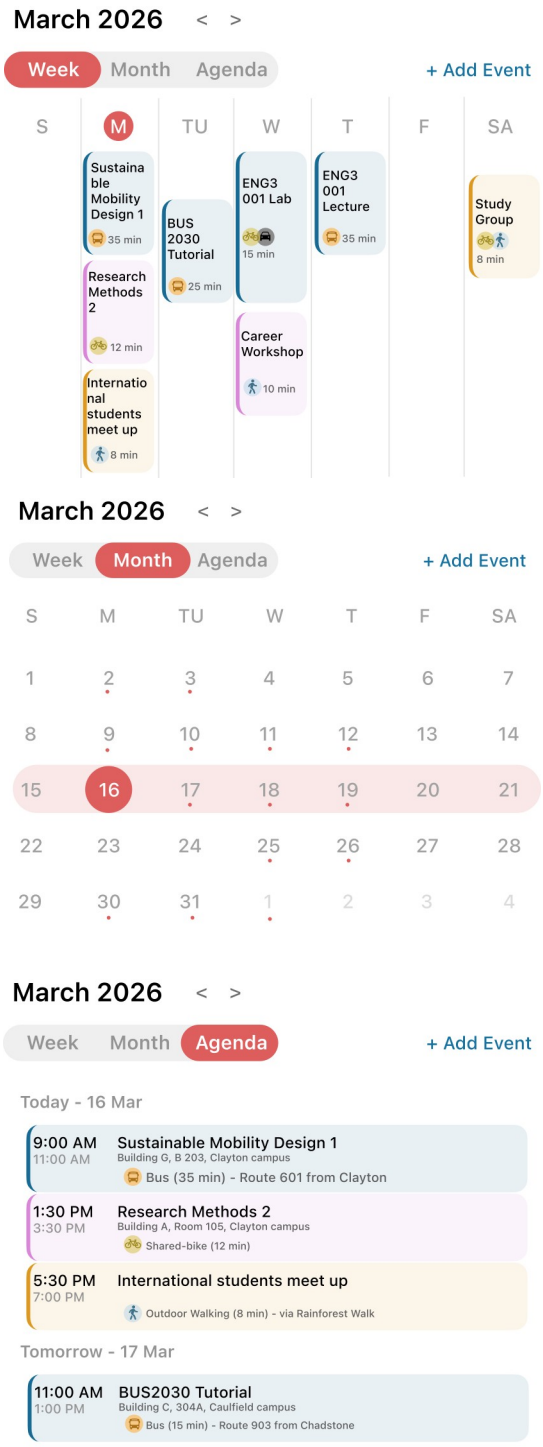


Figure 6.12. The Week, Month, and Agenda toggles of the Calendar view, each pairing a timetabled destination with its transport mode so that trip chaining is read from the schedule instead of planned as a separate task

The interface moves beyond passive display to active intervention through the "Transport Recommendations" panel (see Figure 6.13), which employs algorithmic suggestions to enhance sustainable travel behaviours for users. For instance, the algorithm identifies gaps between classes or events and encourages users to "Stay on campus between classes" to minimise trip frequency, rewarding this activity with "25 bonus points." This feature corresponds with B. Fogg's (2009) behaviour model, which asserts that effective persuasive technology needs to provide triggers at the moment the user possesses both capability and the

motivation to act. The platform also uses social coordination by notifying users of "Carpool opportunity found," specifying particular peers (from the image below "3 Monash students from your area") who are travelling at similar times. This design feature addresses the 'stranger danger' frequently identified as an obstacle to dynamic ride-sharing by highlighting institutional affiliation (refer to discussion in Chapter 5.2.3) to create a foundational level of trust and community.

Finally, the design of the Calendar section promotes reflective learning through a "Weekly Transport Summary" positioned at the bottom of the interface. This dashboard monitors the user's modal split by comparing current usage of "Public Transport", "Walking", "Shared-Bike Services", and "Driving" with metrics from the previous week (refer to Figure 6.14). The interface employs feedback loops crucial for self-regulation by visualising statistics data and juxtaposing current performance against historical benchmarks, for instance, displaying "3 Trips" for driving alongside the metric "12 Last week". As Jain et al. (2012) indicated, eco-feedback technology that provides historical visual comparisons helps users in monitoring their competence and progress, therefore fostering sustained engagement with behavioural change objectives (Canale et al., 2025; Chalal et al., 2022; Francisco et al., 2018).

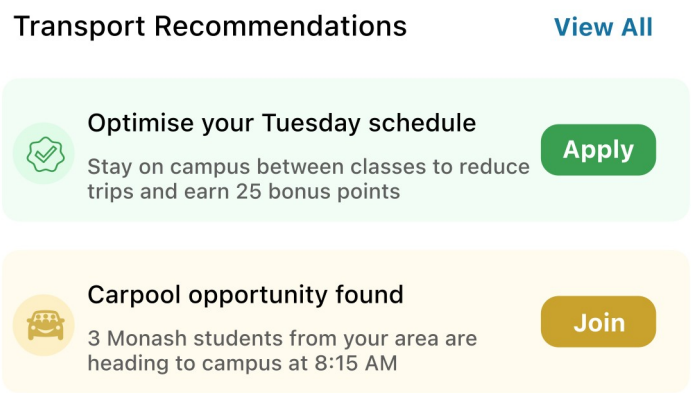


Figure 6.13. The Transport Recommendations panel, moving the platform from passive display to active intervention by proposing sustainable options in the gaps between timetabled classes

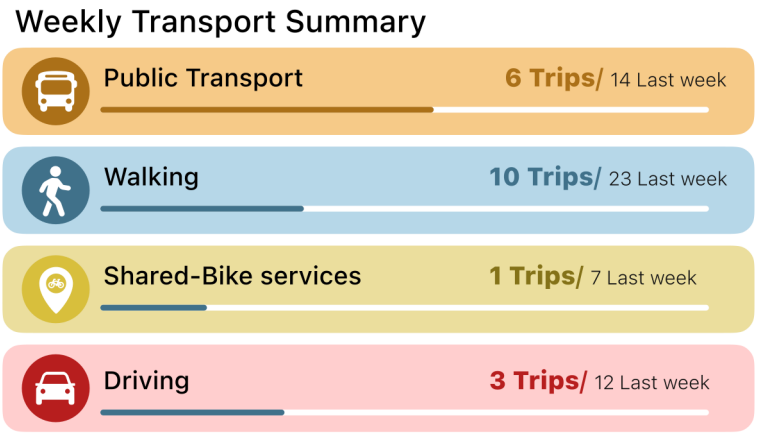


Figure 6.14. The Weekly Transport Summary dashboard, prompting reflective learning by comparing the user's modal split across public transport, walking, shared bikes and driving

6.3.2.3. Transport service integration

The *Service* section of the platform integrates real-time data and information of all relevant transport services around the Clayton context, including public transport routes, campus shuttle services, cycling-related services, and parking availability in one interface (see Figure 6.15). As one of the most significant design features, the platform integrates these services in a unified structure that aims to address the issue of disjointed access to transportation information that characterises many suburban mobility systems (Audenhove et al., 2018).



Figure 6.15. The Service section, consolidating public transport, campus shuttle, cycling, and parking information into a single interface to remove the multi-app switching participants reported

Visual coherence constitutes a foundational interface design principle in the integration of mobility service blocks, as it constructs a uniform design language that enables users to comprehend functional linkages within the MaaS ecosystem (refer to discussion in Appendix K). Uniform icons, colour coding, and streamlined labels facilitate swift scanning and support users who are navigating English-language interfaces as a secondary or tertiary language (see Figure 6.16). The designed widget that integrated real-time updated information of local transport services also aims to mitigate the anxiety related to service reliability, which is a significant obstacle for international students who are

unfamiliar with local transportation systems (refer to research finding in Chapter 4.5.3). Instead of fixed schedules, the design features "live status" indicators, providing detailed operational data for each local mobility service, such as "5 buses active" on the inner-campus shuttle or "42 shared-bikes available nearby". This quantifiable assurance, including statuses such as "on schedule" or "high availability", fosters confidence in the system's reliability for users.

Moreover, the layout of mobility services integration personalises the logic of supply and demand. For instance, in the "carpool system" module, the interface enumerates the "12 rides available today" and filters this information to emphasise relevance, informing the user of "3 matches for you" in high-hierarchy light green colour. This design feature significantly diminishes the cognitive exertion necessary for negotiating shared mobility among international students. To address safety concerns, particularly those associated with night-time travel for female student commuters (refer to related discussion in Chapter 4.5.3), the specialised "security bus" module provides a direct "request pickup" feature. In this way, university-operated security bus services can be booked with minimal effort, enhancing students' perceived safety on campus during evening hours and their confidence in the reliability of non-driving mobility options.

The "M-Pass" (Monash student ID) segment, prominently positioned inside the visual hierarchy, connects information and access. By incorporating a ticketing widget into the service page, displayed in Figure 6.17 as "Mark's M-Pass" with a QR-code scanning feature, the platform reduces the inconvenience of transitioning between navigation and payment platforms of existing mobility mapping

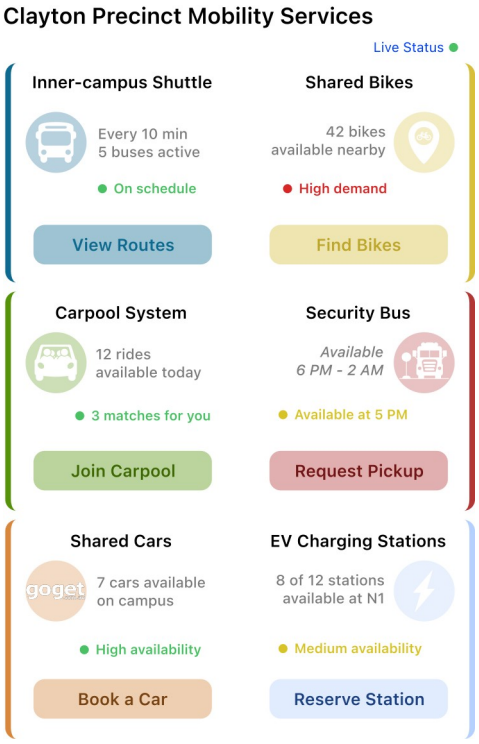


Figure 6.16. The integrated service widget for the Clayton precinct, showing the live status indicators (buses active, shared bikes available nearby) and the carpool module's "matches for you" filter that reduces the effort of arranging a shared ride

apps (refer to discussion in Chapter 2.8.3).



Figure 6.17. The M-Pass ticketing widget, placing scan-ready access beside service information so that information and boarding are resolved in one place

6.3.2.4. User profile and personalisation

The user profile page (see Figure 6.18), labelled Me in the proposed MaaS platform, provides an adaptable layer that reflects the characteristics of everyday mobility practice. Customisable settings allow users to save preferred routes, specify accessibility requirements, review previous journeys, and visualise cumulative carbon savings. These functions are intended to support continued engagement with the platform (Hub et al., 2023; Raihan, 2025; Silvestri et al., 2025b; Xi et al., 2025). Beyond providing a settings menu, the page serves as a reflective space in which users may observe how everyday mobility choices accumulate into environmental and personal outcomes.



Figure 6.18. The Me section, holding saved routes, accessibility requirements and travel history as the adaptable layer that personalises the platform to individual mobility practice

This reflective capacity is implemented through the Sustainability Impact and My Achievement dashboards. These dashboards translate abstract changes in user behaviour into four metrics, including carbon dioxide saved, time saved, money saved, and points earned. Placing financial indicators such as A$145 saved beside environmental measures such as 42.5 kg of carbon dioxide saved connects financial self-interest with environmental values and addresses students' budget constraints.

The platform adapts the financial model of commuting from payment per use to an integrated mobility bundle. The

subscription interface presents tiered plans for weekly, monthly, and annual use, enabling students to align financial commitments with expected travel frequency (refer to Figure 6.19). These plans respond to a barrier to MaaS adoption discussed in Chapter 2.4.3. Cost information is presented through visualisations and concise summaries at predictable intervals, including A$35 per week or A$120 per month, with relevant illustrations. This presentation may improve financial predictability by enabling users to anticipate expenditure and assess affordability. Clear subscription information and plan selection may therefore support engagement with the MaaS platform and its integration into everyday commuting routines.

The temporal differentiation of the subscription plans responds to variability in international students' university routines. The "S" plan addresses short term requirements or examination periods, whereas the "L" plan supports longer term use through a "set and forget" option. Kriswardhana and Esztergár-Kiss (2023b) report that university students are sensitive to package flexibility and may prefer short commitments that accommodate semester breaks and fluctuating schedules. Participant feedback from the workshops and interviews also supported the value of adaptable plan durations (refer to Chapters 4.5.4 and 5.2.3.2).

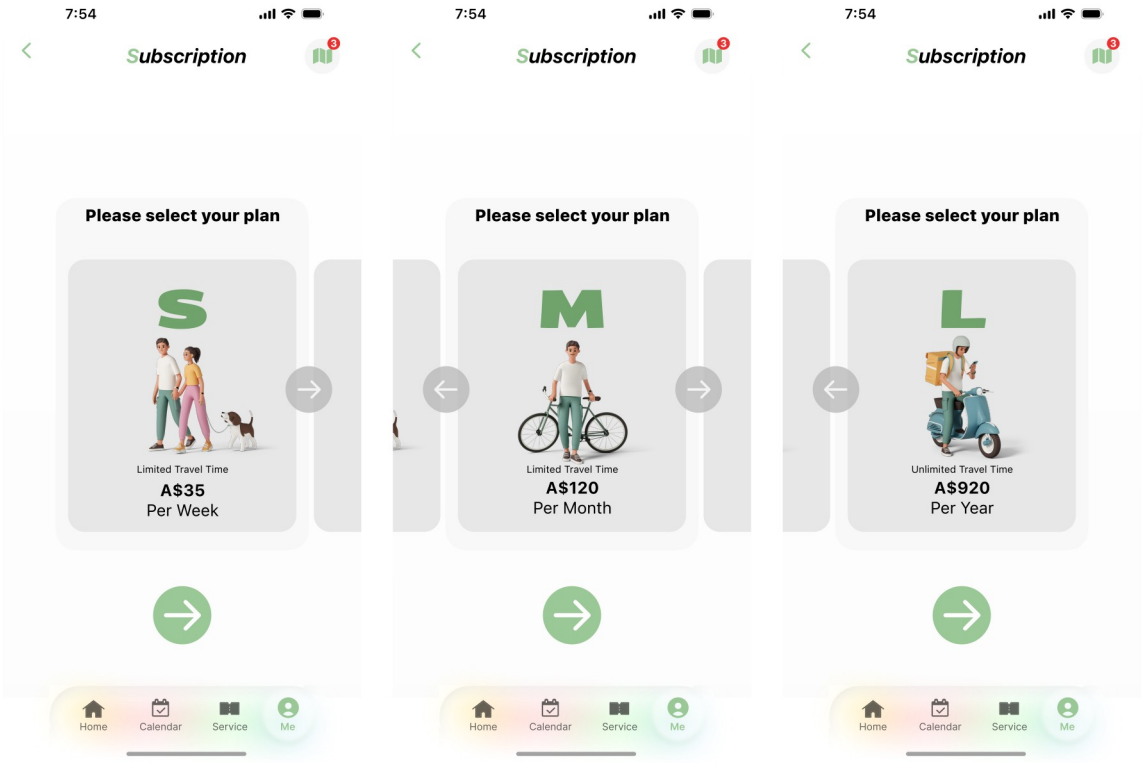


Figure 6.19. The three subscription plans, tiered by duration so that the S plan serves short-term or examination-period needs while the L plan supports long-term retention

6.4. Chapter conclusion

This chapter has set out the design proposition that emerged from the research, together with the evidence warranting it. The proposition is that car dependency among international students at a suburban campus is better addressed by making multimodal commuting legible, temporally predictable and socially supported at the points where students decide, than by appeals to environmental values alone. Section 6.2 traced each design requirement back to the finding that produced it, so that the proposition reads as an outcome of the investigation instead of an assumption carried into it. The outcomes are presented as a portfolio of interconnected artefacts instead of a single “final” solution, because their purpose is to make a tested trajectory for change visible, discussable, and amendable.

Two core interventions carry the proposition. Campus situated multimodal decision support (Section 6.3.1) responds to the informational and spatial constraints participants encountered, including unfamiliarity with local services, absent local detail, and uncertainty about service reliability. It consolidates information at the precinct scale, live service status, and peer knowledge within an ambient layer positioned at the top of each navigation page. Motivation, feedback, and incentives (Section 6.3.2) address the gap between stated values and action. They attach immediate and locally redeemable consequences to each modal decision in the form participants preferred after rejecting withdrawable cash rewards as self defeating.

The interfaces presented here are products of iteration and not initial propositions. Documentation of interface details, including colour selection, iconography, and typographic hierarchy, is provided in Appendix K. The present chapter therefore remains focused on the design proposition and its evidentiary basis. Chapter 7 examines how the two interventions combine across a complete commuting journey and identifies their dependencies beyond the interface.

7. Envisioning the future commuting journey through a scenario and service blueprint

CHAPTER OVERVIEW

The preceding chapter established the design proposition and its two core interventions. This chapter examines how these interventions operate together across a complete commuting journey and identifies the conditions necessary for their operation. Section 7.1 integrates the interventions into a single end to end commuting scenario and represents it through a service blueprint across five journey stages, including pretrip, first mile, travel in progress, drop off and connection, and last mile. The blueprint distinguishes frontstage interactions, backstage procedures, and enabling resources. It also identifies the service ecosystem on which the platform depends, the stakeholder relationships it proposes, and the boundaries of the design claims. Treating the platform as a service system exposes its dependencies on data, infrastructure, and partnerships that the design itself does not control.

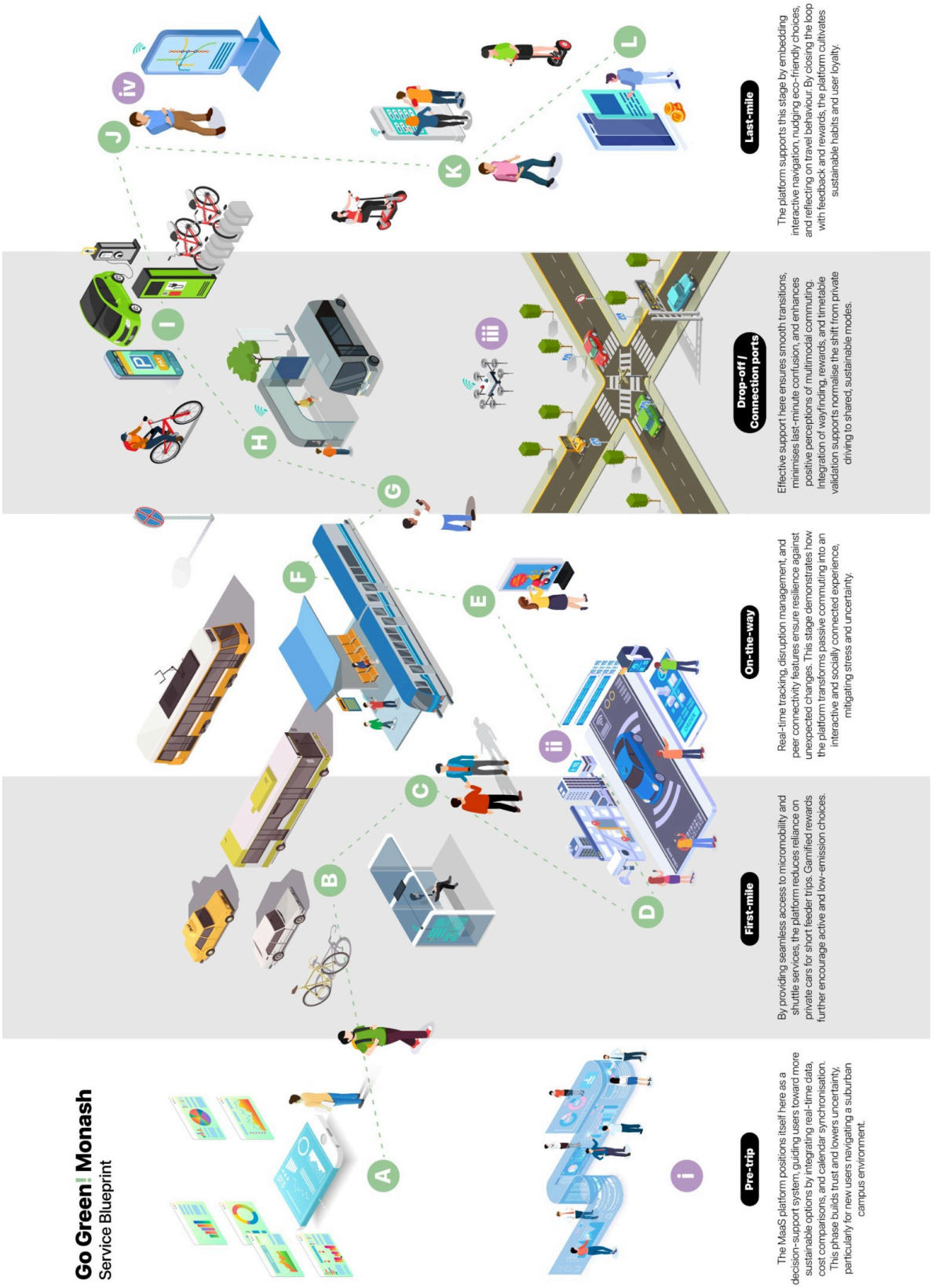
7.1. Integrated future commuting scenario and service blueprint

This section presents the design outcomes through a service blueprint and a prospective MaaS journey. The practice based enquiry focuses on interface design and potential interactions that may encourage more sustainable travel. It does not specify the technical or infrastructural implementation of information technology systems. Frayling (1993) al. (2007b) indicate that design artefacts may function as probes for enquiry and criticism in addition to operating as prospective solutions. The service blueprint and journey map are therefore treated as design artefacts that support the imagination, visualisation, and critical evaluation of how international students may engage with the platform in everyday mobility practices.

This approach employs the blueprint and journey as near-future oriented explorative representations and communicative tools (Auger, 2013; Dunne & Raby, 2013). They facilitate the exploration of the potential experience of sustainable mobility for international students, based on the design insights derived from previous participatory investigation and iterative prototyping sessions. As Frayling (1993: 5) explained the foundation of design research, "How can I tell what I think till I see what I make and do?" The research positions the service blueprint and journey as designed artefacts, exemplifying research through

design. They embody ways of thinking in visual and interactional forms, functioning as mediating tools that enable reflection, facilitate critique, and project potential future possibilities (Gaver, 2012). Therefore, this explorative orientation illustrates the broader role of design practitioners in sustainability transitions, which is prototyping possibilities, materialising futures, and enhancing critical reflection on how target users may reconfigure their everyday commutes instead of predicting or prescribing technical systems (Manzini, 2015; Tonkinwise, 2015a).

This study situates the digital platform within the lived experiences of international students from the Clayton precinct by focusing on front-stage design features, including colour selection, iconography, interface functionalities (refer to the previous section), and interaction flow, brought together in the service blueprint at Figure 7.1. This framing is further implemented through the five basic stages of daily commuting, including pre-trip, first mile, on-the-way, drop-off or connection ports, and last mile, which structure the following subsections. These phases illustrate user interactions with the proposed MaaS platform at various stages of their future commutes, highlighting the interface as an experiential mediator between mobility choices and sustainable behavioural outcomes (Sarasini & Linder, 2018; Stickdorn et al., 2018; Sträuli et al., 2022).


Go Green! Monash
Service Blueprint
Pre-trip
The MaaS platform positions itself here as a decision-support system, guiding users toward more sustainable options by integrating real-time data, cost comparisons, and calendar synchronisation. This phase builds trust and lowers uncertainty, particularly for new users navigating a suburban campus environment.
First-mile
By providing seamless access to micromobility and shuttle services, the platform reduces reliance on private cars for short feeder trips. Gamified rewards further encourage active and low-emission choices.
On-the-way
Real-time tracking, disruption management, and peer connectivity features ensure resilience against unexpected changes. This stage demonstrates how the platform transforms passive commuting into an interactive and socially connected experience, mitigating stress and uncertainty.
Drop-off / Connection ports
Effective support here ensures smooth transitions, minimises last-minute confusion, and enhances positive perceptions of multimodal commuting. Integration of wayfinding, rewards, and timetable validation supports normalise the shift from private driving to shared, sustainable modes.
Last-mile
The platform supports this stage by embedding interactive navigation, nudging eco-friendly choices, and reflecting on travel behaviour. By closing the loop with feedback and rewards, the platform cultivates sustainable habits and user loyalty.

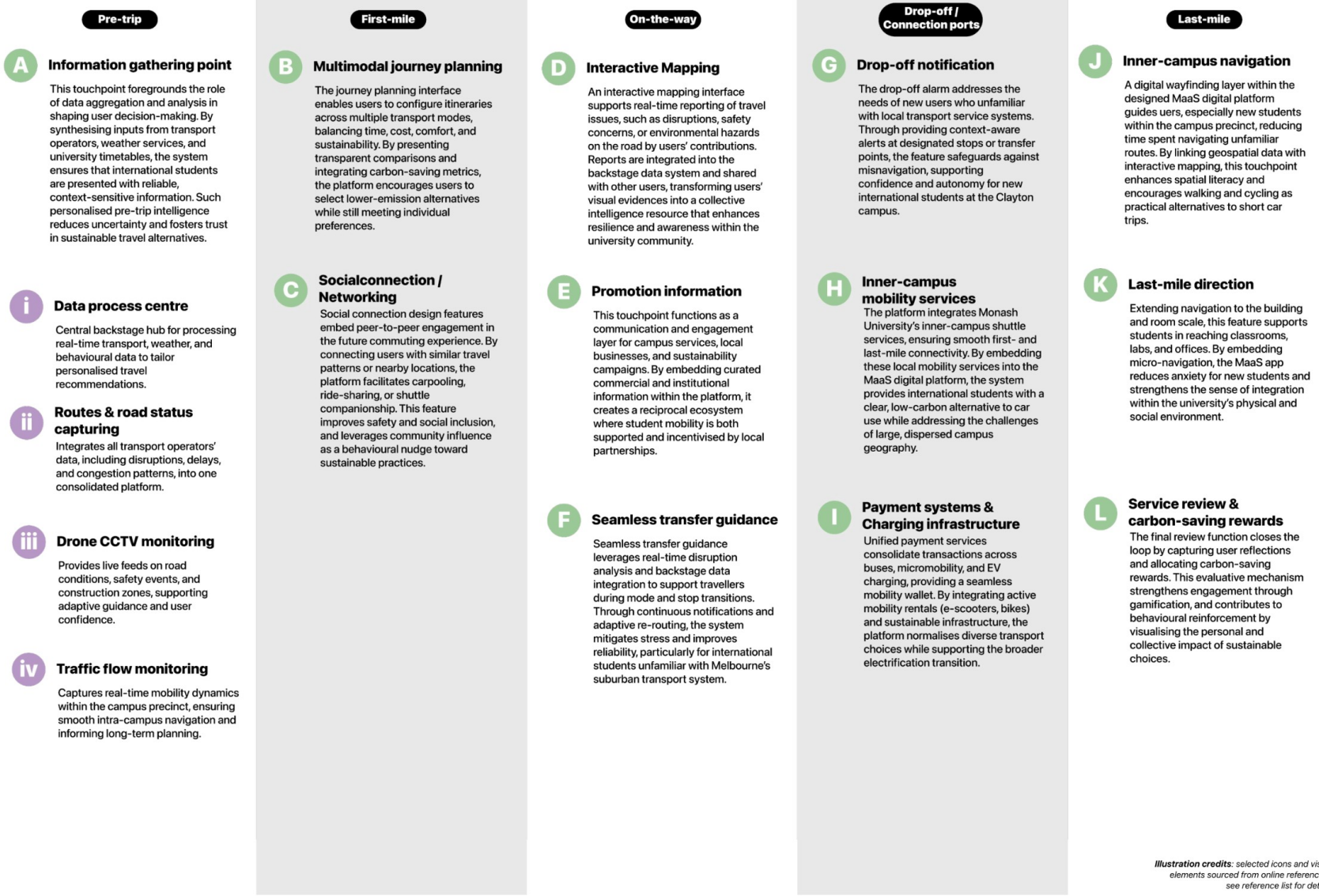


***Illustration credits**: selected icons and visual elements sourced from online references; see reference list for details*

Figure 7.1. The Go Green! Monash service blueprint, mapping user actions, front-stage interface touchpoints and back-stage service dependencies across the five commuting stages

7.1.1. Pre-trip

The pre-trip phase establishes the design of the MaaS platform as a decision-support mechanism that reorganises mobility options prior to a daily trip from home to the Clayton campus. This phase addresses the crucial discovery from the empirical aspect of this research project: international student car drivers experience significant uncertainty when traversing Melbourne's suburban transport network, especially concerning dependability, interruptions, time expenditure, and multimodal transfer (refer to Chapter 4.5). At this stage, the imagined functional or designed features of the MaaS platform effectively address these challenges through trip planning, data integration and visualisation, and personalised travelling guidance. As discussed in Chapter 2.3.1.3, the preliminary functions of multimodal trip planning in the MaaS platforms significantly affect mode choice, especially among users lacking familiarity with local transit systems or those travelling in suburban areas characterised by information asymmetries.

The service blueprint (see figure above) illustrates this layer through Touchpoint **[A]**, where users engage with a dynamic information dashboard that integrates transit statistics, weather conditions, real-time disruptions, and contextual notifications (refer to Trip planning functions). As illustrated in the blueprint, the system employs a Data Process Centre [i] that integrates datasets, including transport timetables, weather conditions, parking availability, university timetables, and user-specific historical travel behaviour or preferences.

From a behavioural perspective, the platform employs choice architecture by comparing carbon emissions, equivalent travel times, and costs. These methods of informational nudging correspond with digital mobility interventions aimed at normalising sustainable transportation options without policy enforcement (refer to Figure 1.4). The design of carbon footprint visualisation (see Figure 7.2) at this stage is crucial for aligning personal travel choices with broader institutional net zero objectives (refer to relevant discussion in Chapter 4.5.4). In contrast to recognising sustainability as a distant institutional goal, the pre-trip phase of the future MaaS-based commuting experience integrates environmental factors into the user's daily travel choices. The concept that information systems can actively contribute to sustainable mobility has been highlighted by Information System (IS) research for smart sustainable mobility, which contends that digital mobility platforms might facilitate transport operations as well as actively advocate for sustainability through design and user involvement (Ketter et al., 2023).

The designed interfaces of the MaaS platform during the pre-trip phase are intended to visualise the environmental impact and potential benefits of engaging in multimodal and sustainable commuting practices at the point of decision-making for users. The platform converts policy-level sustainability objectives into practical, user-friendly guidance through real-time indicators, mode-specific impact visualisation, and comparative

sustainability metrics across transportation options. This design approach corresponds with the overarching sustainable mobility strategy, Avoid-Shift-Improve (ASI), encouraging users to avoid unnecessary trips, shift to greener transportation modes, or improve travel efficiency through their micro-level choices (refer to discussion in Chapter 2.2.3).

7.1.2. First-mile

The first-mile stage addresses the spatial disconnection between a user's residence and the primary public transport network, frequently the weakest aspect of suburban commuting experience presented by international student participants (refer to Chapter 4.5.3). The *Go Green! Monash* platform addresses this gap through personalised and real-time data driven Multimodal Journey Planning **[B]**, enabling users to configure itineraries that effortlessly integrate active mobility, such as walking or cycling with motorised modes, including shared-car, carpooling or on-demand shuttle services. Empirical research indicates that first-mile (FM) barriers significantly hinder the reduction of private car use, especially in suburban university environments where walking distances, weather conditions, coverage of public transportation services, and safety perceptions disproportionately influence

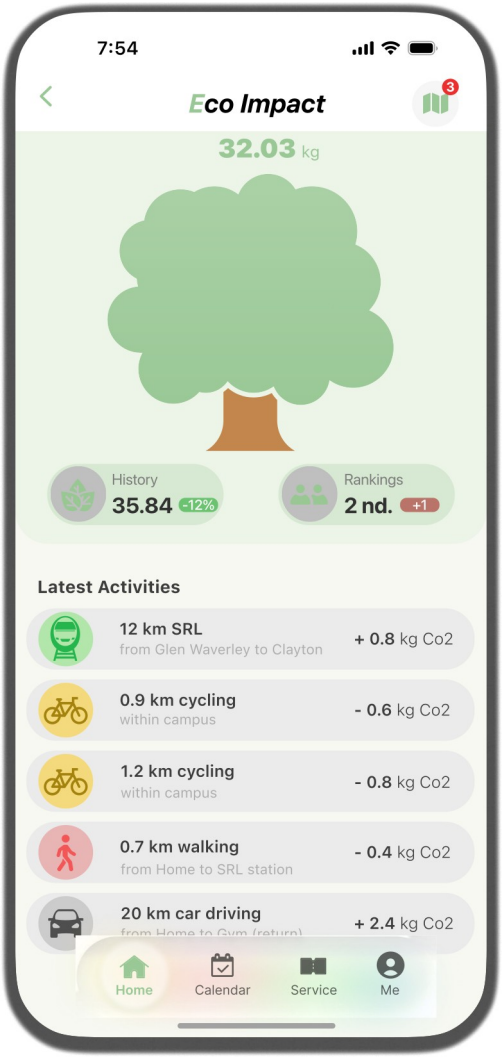


Figure 7.2. Visualisation of transport-related carbon emission

mode choice. In the Clayton precinct, this obstacle is further intensified for international students who need to navigate low-density land-use patterns alongside the limited coverage and unreliability of local transport services (refer to Chapter 4.5.3). The blueprint represents dynamic micromobility integration, real-time departure coordination, and social trip-matching features, reframing the first-mile stage as a shared mobility experience instead of a personal or isolated daily commute routine.

The Social Connection **[C]** design feature incorporates peer anchoring as an actionable behavioural stabilising mechanism during the everyday mobility decision-making process. The anchoring mechanisms act as practical behavioural stability features in everyday mobility decisions (C. Huang et al., 2026; Krull et al., 2024; C. Qu et al., 2008; Ralph & Delbosc, 2017), providing reference points that influence personal and group choices. Their effectiveness depends on the source of the anchor, the social setting, and individual cognitive and emotional factors (Feygin & Pozdnoukhov, 2018; Yik et al., 2019). The platform particularly enables carpooling, ridesharing, or shuttle companionship through connecting student users with similar travel patterns or route preferences (refer to Figure 7.3). This design feature aims to address the barriers of social isolation and limited information on local transportation service systems for newly arrived international students.

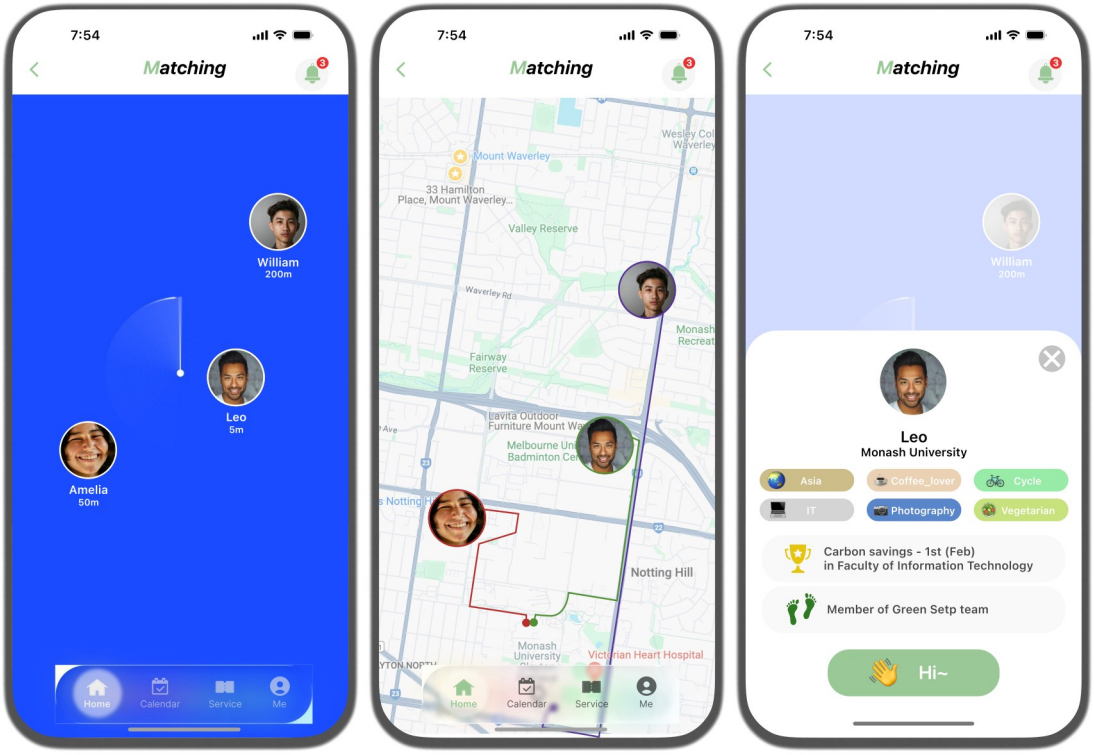


Figure 7.3. The social matching features, operationalising peer anchoring as a mechanism for stabilising sustainable mobility decisions over time

7.1.3. On the way

The "On-the-way" phase constitutes the extended temporal segment of the future MaaS-based commuting journey, during which real-time adaptation, emotional experience, and system trust are most visibly negotiated. The core design feature of the phase is Interactive Mapping **[D]**, which enables users to report transport-related issues on their way to the Clayton campus, such as disruptions, safety concerns, or environmental hazards, through the interface pages (refer to Figure 6.1). The design feature during this phase aims to address the issues of uncertainty in transport service systems in suburban areas and might influence the overall experience of multimodal commuting. The platform's real-time interactive mapping interface visualises the live location of users, but most essentially functions as an emotional regulator, converting network volatility into comprehensible trajectories. By integrating disruptions, safety alerts, crowding conditions, and peer-reported incidents, as shown in Figure 6.2, the platform externalises uncertainty and mitigates the perceived loss of control for future multimodal commuters.

The blueprint's integration of community reporting during commuting corresponds with recent trends in participatory sensing within urban mobility systems. Instead of making passengers or commuters passive data subjects, users transform into distributed observers or data contributors who participate in a collectively sustained situational awareness, thereby enhancing the sense of campus community belonging. This form of "collective intelligence" enhances system responsiveness and fosters users' sense of agency within infrastructural systems and unfamiliar suburban transportation environments. This design feature visualises the idea of crowdsourced mapping into an active operational mechanism, where student users collectively serve as a distributed sensing network embedded in the campus mobility system.

By feeding these user-generated insights into the backend data infrastructure **[ii]**, the platform creates a continuous feedback loop of collective intelligence. Personal reports are compiled, verified, and converted into actionable insights that can be disseminated to the broader user community through adaptive guidance and alerts. This process enables the system to derive insights from patterns of use and disruptions while remaining anchored in practical, real-world experience. The Traffic Flow Monitoring components **[iv]** enhance this functionality by perpetually recording real-time mobility dynamics throughout the precinct area, encompassing congestion points, delays, and modal interactions. These data streams facilitate context-sensitive modifications to route recommendations and service coordination, ensuring that guidance adapts to real-time conditions instead of relying on fixed timetables.

7.1.4. Drop-off and connection ports

The "Drop off/connection" stage of the future commuting journey focuses on the integration of the commuter into institutional and spatial frameworks. This

phase in the blueprint is facilitated by "drop-off notification," **[G]** "inner-campus mobility services," **[H]** and "payment systems and charging infrastructure." **[I]** At this stage, the MaaS platform transitions from inter-suburban navigation to governance of campus-scale mobility, where the platform user's trips are shaped by local circulation rules, designated access points, and the availability of short-distance connection services.

Connection ports are designated nodes at which transport modes intersect and commuters transfer between mobility options or interact with campus transport infrastructure and services (refer to Figure 2.45). They operate as physical and operational interfaces between systems and are therefore important to continuity within the MaaS platform. At the Clayton campus, connection ports include public transport stations and interchange zones, campus shuttle stops, parking facilities, and drop off locations for private cars, carpools, electric vehicles, and shared vehicles. Active mobility connection ports include bicycle arrival stations and parking or docking areas for cyclists and electric scooter users. Because these ports require modal changes, they may create uncertainty, time pressures, and navigational challenges, especially for newly arrived commuters who are unfamiliar with the available infrastructure and services.

The service blueprint treats connection ports as dynamic interactions between the designed MaaS interfaces and local transportation infrastructure or services. The "drop-off notification" **[G]** presents a frontstage interaction that confirms arrival, mitigates uncertainty about where the user is located within the campus perimeter, and facilitates the following actions. The touchpoint of "inner-campus mobility services" **[H]** facilitates the arrival by providing viable last-mile connections through short-distance alternatives that correspond with campus mobility patterns, such as shuttle transfers or shared micromobility links where appropriate. The incorporation of "payment systems and charging infrastructure" **[I]** explicitly indicates that arrival constitutes a transactional moment, whereby the user may need to validate access, finalise payment on the transport services, or manage charging and parking needs for electric cars or shared mobility use (see Figure 7.4).

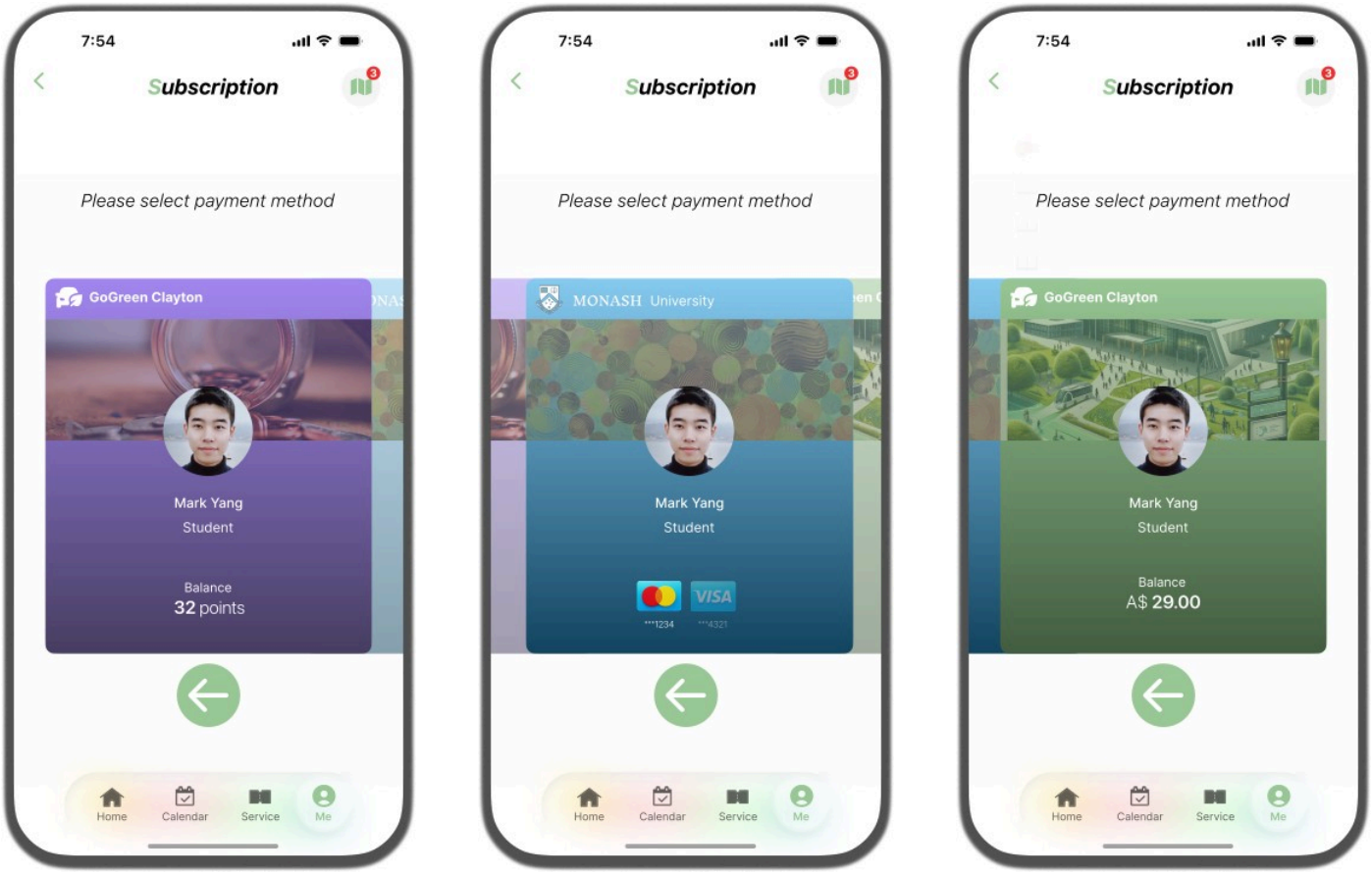


Figure 7.4. The multi-payment interface at connection ports, absorbing the fare and operator differences between modes so that inter-modal transfer remains a single transaction

This stage of commuting significantly impacts perceived usefulness for international students, since it requires rapid interpretation of local transport-related services and infrastructure, especially for those who are unfamiliar or lack relevant knowledge. A clearly defined set of connection ports, made comprehensible through the platform's interface, may diminish dependence on informal knowledge and lower the effort of completing multimodal transfer when approaching the Clayton precinct. This facilitates service continuity by aligning physical infrastructures with reliable digital

indicators, ensuring that the commuters can navigate multimodal information and their last-mile movement on campus seamlessly.

7.1.5. Last-mile

The final phase of the *Go Green! Monash* service journey, the last-mile, addresses the critical transition from the transport services to the student users' destination on campus, such as a lecture theatre, lab, or office. This phase in the MaaS service blueprint signifies a point of high friction where passengers frequently transition from organised mobility systems to localised, context-specific navigation and decision-making.

Through the everyday commuting practice and case studies across academic and field research, the last mile can significantly influence the overall experience of convenience, as it condenses time constraints, uncertainty, and situational demands into a brief interval immediately before arrival and engagement in campus life. In the service blueprint, last-mile interactions are defined by a close connection between digital cues and the prevailing physical circumstances. The requirements of students are seldom uniform at this stage. They rely on the *connection ports (including bus stations,* car parks, or bike arrival stations) and building location, weather exposure, accessibility needs, safety perceptions, and the scheduling of classes or appointments. This makes last-mile support not merely a matter of general information provision but, more significantly, a matter of providing personalised, context-sensitive guidance that helps the student user complete the final connection with less cognitive effort.

In practical design terminology, the last-mile represents a juncture when minor interface decisions can exert significant impact, as they bridge the gap between an abstract plan and the tangible, embodied experience of navigating campus space (see Figure 7.5). The MaaS blueprint delineates the last-mile as a coordinating endeavour across various service layers. The platform can present a clear series of actions that appears straightforward to the user, including confirm arrival, determine the optimal campus entry point, choose a mode of connection (walking, shuttle loop, shared micromobility, or a brief rideshare), and adhere to turn-by-turn or landmark-based directions to the destination building. Underneath this observable layer, the backend service must incorporate schedules, real-time disruption alerts, campus navigation data, and availability indicators for final-mile solutions. When these parts are synchronised, the user perceives continuity; when they are discordant, the user encounters "gaps" that frequently result in irritation or a reversion to private car use for subsequent journeys.



Figure 7.5. A participant testing the proposed MaaS platform for last-mile navigation on campus

7.2. Chapter conclusion

This chapter has examined how the two interventions developed in Chapter 6 operate across a complete commuting journey. The service blueprint integrates decision support, social connection, live information, coordinated transfers, and last mile guidance across five journey stages. Mapping visible touchpoints against supporting processes indicates that the proposed MaaS platform functions as a service system whose continuity depends on data, infrastructure, governance, and institutional partnerships.

The scenario also clarifies the relationship between participant evidence and design decisions. Reported uncertainty, fragmented service information, unfamiliarity with campus transport, and concerns about reliability informed the timing and content of the platform's interventions. Participant feedback therefore shaped the interface features and the service conditions required to support them. Detailed interface documentation, including colour selection, iconography, and typographic hierarchy, is provided in Appendix K, while this chapter retains its focus on the design proposition and its evidentiary basis.

Sustaining a changed modal choice over time differs from prompting a single decision because information alone rarely produces lasting modal shift. As discussed in Sections 2.6.5 and 8.3, the platform combines gamification mechanisms, social comparison, contextually relevant rewards, and live feedback to support a sense of shared effort towards net zero transition without pressuring users. The *Go Green! Monash* platform connects these strategies with the behavioural and cultural conditions participants described, including habits formed through repeated driving and preferences for immediate, tangible benefits within demanding university routines.

The chapter also identifies unresolved boundaries. The platform depends on data and service partnerships that it does not control, and it addresses a specific population within a particular precinct. Within these limits, the designed outcomes contribute by materialising situated knowledge produced through participation and making it available for future implementation in the Clayton precinct. They provide an account grounded in evidence of what a campus MaaS platform would need to do to reduce private car use among international students and what it could not achieve independently.

8. Evaluating the design through participant interviews and iterative refinement

CHAPTER OVERVIEW

This chapter examines the evaluation stage of the research. Following development of the design proposition in Chapter 6 and its integration within the service blueprint in Chapter 7, the enquiry returns to the participants who shaped these outcomes. After the second participatory workshop, semi structured follow up interviews were conducted alongside successive rounds of digital prototyping so that each proposed feature could be evaluated against the commuting conditions it was intended to address. The chapter describes the interview design and method, the prototyping iterations through which the platform was developed, and the design directions produced by participant feedback. These directions include reward mechanisms intended to support continued engagement, gamification elements, and social networking features. Evaluation is treated as part of the design enquiry and examines how international student drivers experienced and interpreted the *Go Green! Monash prototypes. It also identifies the factors that influenced perceived usefulness and acceptability and informs further refinement. Participant responses* were interpreted as evidence of the conditions under which a MaaS platform situated in a suburban university campus may support a sustained change in mode choice, while also indicating where the design proposition requires further refinement.

8.1. Interview design and method

Following Workshop 2, semi structured follow up interviews were conducted with five selected international student participants to elicit detailed evaluative insights concerning the usability, contextual relevance, and potential behavioural influence of the proposed MaaS platform. These interviews constituted the final phase of action research in the study. They extended the participatory design process by enabling reflection and further feedback on the revised interface design and interaction logic. The interview design drew on user centred design principles and emphasised participants' lived experiences and interpretations in the refinement of the final design outcomes (see Figure 8.1).

Each interview followed a semi structured format that combined prepared questions (see Appendix I, Follow up semi structured interview questions) with open ended prompts. This approach supported consistency in thematic coverage while allowing adaptation to emerging participant accounts. The interviews

addressed three interrelated areas that elicited insights across participants' temporal and experiential perspectives.

- **Reflections on the past participatory design workshop experience**

  This introductory segment encouraged participants to reflect on their experiences in both participatory design workshops and to identify aspects of the investigation that they found engaging, challenging, or meaningful. These accounts supported reflexive examination of participatory design within the specific sociocultural context of international students navigating everyday mobility in a suburban Australian university precinct. This framing is consistent with scholarship that questions universal applications of participatory methods and calls for closer attention to contextual, cultural, and affective dimensions. The following sections present the findings.

- **Design insights and interaction feedback on the digital prototype**

  In the second segment of the interviews, participants engaged with an interactive, mid-to-high-fidelity digital prototype of the MaaS platform, developed and refined based on design insights from previous participatory investigation activities. Participants were invited to perform a series of tasks, such as planning a multimodal journey based on their academic schedule of the day, tracking their transport-related carbon emissions, or navigating service functions, while articulating their expectations, interpretations, and challenges. This "think-aloud" procedure (Ericsson & Simon, 1993), combined with future scenario-based prompts, facilitated an embodied and emotive form of criticism.

- **Reflections on potential behavioural change and decision-making**

  The final segment shifted from interface evaluation to broader behavioural and motivational reflection. Participants considered how they might incorporate the proposed MaaS platform into their daily commuting routines. The discussion examined opportunities for behavioural change, with attention to trust in local public transport systems, responses to rewards and gamification, and alignment with academic and personal schedules. As discussed in Chapter 2, interface design alone may have limited capacity to produce sustainable mobility behaviour. Behavioural intentions are shaped by interactions among infrastructural constraints, emotional states, and sociocultural norms (Shove et al., 2012).

Interviews were conducted in participants' preferred language, Mandarin or English, to reduce linguistic barriers and support epistemic inclusivity, an important consideration given the focus on international students. Interviews were recorded in audio and video formats, transcribed verbatim, and coded inductively using a grounded theory informed thematic analysis (Charmaz, 2014). This approach supported iterative identification of usability challenges and opportunities for design refinement. The analysis sought to identify insights that may inform a contextually responsive and adaptable MaaS platform.



Figure 8.1. Semi-structured interviews and digital prototyping sessions with five selected participants, followed by two participatory design workshops

8.2. Digital prototyping

To support the subsequent semi-structured interviews, a refined interactive digital prototype of the *"Go Green! Monash"* MaaS platform was developed, building on insights from the previous participatory workshops with international student participants, with the primary objectives of reducing car dependency and promoting sustainable transportation. This digital platform aims to facilitate an in-depth, user-centred evaluation of the platform's interface design, information architecture, and core service functionalities. Figure 8.2

presents a summary of the interactive digital prototype of the *"Go Green! Monash"* MaaS platform, as tested and evaluated by participants during the follow-up interview sessions. The flowchart illustrates the interrelated framework of the platform's user interface (UI), which is categorised into three essential functional flows: *Flow 1* (personalised home dashboard), *Flow 2* (commute planning and decision-making scenarios), and *Flow 3* (incentive and rewards store). This digital prototype is an effective tool for eliciting user feedback on interface designs, usability, and behavioural engagement (Hinze et al., 2019; Menold et al., 2017) for future sustainable mobility practices.

The interface architecture is structured around four primary functional domains as the main navigation bar at the bottom of the platform, including Home, Plan, Service, and Me. Each domain encompasses a set of strategic design features to facilitate behavioural transition or decision-making through personalised planning, real-time feedback, and peer-support mobility practice.

- The **Home** section, serving as the main landing page of the proposed MaaS platform, functions as a personalised dashboard for monitoring users' transit activities. It enables users to track daily transport-related carbon emissions, physical activity levels, academic-calendar events, and a summary of carbon-saving reward points. By visualising quantitative data and affective cues, the homepage supports self-reflection on commuting behaviours and encourages more informed and sustainable travel decisions for users.
- The **Plan** section enables users to create and adjust personalised travel plans based on their academic-calendar and personal schedules. By integrating multimodal transport options, estimated travel time, costs, carbon footprints, and reward points comparisons iconographically, users can

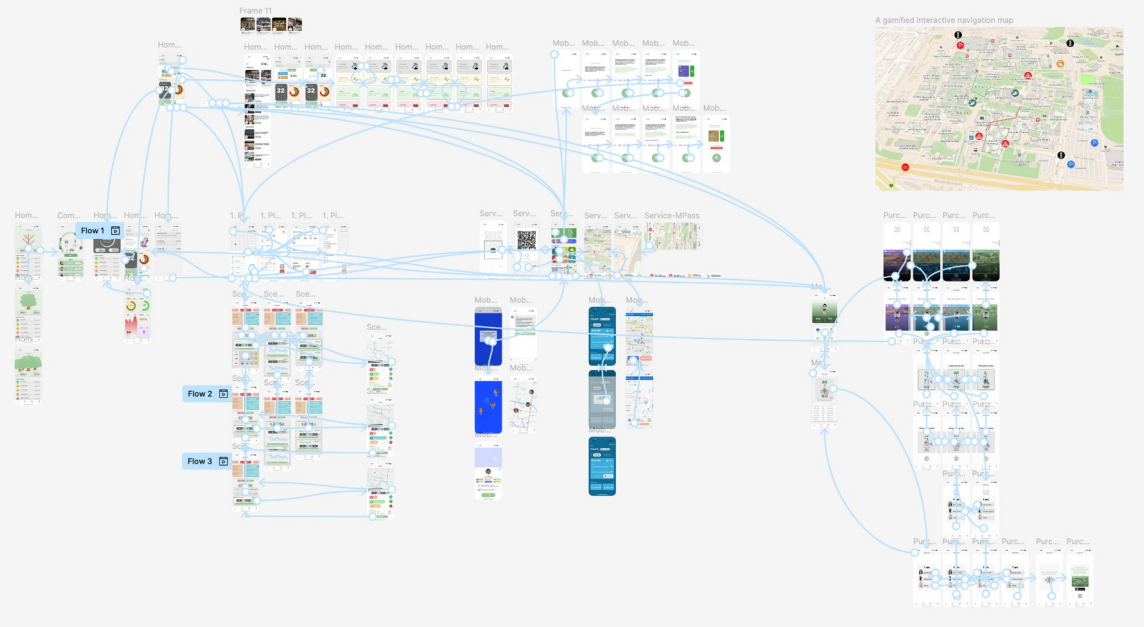


Figure 8.2. Interactive digital prototype interface map tested during follow-up interviews with the participants, screen capture from Figma workplace

easily choose transport modes for specific journeys based on their preferences.

- The **Service** page provides access to multiple on-campus mobility services, including inner-campus shuttle bus, shared bikes, shared cars, carpooling, security bus, and EV charging stations. Additionally, the Service page integrates quick-access buttons on top for the M-Pass (a QR code-based Monash University pass) and a digital Wallet, allowing users to retrieve essential mobility and payment information while in transit.
- Finally, the **Me** section contains user-specific configurations and personal data, including access to a digital ID card, subscription of travel plan details, personal carbon emission records, and institutional- or precinct-wide sustainability rankings. This page also provides user preferences and account settings, thereby supporting a personalised and context-aware interaction with the platform.

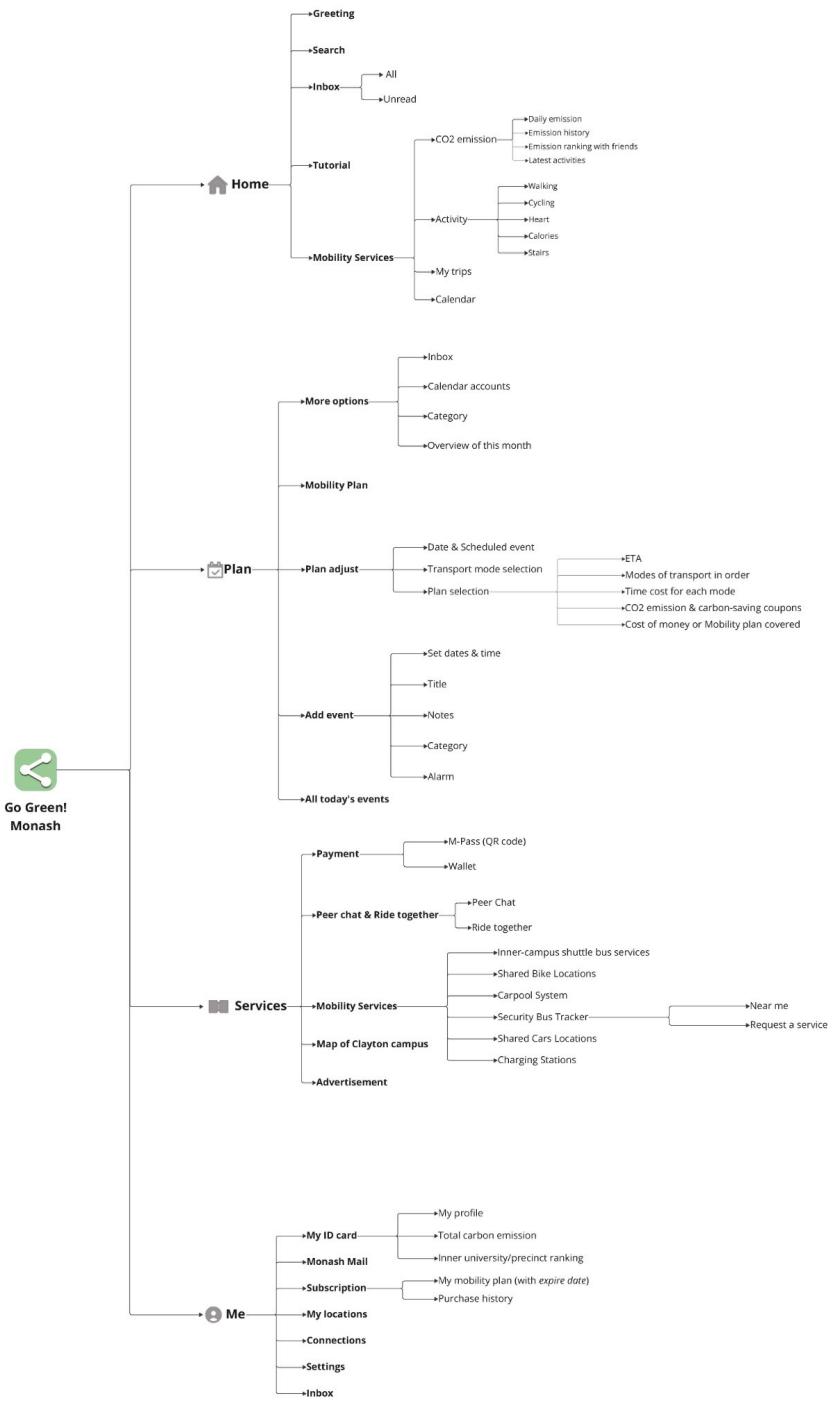


Figure 8.3. Flowchart of the early concept of the "Go Green! Monash" MaaS Platform

8.3. Refined design directions from participants' feedback

The follow-up interviews revealed a range of strategic design-specific insights that emerged through participants' interaction with the refined digital prototype. These insights validated the specific directions set during the participatory workshops and enhanced the comprehension of which design features most effectively aligned with participants' needs, motivations, and expectations on the future MaaS platform.

Building upon the analytical methodology employed in the participatory design workshops (refer to Chapter 4), each interview transcript was subjected to a systematic process of thematic coding. This approach facilitated the identification of recurring user priorities, pain points, and enabling conditions. These summarised design directions reflect the intersection of user values, technological preferences, and strategic design enablers that enhance sustainable travel behaviour and decision-making. The refined design directions are unfolded into three primary categories, including rewarding mechanisms, gamification design elements, and social networking. These design directions align with the three design strategies discussed in literature review, which have been shown to promote sustainable mobility transitions effectively.

Nevertheless, current research has mostly neglected the perspectives of international student drivers from suburban areas in Australia, a context that presents unique behavioural, cultural, and infrastructural challenges (refer to Chapters 2 & 4). The following discussion will analyse how the future MaaS platform can be tailored to address the specific needs and expectations of this demographic group, international student drivers in suburban university contexts, and enhance their sustainable travel decision-making process.

8.3.1. Rewarding mechanism as a primary enabler of continued engagement

In the follow-up interviews, incentive mechanisms were identified as the most consistently mentioned factor for sustaining engagement with the proposed MaaS platform among five selected participants. The participants predominantly identified the inclusion of tangible and trackable incentives as a crucial facilitator for shifting from habitual private car use to more sustainable mobility alternatives (Cools et al., 2016; Verplanken & Wood, 2006), such as transportation credits, discount coupons, or redeemable points gained from the validated sustainable journeys. Furthermore, this preference corroborates previous studies in behavioural economics and persuasive system design (refer to Chapter 2), indicating that extrinsic motivation, particularly when made visible and contextually relevant, can significantly influence transport choices (Alfaro et al., 2025; Bamberg, 2013; B. Fogg, 2009; Hamari et al., 2014).

Participants expressed that the reward system embedded within the proposed MaaS platform provided useful benefits, and it affirmed their efforts and fostered a sense of goal orientation and progress, particularly when combined with personalised carbon emission monitoring features.

> "(*researcher: what would drive a change in your behaviour?*) So my biggest driving force is still the rewards, the money you earn." (C#10_FI_00:21:05)

Nevertheless, as discussed in the Workshop 1 findings, some participants preferred non-monetary, platform-embedded rewards, such as access to exclusive university services, bonus

features, or ranking within a sustainability leaderboard, over direct financial alternatives (refer to Chapter 4). During the interview sessions, some participants further explained their expectations regarding the reward mechanisms embedded within the proposed MaaS platform. For instance, participant #10 further indicated that the visual representation of the "growth chart" is another attractive factor that influenced her continued engagement in sustainable travel. Similarly, participant #4 expressed a desire for playful, real-time feedback mechanisms that communicate environmental impact and reward through his familiar, relatable metaphors to enhance continued engagement on the platform usage (see the quotation below). These preferences on the rewarding mechanisms highlight the significance of designing reward systems that are both economically attractive and socially or culturally relevant.

"Ideally, when I open the app, the upper half of the screen would display something visually appealing—perhaps an animation or a quick summary—showing my total progress for the month, year, or today. The lower half could also feature an animated visualisation, perhaps representing my usage. For example, it might say, '*You've saved enough to buy several hamburgers, a few drinks, or call a ride.*'"
(C#4_FI_00:32:22)

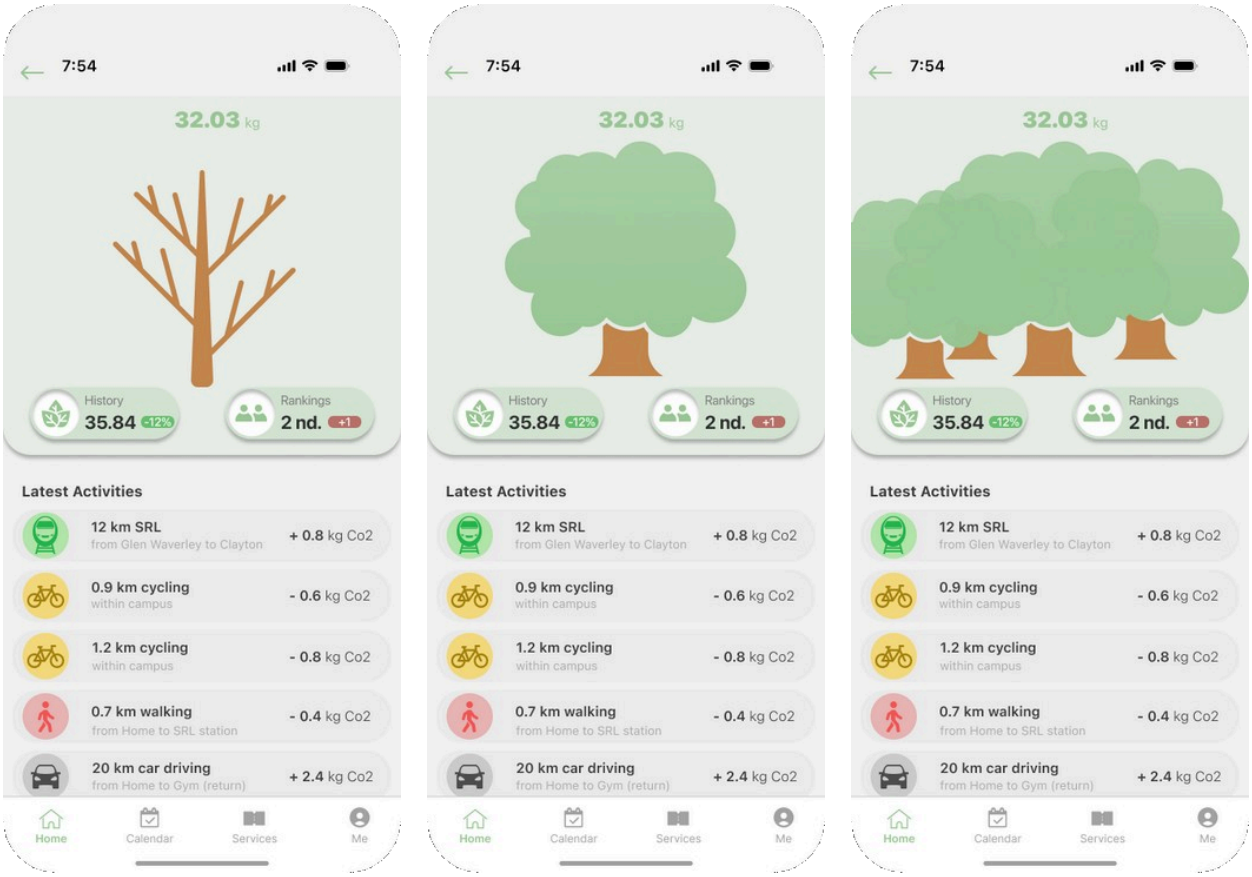


Figure 8.4. Interfaces of transport-related carbon emissions

The interviews revealed that the visibility and timing of incentives were essential for user engagement. Participants underscored that incentives need to be immediate or predictable, preferably integrated into the daily interaction flow on the digital platform, such as after trip completion or in a weekly summary. To address this insight, Figure 8.4 presents a MaaS platform design concept that employs a metaphorical real-time visualisation of transport-related carbon emissions. The interfaces utilise a tree-growth metaphor, progressing from a single trunk to a mature tree and ultimately a dense forest. This ideation conveys users' cumulative environmental impact over time, translating real-time

emissions data into an intuitive, temporally legible representation of their evolving contribution to sustainable mobility practice. This visual metaphor reflects principles of persuasive design, which suggest that immediate affective feedback can enhance user engagement and facilitate pro-environmental behavioural change (B. J. Fogg, 2003; Froehlich, 2011). Through integrating carbon emission tracking functionality within a familiar and emotionally resonant ecological symbol, this design practice aims to enhance user environmental awareness and foster a sustained commitment to low-emission travel choices.

In conclusion, participants regarded reward mechanisms as important components of the proposed MaaS platform's motivational architecture. These mechanisms connect sustainability objectives with personal benefits and may make sustainable commuting choices more tangible and personally relevant. The design direction therefore supports reward systems that are contextually embedded, psychologically meaningful, and behaviourally appropriate. Such systems may foster a reinforcing cycle of sustainable decision making among international student users.

8.3.2. Gamified design elements

As discussed above, participants' feedback highlighted that, alongside economic rewarding mechanisms, gamification design elements also played a significant role in enhancing attractiveness and sustained usage of the proposed MaaS platform. The gamified design features included a carbon-saving competition, progress tracking, and the recognition of personal milestones, all of which were integrated to enhance the user experience of the proposed MaaS platform. In the follow-up interviews, participants also emphasised the motivational benefits of the gamification elements, such as promoting sustained engagement, habit development, and a positive emotional connection with the MaaS platform. The design direction is supported by a substantial collection of literature indicating that gamification can enhance user motivation by fulfilling intrinsic needs, such as competence, social relatedness (Capatina et al., 2024; Chong, 2019; Mabalay, 2025), and autonomy (Capatina et al., 2024; N. Zhang et al., 2025).

Beyond the core behavioural drivers of reward-based mechanisms, participants also responded positively to additional gamified design features, such as carbon-saving leaderboards, sustainability achievement badges, and daily or weekly challenges linked to low-emission mobility. These elements were perceived as motivational methods that could encourage a sense of achievement, friendly competition, and continued engagement with the proposed MaaS platform. For the interview participants, these gamified design features were considered capable of fostering a sense of playful competition among peers or other university students, thereby making their future sustainable commuting experience more engaging, socially relevant, and intrinsically motivating. As participant #2 remarked during the interview session, "Gamification, like leaderboards or virtual

badges, probably interests me most." (C#2_FI_00:42:27)

A notable example is Ant Forest, a feature of the Alipay app in China, which illustrates users' low-carbon activities, such as walking instead of driving and using public transportation, through the growth of virtual trees that are eventually correlated with the planting of real trees in desertified regions (see Figure 8.5). These interfaces include the welcome page (left), which displays medals recognising personal contributions to sustainable behaviours and encourages competition among the app's friends; the main page (middle) allows users to nurture their own virtual trees through the accumulation of "green energy" earned by engaging in various low-carbon activities; and the friends' forest page (right) enables users to collect green energy from others. The app ecosystem reinforces social interaction and collective environmental responsibility. This initiative has engaged over 500 million users and resulted in the planting of more than 100 million trees (United Nations, 2023), demonstrating that gamified and ecologically oriented feedback can promote environmental awareness and sustain behavioural change (Yang et al., 2018; Y. Zhang et al., 2020).



Figure 8.5. The user interface pages of Ant Forest illustrate key gamification and social engagement features

However, participants also expressed concerns about over-gamification and the potential for unnecessary visual complexity within the proposed MaaS platform. Several participants cautioned against excessive or inadequately integrated features that could undermine the platform's usability and fundamental objectives, despite the general positive reception of gamified design components. Participants highlighted the significance of clarity, contextual relevance, and consistency with the platform's core functionality and sustainable travel features, as previously mentioned about design simplicity. These reflections brought attention to the need for a balanced design strategy between

enhanced sustained engagement and straightforward navigation of the platform's environmental goals. As C. S. Deterding and Walz (2015) and Rapp et al. (2019) emphasised, a gamified design strategy requires consideration of a contextualised and user-centred approach to prevent counterproductive effects.

Overall, gamified design elements could provide a potent mechanism for influencing attitudinal changes and daily travel behaviours towards more sustainable conditions among participants when effectively integrated and contextually embedded within the proposed MaaS platform. The design of a university community-based MaaS platform provides design opportunities to foster collaborative and continued engagement and sustainable achievement among the student demographics.

8.3.3. Social networking elements

The third refined design direction summarised from the follow-up interviews points out the possible use of social networking functionalities within the proposed MaaS platform to enhance user engagement, trust, and collective travel behavioural change. Some participants expressed a desire for map-based layers embedded into the proposed MaaS platform that could integrate real-time updates or reviews from other users about their sustainable mobility achievements or share commuting tips. The participants envisaged that the platform could evolve into a socially integrated digital ecosystem for the university-based communities instead of just a travel planning tool.

This research finding corresponds with some recent studies on digital mobility platforms, indicating that social comparison and the visibility of peer behaviours affect the adoption of sustainable transportation (Ahmed, 2025; Blandin et al., 2025; Giubergia et al., 2024). The following design insights articulate two emerging social features identified during the interview sessions: interactive mapping with transport-related information sharing, and social goal framing through visible collective achievements.

- **Interactive mapping and transport-related information sharing**

  A specific subtheme that emerged from this design direction is the proposal of integrating an interactive mapping interface within the MaaS platform that could enable users to share and access transport-related information contributed by peers. Participants highlighted the value of integrating interactive, campus community-informed mapping tools into the MaaS platform to enhance context-specific transportation awareness. The participants sought a dynamic and collaboratively generated layer of spatial information, instead of depending exclusively on static official data, to accurately reflect on-the-ground realities, such as safe pedestrian pathways, route planning, problematic intersections, cycling safety, and bike parking. These features are especially important and relevant for newly arrived international students, who usually lack knowledge and depend significantly on peer-based trust networks. As participant #7 mentioned, "(When I first arrived in Melbourne) I pretty much *stuck* really closely to my

friends; we'd go out together all the time. Then, over time, I gradually figured out how the local transport network worked on my own." (C#7_CR_00:02:33)

From a design perspective, this insight emphasises the need for integrating location-based social annotations, enabling users to tag, rate, or comment on locations within the local transport network. These design features transform the digital map from a conventional navigational tool into a dynamic ecosystem of commuting experiences. In this context, the mapping function within the proposed MaaS platform can be seen as a form of collective sensing, enhancing users' spatial literacy and providing emotional reassurance through real-time awareness of peer mobility patterns and shared routes.

"Suppose I'm travelling from my house to Clayton—I would like to know how many people, at this time, are going to Clayton from somewhere around my address, and how many of them share over 90% similarity with me in terms of travel behaviour and have chosen the same mode of transport using the app." (C#4_FI_00:37:42)

"(I propose) actually, that sounds a bit like *AllTrails* — the hiking app. You can see different routes uploaded by other users. That could be useful, especially for new students who don't know their way around." (C#2_FI_00:44:24)

McLean's (2017) "smellmap" provides a relevant design precedent (see Figure 8.6). In that study, urban pedestrians described as "smellwalkers" collectively recorded olfactory experiences across metropolitan areas to reveal sensory geographies often absent from conventional maps. The study suggests that subjective and qualitative user data may generate localised and affective cartographies. Within a MaaS context, an interactive mobility mapping function might similarly represent collective student perceptions of safety, comfort, efficiency, and trust. As discussed previously, these factors may influence sustainable travel decisions in suburban university settings and indicate the need for transport interventions responsive to diverse user requirements.



Figure 8.6. Visualisation of a "smellmap" by a smellwalker (source: Kate McLean, 2017)

Similarly, participant #4 mentioned a function of route sharing from his previous experience on a bike computer. The participant highlighted the visualisation of a live navigational map designed for a cycling computer (see Figure 8.7). The user interface of a cycling computer provides real-time visualisation of other users' locations and travel routes by integrating a GPS-based mapping system that continuously updates positional data. He also pointed out that the system facilitates real-time awareness of fellow cyclists' positions and movements, enhancing social connection and spatial coordination during group or solo rides. In relation to the proposed MaaS platform, the participant envisaged the potential of integrating a similar concept of an interactive mapping interface that visualises shared commuting routes and supports real-time wayfinding (refer to Figure 8.8). The user interface pages for security Bus Tracking (left) and inner-campus navigation (middle and right) illustrate the integration of core gamification and social engagement design strategies within the MaaS platform. The proposed functionality could enhance familiarity with local transport networks and social

connection, especially for newly arrived international students.

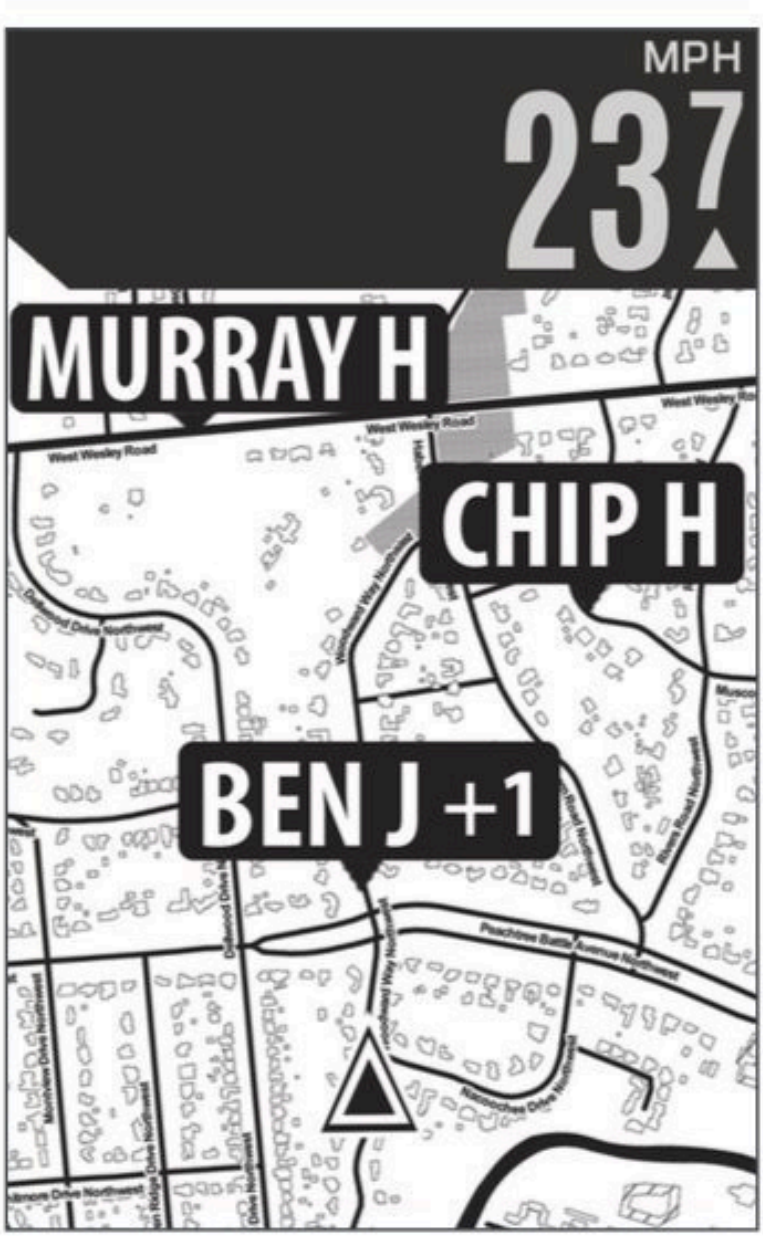


Figure 8.7. User interface on a live navigational map on a cycling computer

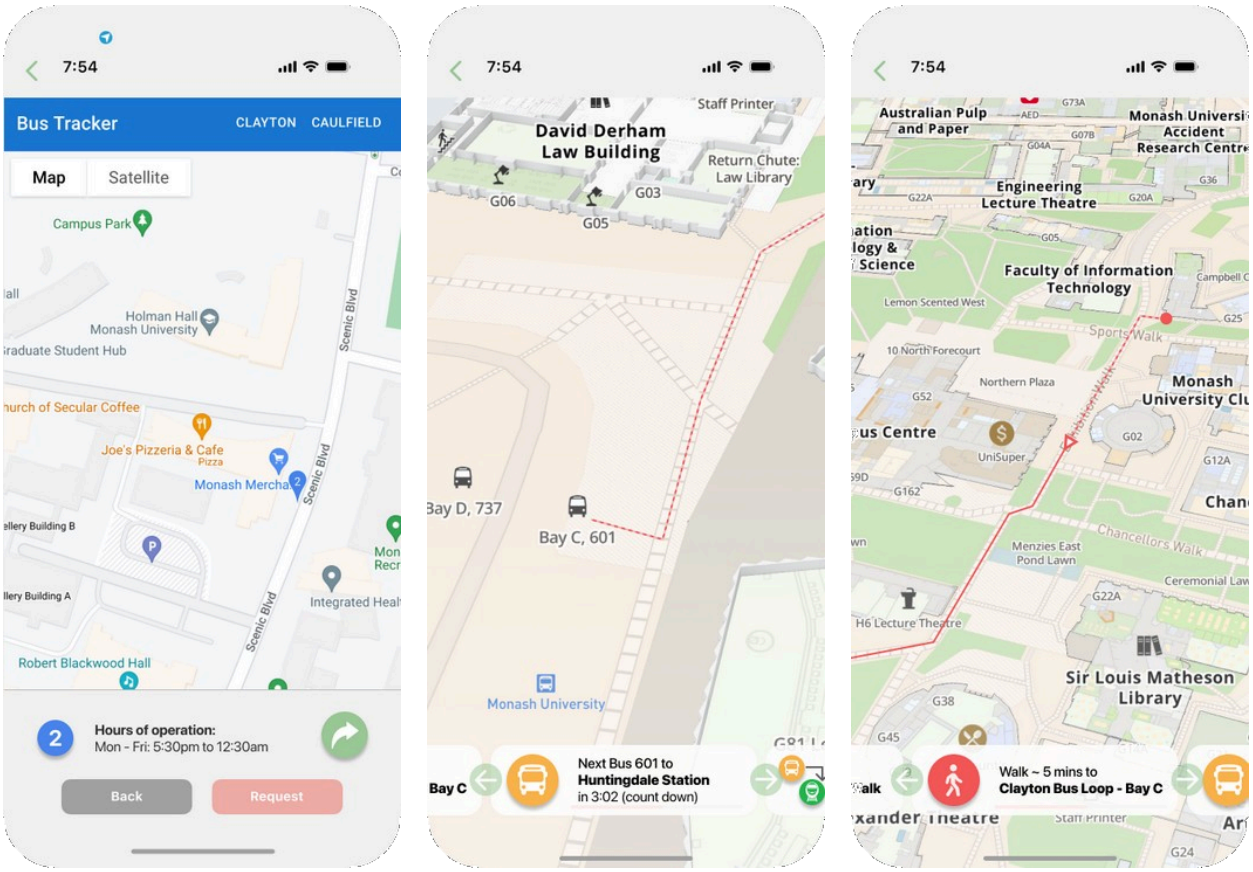


Figure 8.8. The user interfaces of Security bus tracking and inner campus navigation

In summary, the proposed interactive mapping function highlights the significance of environmental information contributed by users. It positions the MaaS platform as a participatory digital medium for community-based transport information sharing and socially embedded sustainable mobility practice, in addition to its logistical and instrumental functions.

- **Social goal framing through visible collective achievements**

The interviews also revealed that participants were more engaged with the MaaS platform when they felt their actions were part of a collective effort toward sustainability, particularly if these efforts were made visible within a broader social and communal context, such as university campus-settings or peer groups.

As discussed in Chapter 2, gamification elements such as badges, points, and leaderboards may enhance user experience and encourage behavioural change in sustainable mobility applications (Avril et al., 2024; Oppong-Tawiah et al., 2020; X. Wang et al., 2022; Wangi et al., 2022; Yen et al., 2019). Interview participants indicated that a point-based incentive system may be effective when it provides real-time feedback and recognises milestones, as in Apple's activity badges (see Figure 8.9). Apple Watch activity tracking has been widely adopted in health and fitness applications and may support behavioural change by visualising progress and rewarding consistency through gamified feedback (Ridgers et al., 2021; Attig & Franke, 2020; Plangger et al., 2022). This precedent suggests that familiar design metaphors may be adapted to sustainable mobility when they provide immediate and personalised recognition of users' efforts.



Figure 8.9. Screenshots of Apple's activity badges (screens captured from Apple fitness application)

To address this design insight, the proposed MaaS platform was iteratively developed to include carbon-saving milestone badges as one of the central motivational design features (see Figure 8.10). These designed badges aim to enhance users' self-determination (Deci & Ryan, 2000) with sustainable travel behaviours and enable social sharing within users' peer networks, facilitating broader participation in low-emission commuting practices across a suburban university-based context. Based on the principles of social influence theory and gamification design, these visual achievements can be used as symbolic incentives that promote personal advancement and serve as social proof

within digitally mediated communities. The interface of the carbon-saving milestone page enables users to review and share their achievements, such as badges for first sustainable travel, winner of the team campaign, and car-free day.

The design concept could leverage intrinsic and extrinsic motivational drivers to encourage and expand sustainable travel practices among student groups on a suburban university campus.

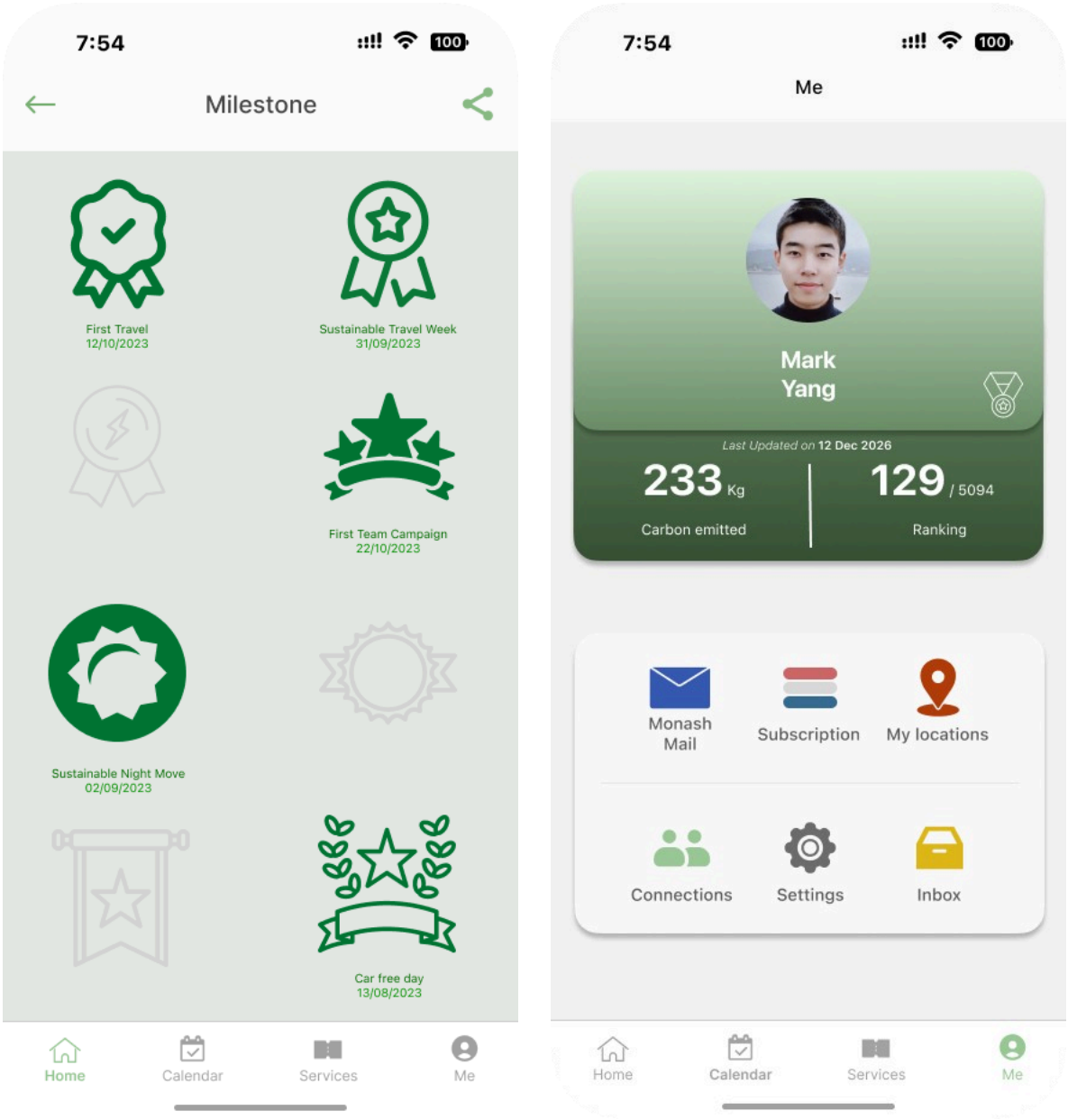


Figure 8.10. Initial design concept of the carbon-saving milestone badges page and personal profile page

This design feature indicates how familiar and emotionally salient patterns may be adapted for a university MaaS platform. Gamified social features, including

achievement badges, progress sharing, and peer comparison, might incentivise individual behaviour and support a collective culture of sustainable travel within the precinct. Consistent with the preceding design directions, these elements would need to be timely, personalised, and socially visible to support a sense of achievement across students' academic and social contexts.

8.4. Chapter conclusion

This chapter has recorded how the design proposition was evaluated with participants and revised in response. The follow-up interviews and iterative prototyping confirmed some design decisions and changed others, and the chapter has recorded both. Three refinements proved consequential: rewards had to be immediate and locally redeemable instead of withdrawable, gamified elements had to support a sense of shared effort instead of individual competition, and social features had to remain optional and low commitment if they were not to deter use. Read together, these refinements indicate that sustaining a changed mode choice depends less on the persuasive force of any single feature than on the fit between the platform and the academic routines, time pressures, and social conditions participants described. These findings are carried into the concluding chapter, where the contribution of the research and the limits of what this evaluation can claim are discussed.

9. Discussion and conclusion

CHAPTER OVERVIEW

This chapter synthesises the exegesis by delineating the project's contributions as a practice-based, participatory design research focused on diminishing dependence on private cars among international student drivers in a suburban university setting. The project elucidates its practice-based research contribution, whereby design work serves as a medium for enquiry and knowledge generation. The following sections explain the contribution of this research project in three areas, including a theoretical framework elucidating how behavioural preferences, social expectations, and infrastructural conditions influence everyday transport mode-choice in this context, a methodological contribution that illustrates participation as context-specific design insights synthesis from workshops, interviews, and iterative prototyping with participants, and a practical contribution that converts these insights into service and interface strategies for a prospective campus-based MaaS platform. The chapter acknowledges significant limits of the project and delineates directions for future research, focusing on unresolved issues and aspects requiring long-term evaluation in everyday commuting environments.

9.1. Introduction

This chapter synthesises the research outcomes and articulates its theoretical, methodological, and practical contributions within the broader field of design for sustainable mobility transitions. This practice-based PhD presents a participatory design methodology that engages international student car drivers within the Clayton precinct to develop actionable mobility interventions that support sustainable travel behaviours. The discourse characterises the Go *Green! Monash* digital platform as a practical outcome of a Research through Design (RtD) investigation (Frayling, 1993; Zimmerman et al., 2007b), instead of as the principal locus of contribution. This approach aligns with current literature, which emphasises the philosophical value of design practice as a mode of enquiry that produces contextual knowledge through creation, reflection, and engagement (Cross, 2007a; Findeli, 2008).

The overarching research question, **How can participatory design with international student drivers inform the interface and service design requirements of a campus-based Mobility-as-a-Service proposition that supports sustainable commuting decisions at the Monash Clayton precinct?**, is addressed by investigating the intersection of design practice, behavioural change, and sociotechnical transition. The study illustrates how participatory and service design approaches can uncover cultural and infrastructural barriers that influence sustainable commuting behaviours, particularly among international students in a suburban university environment.

The chapter is structured to integrate these findings and contextualise them within the three interconnected dimensions of academic contributions (refer to Table 9.1). Initially, the chapter delineates the theoretical contribution, which expands participatory and transition design theories (Irwin, 2015; Manzini, 2015) into the realms of Mobility-as-a-Service and sustainable mobility, situating international students as niche actors whose travel practices are unusually open to reconfiguration within precinct-level decarbonisation initiatives (refer to Chapter 2 and Section 9.3.1). The chapter then clarifies the methodological contributions, illustrating how participatory design studio techniques, such as journey mapping, detective wall construction, Crazy 4's ideation, and future mobility scenario prototyping (refer to Chapters 4 & 5), constitute a transferrable methodological assemblage for sustainable mobility service design (Akama, 2015; Sanders & Stappers, 2014). Finally, the chapter outlines the practical contribution through three design strategies, including rewarding mechanisms, gamification elements, and social networking (refer to Chapters 5 & 6), representing the design outcome of the PhD project.

Table 9.1. Summary of the project's theoretical, methodological and practical contributions, mapped to the research question each one addresses

Dimension	***Contributions***	***Relationship to the project***
Theoretical	The project reframes Mobility-as-a-Service in a net-zero precinct by examining international students as niche actors in a precinct-level transition, thereby connecting place, policy, and lived experience.	Frames the '*Why'* of the research and legitimises the participatory, transition-oriented approach.
	The project promotes a strategic design approach that places emphasis on the "dark matter" of systems instead of interface artefacts and views the platform as the result of research instead of a standalone contribution.	
	The project explains how the Clayton Net Zero Precinct's context and place-making influence sustainable mobility behaviours and design possibilities.	
Methodological	The project develops a participatory design approach that involves international students from the outset, leveraging their past experiences to shape problem framing, criteria, and concepts.	Operationalises the '*How'* of the theory and produces the empirical and design data enabling the practical outcomes.
	Integrates ethnographic engagement, co-design workshops, and service blueprinting into a coherent practice-led research workflow, with reflection used to generate scholarly insights.	
	States the evidential status of the findings: participant critique across two workshops and five interviews establishes what a campus MaaS service would need to do, while efficacy in use remains untested and is scoped as future work.	
Practical	The project develops a concept for a working platform that operationalises the research insights for sustainable mobility practices, showcasing how these participatory insights can be translated into service futures and flows.	Demonstrates and validates the *'What'* of the methodology and feeds back into

Dimension	Contributions	Relationship to the project
	The project communicates its process and outcomes in a form that gives priority to the methodology instead of to the "app", which reduces the risk of a reductive reading of the contribution. This orientation also shaped the final articulation of the project. The design outcomes were presented publicly as the exhibition Navigating Clayton's Sustainable Future: Exploring New Journeys through Design, Mobility, and Community, which placed the *Go Green! Monash* platform alongside the visualised commuting narratives and the wider mobility conditions of the Clayton precinct. The exhibition is treated as the final design research outcome of the project instead of as a dissemination activity appended to it, although visitor responses were not systematically collected and accordingly carry no evidentiary weight in this exegesis.	theoretical refinement through reflection.
	The project defines practical routes and limitations for institutional adoption, such as Monash University's BPD or other suburban communities, while framing collaboration and implementation as future endeavours instead of existing tasks.	

Finally, the chapter reflects on the limitations and outlines future research opportunities, acknowledging the conceptual and contextual boundaries inherent in practice-based design research. The *Go Green! Monash* digital platform is not intended as a ready-deployable product; more importantly, it functions as a near-future oriented designed artefact or outcome in a broader sense that suggests ways to encourage more sustainable travel behaviours or decision-making without claiming it has already achieved the change. This chapter enhances the exegesis by demonstrating how design-led research acts as a methodological and epistemological mediator in facilitating sustainable mobility changes in a suburban university environment.

9.2. Practice-based research contribution

In this project, practice refers to design work as a mode of research, where designing functions as a process of enquiry and knowledge generation, as a means of producing design outcomes. The test of that claim is whether designing produced understanding that analysis of the same material would not have produced. Three instances are worth stating plainly, because each began as a design decision and ended as a revision to what the research understood.

The first concerns rewards. The literature on incentivising sustainable travel, and the initial design response drawn from it, treated financial reward as the strongest available motivator. Participants rejected the withdrawable cash mechanism when they encountered it in prototype form, not as a matter of preference but with an argument: money removable from the platform would be removed, and the behaviour would stop when the balance

was spent. That objection was only available because there was something to object to. It changed the design towards immediate, locally redeemable benefit, and it changed the research position on the relationship between reward structure and habit maintenance.

The second concerns the social features. Designing them required deciding what the social dimension was for, and the two candidate framings, comparison and competition on one hand, shared effort and local knowledge on the other, were indistinguishable in the literature but not to participants. Their responses separated them decisively, and in doing so identified belonging instead of competition as the operative mechanism. That distinction is now part of the theoretical account; it was produced by having to build both.

The third issue concerns the boundary of the design. Constructing the service blueprint required identification of every dependency that the platform could not satisfy. These dependencies include operator data, fleet maintenance, lighting, and footpath conditions at connection points, and institutional parking policy. Earlier analysis of campus car dependency had identified these factors as contextual conditions. Service design recast them as structural dependencies because the blueprint could not be completed without them. This constitutes a more specific claim than a literature review alone could support.

What these instances share is that the artefact created the conditions for its own critique. Participants could not have argued about an incentive structure described to them in the abstract with the precision they brought to one they had used, and the researcher could not have located the design's dependencies without attempting to specify the service end to end. This is the sense in which the practice was research instead of the application of research. The digital platform, albeit visually and interactively engaging, provides evidence of an underlying methodological process through which knowledge may be generated. In alignment with research-through-design (RtD) paradigms, an artefact serves not as a final product but as a medium for generating, conveying, and scrutinising knowledge during the design process (Frayling, 1993; Koskinen et al., 2011; Zimmerman et al., 2007b). This research project enhances design scholarship not by assertions of technical innovation, but by formulating a unique methodological framework for participatory service design within the realm of Mobility-as-a-Service systems and suburban sustainability transitions.

In practice-based design research, the artefact-as-knowledge paradigm acknowledges that the output serves as a crystallisation of enquiry instead of a definitive answer (Cross, 2007a; Findeli, 2008; Jonas, 2007). As Findeli (1998) argues:

"…'project-grounded research'… is a kind of hybrid between action research and grounded theory research, but at the same time it reaches beyond these methods, in the sense that our researchers in design are valued both for their academic and professional expertise, which is

not the case even in the most engaged action research situations.

…although the importance of the design project needs to be recognised in project-grounded research, it should never become the central purpose of the research project, otherwise we fall back into R&D. Therefore, since practice is only a support for research (a means, not an end), the main product of which should remain design knowledge."

The *Go Green! Monash* platform embodies the iterative design process by which the project examined the behavioural, social, and infrastructural dynamics of international student mobility around the Clayton precinct. The objective is to make the research process concrete by converting theoretical and methodological discoveries into a communicative and experiential format. This viewpoint aligns with Gaver's (2012) concept of research artefacts as generative forms, whereby planned outputs encourage interpretation, incite reflection, and foster conversation instead of addressing specific issues.

This research project presents the *Go Green! Monash* digital mobility service platform as an artefact derived from recognising and understanding the sustainable travel challenges faced by international student car drivers. The designed platform was developed through ideation and prototyping phases shaped by participatory workshops and concluded with evaluative feedback loops that enhanced the artefact and the foundational theoretical comprehension of behavioural change in a suburban university context (refer to Table 9.2).

Table 9.2. Project-specific Design Research Process, adapted from Vaishnavi et al. (2015)

Process stage (in chronological order from top to bottom)	***Purpose***	***Activities***	***Outputs***
Awareness of the problem, **Contextual grounding**	Identify and understand the behavioural, sociological, and infrastructural barriers influencing international students' everyday mobility practices around the Clayton precinct.	**Literature and Case review** on design strategies and cases of sustainable mobility transition at the university or higher educational environments, particularly focused on international student groups (refer to *Chapter 2*) **Field observation** with reflexive journaling and situational documentation **Secondary data mapping**, including BPD datasets (refer to *Chapter 2.8*)	Framework of mobility challenge at the Clayton campus Contextual mapping of car-dependence patterns Initial problem statements

Process stage (in chronological order from top to bottom)	***Purpose***	***Activities***	***Outputs***
Suggestion- **Participatory ideation & co-envision**	Gather and transform empirical research findings into design brief of the research project through participatory investigation with international student participants	**Participatory design workshop 1, including sessions** of *postcard past-storytelling, radar mapping, detective wall building, Crazy 4's and future mobility scenarios structuring* (refer to *Chapter 4.4*)	*Tentative* design hypothesis and participant narratives A service requirement which guides the designed platform Physical prototypes of the service platform
Development- **Iterative prototyping**	Convert initial research findings and design ideas into early-stage interfaces of the Mobility-as-a-Service digital platform	**Participatory design workshop 2, including sessions** of *contextualised evaluation and future storytelling, co-ranking,* and *re-radar mapping* (refer to *Chapter 5.2*)	A functional and interactive digital prototype Evolving platform architecture integrates behavioural motivation factors and working flows
Evaluation- **Reflection and participant critique**	Further refine and test the designed platform's digital prototype with selected international student participants. In-depth participant evaluation of the platform's plausibility, and of the conditions participants judged necessary for a change in MaaS-based commuting	**Semi-structured follow-up interview** with selected participants (refer to *Chapter 8)* **Thematic qualitative data analysis** (refer to *Chapter 4.2.2*)	A service blueprint, which details the potential future user journey of the platform Evaluative insights into motivation and adoption in future MaaS systems among international student groups
Conclusion- **Knowledge contribution & circumscription**	**Dynamic loop / iterative procedure:** Each step of the research iteratively informs the subsequent one, with circumscription facilitating the refinement of theory and artefact design through contradictions revealed in practice.	**Knowledge contribution:** Emergent insights enhance the understanding of design science and contribute to the developing field of participatory mobility service design. The public exhibition *"Navigating Clayton's Sustainable Future"* presents the design research outcomes as a connected mobility proposition instead of as a digital product.	

The iterative development of the digital platform embodies methodological innovation. The platform is the result of a participatory approach that actively involved international students as co-designers through each essential stage of design concept development in the design decision-making framework. As Akama (2015) asserted, the significance of participatory design is in relational interactions and contextual awareness instead of in deliverables. The interactive and creative activities during the participatory investigation process, including journey mapping, detective wall building, Crazy 4's brainstorming, and future mobility scenario prototyping, formed a methodological framework for

extracting and converting intricate subjective realities into human-centred design artefacts. These processes have illuminated how international students navigate social, infrastructural, and emotional dimensions of commuting within a suburban university environment. By attending to everyday routines, contingencies, and embodied experiences that shape their mobility or decision-making, this approach provides an empirically grounded understanding of movement as a lived, dynamic practice. Using design ethnography perspectives (Abelsson & Bisholt, 2017; Guell et al., 2012), it underscores that commuting is not merely a logistical activity but a continuous, contextually embedded process through which students interact with and acclimatise to their surroundings, navigate social relationships, and regulate emotional states in their daily lives (Pink, 2012; Pink et al., 2020).

This research project positions the designed platform as a means of methodological articulation, consequently enhancing the discussion on the epistemic agency of design (B. Chen & Zhang, 2016), which is the ability of design to generate context-specific knowledge through action, creation, and contemplation (Koskinen et al., 2011; Niedderer & Roworth-Stokes, 2007). The artefact designed for this project is the *Go Green! Monash* digital Mobility-as-a-Service platform, which can be seen as a boundary object (Akkerman & Bakker, 2011; Caccamo et al., 2023; Dhaundiyal & Sharma, 2022; Star & Griesemer, 1989) that connects theory, method, and practice. In this research project, the designed artefact aims to translate design insights and empirical findings from the participatory investigation with participants into an early concept of an imaginative digital platform that can be experienced, evaluated, and contemplated by international students on the Clayton campus. In Monash's Net Zero Precinct initiative, this approach positions design not merely as a tool for technological optimisation but as a facilitator of sociotechnical transition, promoting discussion on how behavioural change may be encouraged through everyday mobility practices.

In conclusion, this research project establishes that the academic contribution lies not in the proposed digital platform itself, but more importantly in the methodological and theoretical innovations achieved through participatory design enquiry with the international students. By conceptualising the platform as a methodological artefact instead of a technological product, it enhances research through design and participatory design discourses, illustrating how lived experiences can contribute to sustainable mobility transitions in suburban university settings. The research project positions international students as niche actors in the sense specified in Section 9.3.1, and participatory service design as a mediator among the behavioural, infrastructural, and cultural aspects of the future Net Zero Precinct.

9.3. Contribution to knowledge

The contributions are structured around three subsidiary research questions, as organised in Table 9.3, guided by the overarching research and design question. Each subsidiary research question corresponds to a distinct category of design knowledge generation, theoretical, methodological, and practical (artefact-led), enabling the exegesis to illustrate how explanatory insight, research process evolution, and design outcomes collectively enhance comprehension and action within a suburban university mobility context.

"New knowledge is embedded in and manifested by artifacts and the supporting materials that describe them."

- (Wobbrock & Kientz, 2016, p. 40)

The three subsidiary research questions collectively operationalise the project's central proposition, that design practice, situated within a Design Science Research (DSR) framework and participatory design methodology, can produce substantial knowledge regarding everyday commuting behavioural change, co-creation dynamics, and sustainable service innovation in a suburban university setting. The first subsidiary research question (RQ1) provides a theoretical contribution by elucidating the behavioural, social, and infrastructural factors influencing international students' mobility choices and their implications for sustainable transition theory. The second subsidiary research question (RQ2) provides a methodological contribution to illuminate how participatory and service design methodologies serve as reflective tools for enquiry and engagement in suburban university mobility contexts. The third subsidiary research question (RQ3) leads to a practical contribution in iteratively developing the *Go Green! Monash* digital platform, which converts cultural and contextual insights into design interventions. The subsequent subsections elaborate on each of these contributions in detail.

Table 9.3. The research question framework, showing how the three subsidiary questions operationalise the central proposition that situated design practice can produce knowledge about commuting behavioural change

Question type	Research question	Primary focuses & objectives	Knowledge contributions	Design research activities/ methods
Overarching research question	How might design research and practice enhance the digital experience of a future Mobility-as-a-Service (MaaS) platform for international students to facilitate sustainable travel decision-making?	Establishing the integrative objectives of the research project, which connects design practice with sustainable mobility behavioural change	Integrative and epistemological contribution, which advances understanding of design as a research mode for sustainable mobility transitions	Framing of research objectives; Literature review and synthesis Application of design research and sustainability transition theories Iterative evaluation and validation of designed artefacts with participants

Question type	Research question	Primary focuses & objectives	Knowledge contributions	Design research activities/ methods
Design question	How might we design a campus community-based and user-centred MaaS interface that supports sustainable commuting with international students?	Guiding the practical and service-oriented design of the *Go Green! Monash* digital platform	Applied and practice-based contribution, which demonstrates how designed artefacts can function as communicative and reflective tools	Iterative prototyping; Interface development; Proposed a design model of participatory design investigation sessions Generating a future mobility service blueprint
Sub-Research Question 1	What are the existing barriers and facilitators influencing international student car drivers' decisions to adopt sustainable MaaS solutions?	Understanding the contextual dynamics shaping participant students' mobility behaviours and sustainability adoption	Theoretical contribution, which extends social practices, behavioural, and transition theories through design-based enquiry	Contextual inquiry, including field observation and reflexive note-taking; Participatory design workshop 1 Semi-structured follow-up interviews Thematic data coding and synthesis
Sub-Research Question 2	How can participatory workshops and iterative prototyping translate international students' situated mobility experiences into traceable design requirements for a campus-based MaaS service?	Exploring co-design as a methodological instrument for generating new knowledge through participation	Methodological contribution, which adapts the Design Science Research (DSR) model for practice-based design research, and positions participatory design as a primary method of enquiry	Participatory design workshop 1 & 2 Semi-structured follow-up interviews Iterative physical and digital prototyping sessions Thematic data coding and synthesis
Sub-Research Question 3	How can design practice transform insights from international students' mobility experiences into MaaS design interventions that promote sustainable commuting?	Translating contextual insights into actionable and communicative digital interventions	Practical contribution, which delivers a user-centred and research-informed design artefact that supports behavioural change through future digital experiences	Participatory design workshop 1 & 2 Semi-structured follow-up interviews Iterative physical and digital prototyping sessions

9.3.1. International students as niche actors in the mobility transition

The claim that international students are agents of change has carried three distinct meanings in the sustainable mobility literature and, until now, in this exegesis. It has been used to describe epistemic agency, where participants shape how a problem is framed and what counts as a workable response; behavioural agency, where individuals change their own travel practices; and systemic agency, where a population's practices seed change in a wider socio-technical configuration. These are not equivalent claims, and they carry different evidential burdens. This section states which of them this research advances, and on what basis.

The claim advanced here is systemic in the specific sense used in transition theory. International student drivers constitute a niche population whose mobility practices may be unusually open to reconfiguration and whose practices are visible to the regime actors governing the precinct. Geels's (2012) multi-level perspective locates systemic change in interactions among niche innovations, an incumbent regime, and landscape pressures. Three coincident conditions make this population a niche and not solely a user group at the Clayton precinct. They comprise a concentrated cohort arriving without established local travel habits, an institution with the mandate and operational capacity to alter mobility provision within its boundary, and landscape-level decarbonisation pressure that provides a reason for institutional action.

The first of these conditions is where the empirical material is strongest, and it connects this research to the habit-discontinuity literature. Habits are context-dependent, and form through repetition in stable settings and are most amenable to change when that setting is disrupted. Relocation to another country is among the most complete disruptions available, and it occurs at a known moment for a known population. Participants from this study described this period and, in most cases, described its closing, a mode chosen in the first weeks under conditions of unfamiliarity, time pressure, and safety concerns, then repeated until it was no longer a decision. That the chosen mode was predominantly driving is the finding that matters: the window was open, and the conditions present at arrival closed it around the car. This reframes the design problem. It is not a problem of persuading established car users to reconsider, but of what is legible, available and socially supported during a short and identifiable period.

This argument also brings mobility research into contact with work on migration and cultural adaptation, which transport studies have largely treated separately. Participants' accounts positioned travel as a site of ongoing social and cultural negotiation instead of as a solved logistical matter: route knowledge acquired through co-nationals instead of official channels, safety assessments shaped by unfamiliarity with the suburban night, and mode choice entangled with the

wish to appear competent and independent in a new setting. Cultural adaptation is therefore not context surrounding the travel decision; it is part of its content. A design response that addresses information and incentive while ignoring this addresses only part of what participants described.

Two limits bound this claim without negating it. First, the systemic argument is theoretical. The study indicates that conditions for niche influence are present at Clayton, but it does not establish that such influence occurred. No regime-level change was observed or attempted during the study. Second, the evidence provides limited support for claims of behavioural agency. Ten participants across two workshops and five subsequent interviews engaged with a prototype, not a deployed service. Their accounts may specify conditions under which mode shift could occur, but they cannot establish that it will occur. Where earlier chapters use the language of agency, the intended meaning is specified, and the behavioural claim should be read as a proposition for testing.

9.3.2. Theoretical contributions

This subsection addresses the subsidiary Research Question 1.

What are the existing barriers and facilitators influencing international student car drivers' decisions to adopt sustainable MaaS solutions?

The theoretical contribution of this project is a reframing of international student car drivers as a niche population within the socio-technical transition to sustainable mobility at an Australian suburban university precinct, a population whose travel practices are unusually open to reconfiguration because relocation interrupts established habit, and whose reconfiguration is legible to the institution that governs the precinct (the argument is developed in Section 9.3.1, together with its limits), demonstrating how their life-stage transition and everyday commuting practices create a practical window or gap for transportation mode-shift interventions. This viewpoint reframes international students from a mere demographic of transportation users into a catalyst for design-driven transformation informed by their lived experiences, adaptive behaviours, and intercultural mobility practices. International student car drivers, especially those from Asian cultural backgrounds at the Clayton campus, occupy a unique position in the transition to sustainable mobility (Shafi et al., 2019, 2020a). Their experiences shifting from private car dependence to sustainable multimodal transportation behaviours illustrate the connection between individual agency (An et al., 2022; Mao et al., 2016), cultural adaptation, and systemic constraints (Sheller, 2018; Shove et al., 2012). The project emphasises participatory engagement, demonstrating how design researchers can leverage their contextual knowledge to enhance the development of more inclusive and responsive mobility services.

The position of international students as niche actors in this research, instead of as agents of change in the looser sense the term often carries, is based on theories of sociotechnical transitions (Geels, 2012),

which point out that systemic transformation arises from the interaction of niche innovations, the prevailing regime, and landscape pressures (refer to Chapter 2.2.1). From this multi-level perspective (MLP), behavioural changes enacted by small, motivated groups, such as the international students involved in this project, under the conditions specified in Section 9.3.1, may contribute to wider cultural and infrastructural change. Participatory design serves as a mediating instrument that reveals and translates micro-level practices and narratives into design strategies that foster sustainable mobility behaviours. This aligns with transition design principles (Irwin, 2015), which promote design-driven interventions that function across various levels of change, from personal behaviours to institutional frameworks. The principles emphasise involving communities as active contributors in the co-creation of sustainable futures.

Empirical evidence from the participatory workshops and interviews indicated that international students perceived mobility as a functional necessity and as a continuous process of social and cultural negotiation. Numerous research participants described driving as a representation of autonomy, safety, and temporal efficiency, attributes that offset the perceived unreliability and disjointedness of Melbourne's public transport system in the Monash Clayton areas. Simultaneously, institutional incentives for sustainable travel, such as inner-campus shuttle services or student discounts on public transport (PTV) passes, were frequently perceived as peripheral instead of integral elements of daily mobility practice. This project employs participatory design methods to map interrelations, situating mobility behaviours within a relational framework of capability, accessibility, and cultural belonging and thus enhancing theoretical discourse on sustainable mobility transitions (F. W. Geels, 2012; Shove et al., 2012).

This project enhances the theoretical foundations of sustainable mobility research in three significant ways by emphasising these insights. Initially, it incorporates cultural adaptation in the study of behavioural change, illustrating that a sustainable transition cannot be isolated from the actual experiences of international students' daily commutes. Furthermore, the project recontextualises the suburban university campus as a mobility living lab (Maeder et al., 2023; Rérat, 2021) or microcosm (Purcell et al., 2019) of transition, a bounded yet dynamic environment where socio-technical changes can be observed, tested, and expedited through designed interventions (Munaro & John, 2025; Sjöman et al., 2020). Finally, the project integrates design research with behavioural theory by demonstrating how iterative participatory investigation processes can illuminate the underlying motivations, frictions, and aspirations that might influence international students' daily transportation mode choices.

The research project enhances theoretical comprehension of behavioural change by moving beyond linear models of persuasion or incentives and adopting a

system-oriented and culturally embedded design approach. This contribution is conceptual instead of demonstrated. The research establishes that the conditions for niche influence exist at Clayton and specifies the mechanism through which arrival shapes mode choice; it does not evidence a transition, and no regime-level effect was observed within the study period. International students who are new to the contexts of a suburban university campus, as everyday commuters of local mobility service systems, may have the capacity for small-scale behavioural changes to aggregate into broader trends of sustainability transition. This framing provides a theoretical basis for the subsequent methodological and practical contributions of the research.

9.3.3. Methodological contributions

This subsection addresses the subsidiary Research Question 2.

How can participatory workshops and iterative prototyping translate international students' situated mobility experiences into traceable design requirements for a campus-based MaaS service?

The methodological contribution of this research is to illustrate how participatory design functions as a reflexive enquiry mode (Aguirre et al., 2017; Wilde, 2020) that simultaneously produces situated knowledge and design insights (Omodan, 2023; Seidelin et al., 2020). The project modified the five cyclical stages of the Design Science Research (DSR) model, including awareness, suggestion, development, evaluation, and conclusion (refer to Table 9.1 in the previous section), into a practice-based design framework (refer to Chapter 3, discussion on design research framework). Each stage of the investigation involved international student participants as collaborators instead of informants in the framing of the problem, the generation of ideas, and the evaluation of proposals, while the analysis of the resulting data and the final design decisions remained with the researcher. This methodological adaptation underscores participation as a means of knowledge production (Coenraad et al., 2022; Nakao, 2025), illustrating that a collaborative design process may elucidate the complex realities of sustainable mobility transitions.

This research project established participatory design (PD) as a fundamental methodological perspective for re-evaluating the conception, design, and validation of future mobility services within the framework of Sustainable Mobility-as-a-Service (S-MaaS). Conventionally, MaaS research has predominantly focused on systems engineering, transportation modelling, and technological integration methodologies (Hensher et al., 2020; Kamargianni et al., 2016), with user requirements frequently articulated abstractly through data or market segmentation. This research project adopts a participatory design approach to emphasise lived experience and user agency as epistemological foundations for future mobility services. PD, as described by Sanders and Stappers (2014),

highlights design as a co-creation process that prioritises the experiential and tacit knowledge of participants, positioning them as "experts of their experience". This position shifts from designing for users to designing with them, transforming the role of international student participants from passive consumers of future mobility services to active co-researchers who influence the parameters of sustainable mobility design strategies.

Two limits bound this contribution. The participant group was small (n = 10) and self-selected through university campus channels, which favours students already disposed to engage with sustainability initiatives; and participation ended at the point of evaluation instead of continuing into implementation, so the claim concerns co-design of a proposition instead of co-production of a service. Within the framework of service-oriented mobility design, the participatory approach functions as a methodological and ethical position, which represents how, why and for whom we design, respectively. Akama (2015) and Robertson and Simonsen (2012) emphasise that the objective of participatory design is to foster empathy, trust, and contextual knowledge through continuous interaction instead of isolated consultation. This research project employs a participatory design framework through iterative workshops, interactive journey mapping, semi-structured interviews, and prototyping sessions, enabling participants to articulate their commuting experiences and collaboratively envision emerging sustainable travel possibilities (refer to Chapters 5 and 8). This approach aligns with the service design framework outlined by Stickdorn et al. (2018), which perceives services as dynamic interactions among systems, people, and infrastructure that necessitate participatory involvement to tackle the intricacies of behavioural and environmental factors.

This research project further integrates the participatory design approach within the sustainability transition domain, connecting user-centred service design with broader sociotechnical developments (Pereverza et al., 2019; Quist et al., 2011). The participatory framing allows for an extended understanding of mobility as a logistical issue and, more significantly, as a social practice embedded within daily routines, infrastructures, and cultural identities (Barr et al., 2021; Kent et al., 2017; Selzer & Lanzendorf, 2019; Shove et al., 2012).

Therefore, the research project employed a service-oriented participatory design model that repositions users as co-creators of transition pathways instead of end-users of predetermined mobility service systems. The extent of that repositioning should be stated precisely, since "co-design" and "co-creation" describe a spectrum instead of a single condition. Participants exercised meaningful authority over problem framing, over which barriers counted as significant, and over the acceptance or rejection of design directions, as the withdrawal of cash-based rewards and the reworking of the social features followed participant objection instead of

researcher preference. They did not hold authority over the research questions, the choice of MaaS as the object of design, the analytical coding, or the final interface decisions, all of which remained with the researcher. The contribution is therefore a demonstration of participation as a mode of enquiry at the level of design judgement, not a claim to distributed control over the research programme. The project provides empirical evidence that participatory design methods can uncover sociocultural aspects of mobility behaviour and generate actionable insights for sustainable service interventions.

9.3.4. Practical contributions

This subsection addresses the subsidiary Research Question 3.

How can design practice transform insights from international students' mobility experiences into MaaS design interventions that promote sustainable commuting?

The practical contribution is the most substantial of the three, and it is more specific than a platform. What the research delivers is an evidenced specification of what a campus MaaS service would have to do to be used by newly arrived international students, expressed at three levels of resolution: a set of design requirements each traceable to the finding that produced it; an end-to-end service blueprint that distinguishes what the platform controls from what it depends upon; and a tested interface proposition whose substantive features were retained or revised after participant objections. Each level is usable independently. An institution that never builds the platform can still act on the requirements. These requirements specify that route information must be hyperlocal and current, that alternatives must be legible at the moment of decision, that incentives must be immediate and locally redeemable, and that safety at the campus boundary after dark is a precondition instead of a refinement. The blueprint identifies which of these an institution can deliver alone and which require operator or commercial partnership, which is precisely the information a mobility plan needs and which a finished interface would obscure. This specification, not the artefact that expresses it, is what the research contributes. The *Go Green! Monash* digital platform translates contextual and cultural insights from participants' engagements into an interactive, user-centred Mobility-as-a-Service prototype. The research employs iterative cycles of ideation, prototyping, and evaluation to convert lived experiences, behavioural insights, and design feedback from international student car drivers into tangible service solutions that promote sustainable commuting options at the Clayton campus. This translation process illustrates how design practice may connect empirical understandings with actionable service innovation, transforming interpretive findings into objects that inform and stimulate change.

The platform serves as a design intervention that transforms the perception and experience of sustainable mobility services in the suburban university context among international student car drivers. The platform

incorporates persuasive design strategies aimed at behavioural change towards sustainable travel mode choice or decision-making, such as gamification, incentive systems, and social networking elements (refer to the discussion in Chapter 2.6.5 and Chapter 8.3). The finalised design interfaces convert these behavioural motivators into tangible interaction pathways, such as incentives and reward points for low-emission commuting, social leaderboards promoting inner-campus community competitions, and multimodal planning tools that synchronise real-time mobility data with university or personal calendar schedules (refer to Chapter 8.2). These design features transform the platform into a communicative medium that incorporates behavioural change mechanisms into the daily digital routines of its users.

The limit of this contribution is the status of its evidence. The specification was tested through participant response to a prototype, not through use of a deployed service, and it therefore states what participants judged would be necessary and sufficient instead of what proved effective in practice. It should be read as a design hypothesis of a specific and actionable kind, with sufficient detail to be implemented and detailed enough to be falsified by implementation. The findings suggest that design artefacts can be seen as behavioural mediators or transformation agents (Lopes et al., 2012; Sage et al., 2014; Zacarias et al., 2010), effectively converting sustainability from an abstract policy objective to an experiential and participatory process. The iterative development process of the *Go Green! Monash* platform illustrates that integrating user insights into future digital service designs might enhance travel decision-making and foster new mobility identities and collective involvement. In this sense, the artefact operates within what Buchanan (1992b) refers to as the fourth order of design, which is the design of systems and interactions that influence human experience. Buchanan (ibid., p. 6) observes that "designers are exploring concrete integrations of knowledge that will combine theory with practice for new productive purposes…" The design outcome indicates that research through design can yield practical interventions, specifically a communicative digital prototype in this research project, that serve not as final products but as tools to make socio-technical changes visible and debatable (Hoadley, 2010; Singh et al., 2021; Vezzoli et al., 2015).

The practical contribution of the project positions international students as co-creators or contributors and potential future behavioural change agents, emphasising their active role in shaping a sustainable mobility future at the Clayton precinct. The designed mobility service digital platform functions as a representation of their collective knowledge and a catalyst for institutional sustainability transformation within the precinct. The proposed near-future commuting services and interface design of the digital platform, grounded in culturally attuned user insights, illustrate how a localised, practice-based design might influence the broader implementation of mobility as a service in

various suburban and higher education institutions. Therefore, the project extends the practical boundaries of design research by demonstrating that behavioural change in sustainable travel may be encouraged or promoted through a designerly synthesis (Bazzano et al., 2017; Paay et al., 2021; J. Wang et al., 2025) of contextual understandings, participatory engagement, and experiential digital service interventions.

9.4. Assessing the behaviour change strategies and the limits of a digital response

This exegesis has adopted three design strategies aimed at encouraging sustainable travel behaviour change among the recruited international student participant group: reward mechanisms, gamified elements, and social networking features. However, the evaluation discussed in Chapter 8 demonstrates that the empirical support for these strategies is limited. The following discussion details the evidential basis for each strategy and distinguishes supported findings from speculative propositions.

The reward mechanism held up best under participant scrutiny, though only in a particular form. Participants rejected withdrawable cash on the grounds that it would substitute for the behaviour instead of supporting it and preferred in-app points redeemable against campus services and transport costs (Chapters 4.5.4 and 8.3.1). The strategy therefore survives the evaluation, but with its mechanism altered by the participants who tested it.

The gamified elements were accepted with less conviction during this research procedure. Participants responded to progress indicators and recognition, yet several also anticipated that challenges and badges would lose their hold once novelty passed, which is the effect reported in the literature reviewed in Chapter 2.7.2. The strategy is retained in the design, but the evidence for it is weaker than for rewards, and this exegesis does not claim it would sustain mode change on its own.

The social networking features are the least supported of the three. Participants valued route knowledge acquired informally from peers and proposed making peer coordination visible, but the interviews produced no evidence that a social layer inside an application would reproduce the trust carried by an existing friendship. Chapter 8.3.3 records the interest instead of demonstrating the effect, and that distinction matters, since a claim to have designed social influence would exceed what was tested.

Under Fogg’s (2009) behaviour model, these verdicts are legible but incomplete. The model holds that behaviour occurs when motivation, ability, and a prompt converge, and it accounts well for the strengths of the design. Decision support raises ability by making a multimodal journey easier to plan, points raise motivation, and the pre-trip notification

supplies the prompt (Chapters 6.3.1, 6.3.2 and 7.1.1). What the model does not explain is the matter participants emphasised most, which is the difference between choosing a sustainable option once and continuing to choose it. Fogg's model describes a moment of behaviour and is silent on the weeks that follow it. The staged account of transition offered by Sunio (2018) covers that interval more adequately, and the design presented here is accordingly built to operate across an arrival period instead of at a single decision point. Persuasive technology supplies the mechanism for this design without supplying its temporal frame.

Critiques of digital or technological solutionism (Morozov, 2014) argue that reducing structural challenges to design problems obscures the institutional, political, and infrastructural conditions from which they arise. Applied to mobility, this critique suggests that a digital platform may appear to address car dependency while leaving intact the fundamental determinants of travel behaviour, such as transport service frequency, land-use planning, and pricing policies. Therefore, the interfaces of the proposed platform do not address material conditions, such as bus service coverage, first- or last-mile issues and unreliable public transport timetables, and the barriers reported in Chapter 4.5.3 are largely of that kind.

The response of this exegesis is not that the platform overcomes those conditions, but that it addresses a narrower problem situated within them. The Clayton precinct already contains alternatives that go unused because they are illegible to a newly arrived student whose knowledge of the local network is incomplete and whose default is therefore the car. Making existing provision legible, comparable and reliably timed is a design problem, and one an interface can act upon. The claim is also bounded by the setting. A university campus controls its own parking, roads, shuttle services and information channels, which is what makes it a niche in the sense set out in Chapter 2.2.1, and what distinguishes an institutionally hosted platform from a commercial application deployed into a city it cannot influence.

The design should not be read as a substitute for service investment, and this exegesis makes no claim that it reduces private car use, since no such measurement was undertaken. What it claims is that a participatory design process with international students produced a platform proposition answerable to their reported experience, and that the same process identified where a digital response reaches its limit. Those limits are set out in the following section.

9.5. Research limitations

Each contribution has been stated above alongside the limit that bounds it. This section aims to address the limitations, including the risk that a platform response substitutes for structural change, the boundaries of transfer beyond this population and precinct, and the methodological, epistemological and ethical constraints of the study design.

The risk of a technological fix

A digital platform offered as a response to car dependency invites the objection that it substitutes an app for the infrastructural and institutional change the problem requires. The critique is that technological interventions displace attention from structural causes, individualise responsibility for collective problems, and offer the appearance of action at low political cost. It applies here with force: car dependency at a suburban campus is produced by land use, parking supply and pricing, transit frequency and coverage, and the absence of safe active-travel infrastructure, and a journey-planning and incentive platform changes none of these.

The research answers the objection in one specific way and concedes the rest. The design is explicitly dependent, and its dependencies were mapped instead of assumed away: the service blueprint identifies where each function relies on provision the platform does not control, operator timetable and real-time data, commercially maintained shared-mobility fleets, the physical condition of connection points at the campus boundary, and institutional decisions on parking and subsidy. The platform becomes useful when these are in place and visibly fails when they are not; a platform that surfaces the unreliability of a service documents an infrastructural deficit instead of concealing it. Participant evidence points the same way: where the alternative was not viable, such as an evening return with a long unlit walk, or a connection with an unpredictable wait, no interface affordance was reported as sufficient.

What remains a genuine limitation is that the research cannot demonstrate the complement it argues for. It specifies the informational, motivational and social conditions under which existing and planned provision would be more likely to be used, but it did not test the platform alongside infrastructural or policy measures, and it cannot say what the relative contribution of each would be. Read as a complement to such measures the proposition is defensible; read as an alternative to them it would be the techno-fix the critique describes, and nothing in this study supports that reading.

Transferability and boundaries of the findings

The findings were produced with a specific population in a specific precinct. The most transferable element is the structural argument about arrival and habit, specifically the population group undergoing a comparable disruption to its travel context, for instance, domestic students relocating from interstate or regionally, new staff, residents new to a suburb, who encounters the same open window and the same closing mechanism. What does not transfer is the intensity. Participants who involved within this project combined unfamiliarity with the entire transport culture, absence of local networks through which route knowledge circulates, and constrained language and financial resources. Nevertheless, the domestic students relocating within Australia experiences a weaker form of the same discontinuity and would resolve it faster, with less reliance on the informational scaffolding this design provides.

The findings may transfer less readily to populations whose travel is not organised around a timetabled institutional destination. Staff commuting is shaped by contractual hours, seniority, and caring responsibilities, so the calendar integration central to this design has no equivalent anchor. Precinct residents also travel to dispersed destinations at varied times, making connection points at the campus boundary peripheral to their journeys. The underlying insight that decision support should operate at the point and time of a decision may remain relevant, but the design response would require reconstruction and further evaluation with these groups.

Transfer to other universities depends on three features of the Clayton setting that are not universal. These comprise a suburban and car-accessible campus where parking makes driving a practical default, a precinct decarbonisation commitment that provides an institutional rationale for intervention, and an international cohort sufficiently large to support peer information networks. A dense inner-city campus presents different barriers, including cost and crowding. A regional campus with minimal public transport presents a problem that the platform cannot address because its value depends on coordinating alternatives that already exist. The review of ten Australian universities suggests that the Clayton configuration is common but not universal, and its applicability should be tested in each setting. Consistent with case-based design research, which prioritises depth over breadth (Flyvbjerg, 2006), the study follows an analytical generalisation framework (R. K. Yin, 2018) in which findings extend theoretical concepts without supporting universal claims.

At the regional scale, the contribution is methodological. The study provides a transferable process for developing context-specific MaaS interventions. It does not advance a universally applicable solution. The process begins by situating the enquiry within the lived experiences of a selected population, defines a service proposition, maps socio-technical and institutional dependencies, and treats participants' ideas and critiques as empirical evidence. This methodological orientation is not limited to campus mobility or international students. It may be adapted to other place-based mobility challenges in which complex stakeholder relationships, contextual constraints, and situated practices require responses to emerge through participatory engagement.

Contextual limitations

Two further features of the study context bound the findings. Participants were enrolled at a single institution and were predominantly from a Chinese cultural background. The sample therefore reflects a shared institutional culture, socio-economic position, and educational background, and the account of arrival and adaptation is weighted towards one migration pathway. Consistent with Flyvbjerg's (2006) defence of information-oriented case selection, this emphasis constitutes a deliberate methodological choice. Its value lies in

producing detailed, context-dependent knowledge, not statistical representativeness. The findings should consequently be interpreted as one migration and mobility trajectory and not as a general characterisation of international student mobility across institutional, cultural, or geographical contexts.

Additionally, the research period coincided with post-pandemic mobility changes in Melbourne, which were characterised by variable transport services and modified commute patterns (Currie et al., 2021). Temporal circumstances influenced participants' perceptions of public transport dependability and safety, potentially enhancing the significance of private automobile usage and ownership. Thus, the observed behavioural trends may partly indicate temporary infrastructural and psychological influences instead of enduring cultural orientations.

Methodological limitations

The participatory design workshops and subsequent interviews, crucial to this project's methodological framework, were conducted with relatively small participant groups (n = 3 to 10 per session, total = 10), aligning with exploratory practice-based research but lacking statistical representativeness. Although qualitative depth and iterative involvement were emphasised (Sanders & Stappers, 2014), the restricted sample limits the diversity of viewpoints represented, especially for gender, discipline, and cultural subgroups among the international student population. This constraint reflects assertions in design anthropology that highlight the partial and interpretative nature of co-design interactions (Pink et al., 2018).

Furthermore, the constructivist grounded-theory methodology used for data analysis requires interpretive coding, whereby research subjectivity is essential to the process of meaning-making (Charmaz, 2014). Despite the use of triangulation across transcripts, visual artefacts, and memos to enhance credibility, absolute neutrality remains elusive. The researcher's dual role as a facilitator and analyst generates positional biases, especially when directing workshop discussions and evaluating participant-generated artefacts. This reflective entanglement is recognised as a constraint in research-through-design methodologies (Zimmerman et al., 2010); however, it simultaneously represents a generative epistemic stance, facilitating the emergence of theory through embodied interaction with participants.

Design and prototyping limitations

The digital prototype developed through this project, the *Go Green! Monash* platform, was conceptual and experimental in nature instead of a fully operational system. Despite gaining usability and interaction feedback through participatory evaluations, technological implementation limitations hindered extensive development and longitudinal behaviour tracking. Thus, the platform's ability to effectuate quantifiable changes in travel behaviour or carbon emissions remains hypothetical. According to

Krippendorff (2005), design artefacts mainly serve as "propositions for possible worlds," functioning as epistemic tools for envisaging change instead of as definitive solutions.

The design strategies embedded within the prototype, including gamification, rewards, and social networking, were evaluated in simulated scenarios using interactive mock-ups (refer to *Chapter 8*). The absence of real-time data integration, such as transit APIs (Application Programming Interfaces), live ticketing, or emission calculators, constrained ecological validity. Future work involving experimental development with institutional transportation partners will be essential for assessing behavioural effectiveness under real-world constraints.

Epistemological and theoretical limitations

The project's interpretive approach, informed by socio-technical transition theory (F. W. Geels, 2012) (refer to discussion in *Chapter 2*), participatory design (Bannon et al., 2018), and practice-based mobility research, emphasises qualitative, experiential, and explorative forms of knowledge. This epistemic stance limits engagement with quantitative modelling methodologies used in transportation planning and behavioural economics, such as discrete choice models or travel demand simulations. Therefore, while the project provides conceptual depth into the significance of mobility practices, it lacks predictive analytics or cost-benefit evaluations typically required for policy implementation.

The design led focus constrains the temporal scope of the study because prospective prototypes and participatory workshops indicate potential without providing longitudinal evidence of behavioural change in sustainable commuting. Manzini (2015) and Fry (2009) suggest that design for sustainability operates through anticipatory imagination and cultural reframing before measurable transformation occurs. The theoretical contribution therefore concerns how design may support reflection and negotiation within user groups. It does not demonstrate measurable behavioural change.

Ethical and cultural limitations

The project navigated cultural and linguistic diversity among international student participants, where differing levels of English proficiency and cross-cultural communication styles may have impacted expression during workshops and interview sessions. Despite the multilingual facilitation of sessions (English-Mandarin) when necessary, translation may have lost or misinterpreted nuances of meaning and expression. This situation corresponds with ethical concerns in multicultural participatory design that caution against presuming equivalency in participation and voice (Winschiers-Theophilus et al., 2012). Additionally, the voluntary recruitment process on campus may have drawn participants who were already predisposed to sustainability or innovation, leading to

an attitude bias that skews the representation of behavioural obstacles within the larger student population.

9.6. Future research

Future research opportunities emerge from the constraints found in this project, particularly regarding the scalability, evaluation, and contextual transferability of the designed *Go Green! Monash* MaaS platform. Because the final prototype for this project is conceptual and exploratory, future research may focus on developing a high-fidelity operational prototype to evaluate its usability, efficacy, and long-term behavioural impact in a real-world campus setting. This would facilitate the gathering of quantitative evidence on user interactions, travel mode shifts, and results related to carbon reduction, hence strengthening the qualitative insights obtained from the participatory investigation sessions of this project.

Subsequent research may concentrate on enhancing the intermodal travel experience at the Clayton precinct and the surrounding suburban regions of Melbourne, addressing the issues pertaining to first- and last-mile connections, real-time multimodal journey planning, and the interaction with current transportation systems. The application of digital technologies, including artificial intelligence-driven predictive algorithms and location-based suggestion systems, may be investigated to mitigate the cognitive load associated with trip planning and commuting mode shifting. These developments may facilitate an evaluation of how design interventions can support travellers' decision-making in multimodal settings and improve perceptions of accessibility, convenience, and safety in the future.

Additionally, comparative analyses across diverse university campuses or suburban mobility contexts would yield substantial insights into the cultural and infrastructural variances in MaaS adoption among international students. Examining the behavioural and cultural aspects of high-density urban areas or transit-oriented campuses may enhance our comprehension of how environmental and regulatory frameworks affect sustainable commuter behaviours.

Finally, the iterative design process should continue through engagement with institutional stakeholders, transport providers, and policy organisations. Evaluation under more complex operational and governance conditions could connect the design outcomes with precinct sustainability strategies. Future integration of the platform with Monash University's Net Zero Precinct initiatives and Moodle could clarify how design-led innovation may support the decarbonisation of campus transport for students and staff.

9.7. Conclusion

This study indicates how participatory and practice-based design research may contribute to contextually relevant and socially responsive MaaS systems within the institutional and socio-spatial setting of Monash University's Clayton campus. Through participatory workshops, grounded theory analysis, and iterative prototyping, the study examined how

international student drivers conceptualised, negotiated, and envisioned preferable commuting futures. Although conceptual and exploratory, the *Go Green! Monash* platform functioned as a research artefact through which participants articulated mobility concerns and co-developed responses aligned with the Net Zero Precinct objectives.

The theoretical contribution of this project is in framing international students as catalysts for change in sustainable mobility transitions. This project enhances existing discourses on user-centred mobility systems through participatory design, illustrating how lived experiences and sociocultural adaptations influence transportation patterns. The findings indicate that mobility identities are not static but are constantly redefined through the negotiation of personal and cultural backgrounds and infrastructural factors among the international students. This insight deepens our understanding of how inclusive and context-specific design practices can foster socio-technical transitions to low-carbon transportation.

Simultaneously, the project methodologically proposes an integrative framework that combines research-through-design (RtD), participatory action research (PAR), and constructivist grounded theory (CGT), and collectively frames how knowledge is generated, interpreted, and materialised through design practice. The combination of these three components deepened the experience and increased the analytical rigour, which produced valuable design insights and a richer understanding of the user experience. The methodology of this project encompasses participatory design workshops, iterative prototyping sessions, and reflective interviews with the international student participants who played an essential role in co-developing the final design outcomes. The findings indicate that participatory design, integrated within institutional sustainability initiatives, serves as an investigation method as well as a transition-oriented intervention.

This project proposed an integration of design principles and strategies, including gamification, reward mechanisms, and social networking, that guide the development of digital mobility services promoting behavioural change or decision-making towards more sustainable commuting. The integration of these design strategies demonstrated how engagement, motivation, and university community involvement could be implemented to encourage sustainable mobility behaviours among international student car drivers. Based on this, the designed *Go Green! Monash* platform illustrates how a university-led Mobility-as-a-Service initiative can foster collective responsibility for sustainability objectives by connecting personal mobility choices to broader institutional and environmental outcomes.

To conclude, this research establishes what a design-led enquiry can and cannot settle. It specifies the informational, motivational and social conditions under which international students at a suburban university campus would be more likely to choose alternatives to driving, and it identifies the moment, arrival, before habit forms, at which that specification matters

most. Whether those conditions, once met, produce durable change in everyday commuting practice is a question this research frames precisely and leaves open, despite contextual and methodological limitations. This project provided theoretical and practical bases for further experimentation and evaluation in other precincts or communities, presenting a direction towards scalable and socially integrated MaaS solutions. Ultimately, this research illustrates that design extends beyond its role in technological innovation, serving as a vital epistemic and social practice through which communities collaboratively envision, negotiate, and implement more sustainable futures for mobility transitions.

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Appendix

Appendix A. Summary of MaaS products and services with their implementation status under review

Case (Areas) [Platform]	State (Year)	Transportation modes & services	Available functions	Personalised options	Customised services	Integration level[7]	Modes
Mobility Shop (Hanover, Germany) [Web]	Operating (2016-now)	Public transport, Shared vehicles, Taxi, regional trains	Realtime-information; booking, ticketing, payment, invoices, service alarm	Save preferred routes and reproduce historical routes	Users can customised travel package based on quotas, cancellation	2	PPP[8]
SMILE (Vienna, Austria) [Android]	Trial (2014-2015)	Public transport, shared bikes, shared vehicles, taxi, parking services, charging services, regional trains, ferry	Realtime-information, travel plan, booking (shared modes/taxi/regional trains), ticketing, payment, invoices, service alarm	Optimised travelling plans for users (annual pass, family member subscription services)	Select travel options based on cost, time and carbon emissions	2	n/a
Tuup (Turku, Finland) [IOS & Android]	Operating (2016-now)	Public transport, shared bikes, shared vehicles, rental cars, P2P rental cars, taxi & carpooling, parking space rental, freight services (scheduled service)	Realtime-information, travel plan, booking, ticketing, payment (public transport, taxi and shared modes)	User-schedule-based personalised plan optimisation	Select travel options based on cost and carbon emissions	2	n/a
EMMA (TaM) (Montpellier, France) [-]	Operating (2014)	Shared vehicles and bikes, public transport, parking	n/a	Monthly and annual travel passes	Customised services for different user-groups	2	PPP
myCicero (Italy) [-]	Operating (2015-now)	Public transport, taxi (plan), parking services, regional trains and buses, congestion charging zones (plan)	Realtime-information, travel plan, booking, ticketing, payment, invoices, municipal services	Save ticket types, record & share trip information	Service recommendations based on users' travel and payment preferences	2	Private
Moovel (Germany) [IOS & Android]	Operating (2015-now)	Public transport, shared bikes, shared vehicles, taxi, ferry, regional trains	Realtime-information, travel plan, booking,	Save preferred routines, personalised	Connection with social networks, cancellation of	2	Private

7 Refer to (Sochor et al., 2018)
8 Public-Private Partnership

Case (Areas) [Platform]	State (Year)	Transportation modes & services	Available functions	Personalised options	Customised services	Integration level	Modes
			ticketing, payment, invoices	notification, Pay-as-you-Go	rental services		
NaviGoGo (Dundee, Scotland & North East Fife, UK) [IOS & Android]	Operating (2017-now)	Shared vehicles, taxi, bus, regional trains	n/a	n/a	n/a	2	n/a
WienMobil (Vienna, Austria) [Web]	Operating (2017-now)	Public transport, shared bikes, shared vehicles, taxi, parking services	Realtime-information, travel plan, booking, payment, invoices	Save personal data, storage of personal cars and bikes,Pay-as-you-Go	Select travel options based on cost, time and carbon emissions	3	Public
UbiGo (Gothenburg, Sweden) [IOS & Android]	Trial (2013-2014)	Public transport, shared bikes, shared vehicles, rental cars, taxi	Travel plan, booking, ticketing, payment, invoices, 24-hour customer service	Personalised monthly pass packages	Add-on travel budget available	3	Public
Whim (Helsinki, Finland) [IOS & Android]	Discontinued (2016-2024)	Public transport, rental cars, taxi, regional trains, shared bikes (plan), shared vehicles (plan)	Realtime-information, travel plan, booking, ticketing, payment, invoices	Pay-as-you-Go, monthly travel pass, sync calendar, user information sharing, social media	Cancellation and adjustment of booking services	3	Private
In Australia							
Tripi (Sydney, NSW) [-]	Trial (2019-2020)					2	Public
ODIN Pass (Brisbane, QLD) [IOS & Android]	Trial (2021-now)	Public transport, regional trains, ferry, shared bikes (e-scooters), taxi, rental cars	Realtime-information, travel plan, ticketing, booking, payment, invoices	Unlimited public transport, e-scooter & e-bike passes, 7-90 days access		3	Public

Appendix B. Studies reviewed on mobile app-design for mobility behavioural change

Study	Type	Primary Focus	Context	Key Features of the mobile-apps
(Anagnostopoulou et al., 2018)	Pilot study (n=30)	Nudging	Vienna, Austria	Personalised persuasive messages
(Anagnostopoulou et al., 2019)	Experimental study	Nudging	-	Personalised interventions, messages and visualisations
(Avril et al., 2024)	Systematic literature review	Gamification	-	Lack of knowledge (change behaviours and attitudes) on gamified intervention in the field of mobility and transport
(Barratt, 2017)	Qualitative observational study (n=20)	Gamification	UK (Staffordshire Cheshire, Derbyshire)	Virtual trophies, leaderboards, challenges
(Barros, 2019)	Pilot study	Social networking, gamification	-	Social network mechanism, gamification techniques
(Bowden & Hellen, 2019)	Observational study (n=667)	Gamification	Bologna, Italy	Gamification and rewards
(Casquero et al., 2022b)	Literature review	Nudging, gamification, social network	-	Eco-feedback, rewards, social challenges
(Cellina, Bucher, Veiga Simão, et al., 2019)	Experimental study (n=150)	Gamification, social network	Switzerland	Eco-feedback, social comparison, gamification
(Cellina et al., 2020)	Experimental living lab	Gamification, social network	Switzerland	Individual achievement, competition mechanics
(Cellina et al., 2023)	Living lab experiment	Gamification	Switzerland	Famified approach, real-life prizes/incentives
(Y. Chen et al., 2014)	Experimental study (n=24)	Social, gamification	-	Social accountability, leaderboards
(Y.-M. Cheng & Lee, 2015)	Pilot study	Gamification, social network	Taipei city, Taiwan	Competitive elements, social pairing
(Daniel et al., 2022)	Observational study	Gamification	Lisbon, Portugal	Gamified app, reward system
(Dio et al., 2015)	Exploratory study	Gamification, rewards	Palermo, Italy	Point system, challenges, prizes
(Dio et al., 2020)	Exploratory study (n=100)	Gamification	Urban areas	Game-based involvement, rewards

Study	Type	Primary Focus	Context	Key Features of the mobile-apps
(Esztergár-Kiss et al., 2021)	Quantitative study	Nudging	Budapest, Hungary	Persuasive strategies
(Ferreira et al., 2024))	Literature review	gamification	-	-
(Foster et al., 2010)	Experimental study	Social	UK hospital	Social comparison, competition
(Gabrielli et al., 2013)	Observational study	Nudging, social	Milan, Barcelona, and Helsinki cities	Goal-setting, self-monitoring, sharing
(Gabrielli et al., 2014)	Observational and Pilot study (n=8)	Nudging, social	Trento, Italy	Goal-setting, self-monitoring, sharing
(Habib et al., 2008)	Observational study	Rewards	Birmingham and Vienna	Points, monetary rewards
(X. Huang et al., 2019)	Experimental study	Gamification, rewards	Dutch region of Twente	Challenges, points, in-kind gifts
(H. Huang, 2022)	Experimental study	Gamification	Dutch region of Twente	Cycling-related challenges
(Kazhamiakin et al., 2021)	Practical study	Rewards, social	Trentino, Italy	Points, badges, leaderboards, community engagement, challenges generator
(Kelpin et al., 2016)	Pilot study	Gamification	-	Competitive gamification, incentives
(Y. Kim & Chung, 2020)	Randomised controlled trial (n=66)	Gamification, rewards	-	Monetary rewards, goal setting, gaming
(Klecha & Gianni, 2018)	Systematic literature review	Nudging	-	Persuasive strategies
(Kracheel et al., 2014)	Mix-methods study	Gamification	Luxembourg	Gamification elements
(J. Li & Xu, 2024)	Systematic literature review	Gamification	-	Sustainable travel behaviours interventions, knowledge incentives, school intervention
(Luger–Bazinger & Hornung–Prähauser, 2021)	Explorative study (n=587)	Nudging, gamification, social	Salzburg, Austria	Notifications, social comparison, rewards
(Manca et al., 2022)	Observational study (n=83)	Rewards, social	Milan, Italy	Non-monetary tokens, social sharing
(Marconi et al., 2018)	Observational study (n=1079)	Gamification, rewards	Trento, Italy	Points, badges, leaderboards, challenges
(Kracheel et al., 2015)	Case study	Gamification	Luxembourg	Gamification, incentives

Study	Type	Primary Focus	Context	Key Features of the mobile-apps
(Máca et al., 2020)	Randomisd controlled trial	Gamification, rewards	Czech Republic	Financial rewards, points, badges, challenges
(Næss & Stadheim, 2016)	Pilot study (n=10)	Social, nudging	Norway	Social network, prompts
(Poslad et al., 2015)	Experimental study (n=518)	Rewards, gamification, social	Enschede, Gothenburg, Leeds	Points, challenges, social sharing
(Roider et al., 2019)	Pilot study	Gamification, rewards	Lower Austria	Point systems, non-financial incentives
(Schillaci et al., 2022)	Mix-method study	Gamification, rewards	Multiple European cities	Points, badges, team-based tournament
(Sheffler et al., 2020)	Field experiment	Gamification, social	-	Badges designs, social sharing
(V. Sunio & Schmöcker, 2017a)	Literature review	Nudging	-	Persuasive technology
(Wernbacher et al., 2015)	Pilot study	Gamification, social	Vienna	Points, badges, levels, shared goals
(Zheng et al., 2015)	Randomised controlled trial	Nudging	New York City	Personalised knowledge of emissions and calories

Appendix C. Review on ten selected Australian universities

Name of the university	***Sustainable transport strategies***	***Modes of transport indicated***					
		Walking	***Cycling***	***Public Transport***	***EV***	***Sharing***	***Others***
Deakin University	Encourages most of the students and staff to use sustainable transport options to and between campuses, through carpooling, walking or cycling Takes action to increase sustainable modes of transport by enhancing public transport, ride-share and active transport options	✓	✓	✓		✓	Carpool program with ***Liftango*** E-bike sharing program, operated by ***Lime*** on the Geelong campus
La Trobe University	Encourages students and staff to choose sustainable transport options, such as active mobility and public transport	✓	✓	✓	✓		
Australian National University	Encourages staff and students to use sustainable transport options, including walking, cycling, public transport, car-sharing scheme, carpooling, shared bike programs, and low-emission vehicles	✓	✓	✓	✓	✓	
RMIT University	Setted Integrated Sustainable Transport Plan (ISTP) 2015-2025: Improve the bicycle facilities across each campus; Design a smartphone application to support sustainable travel; Undertake advocacy to improve access by sustainable transport options; Provide a shuttle bus between the Bundoora campus and local train stations; Improve the capability of staff and students to make sustainable travel choices; Improve the capability of staff and students to make sustainable travel choices	✓	✓	✓			
Swinburne University	Encourages staff and HDR students to attend events virtually when they can and choose greener transport and accommodation options as much as possible Measuring the carbon footprint of processed trips to encourage more sustainable travel decisions Implementation of mandatory carbon offsetting for travelling and formalise a partnership with 'greener' airlines and accommodation providers						

Name of the university	Sustainable transport strategies	Modes of transport indicated					
		Walking	*Cycling*	*Public Transport*	*EV*	*Sharing*	*Others*
University of Melbourne	Provides alternative ways to reduce and avoid air travel, such as high-quality teleconferencing facilities, and offset the carbon emission Reduce carbon emissions through pool car system implementation and sustainable vehicle recommendations Provides facilities for cyclists and promotes efficient, sustainable travel and transport options for staff and students commuting	✓	✓	✓	✓	✓	
UNSW	Living campuses were set up, one of the targets within the environmentally sustainable plan: Supporting active lifestyles through an active travel masterplan and improving facilities At least 85% of students and staff travel to campus by sustainable travel modes; develop and implement an active travel masterplan	✓	✓	✓	✓	✓	
University of Tasmania	Supporting staff and students to choose sustainable transport options and has developed a sustainable transport strategy since 2012 to guide and support investments and actions that deliver more socially, economically and environmentally sustainable transport outcomes and travel behaviours in the following objectives: Maximise access to the university by healthy and sustainable transport options; Reduce the incidence of single-occupant vehicle use and unnecessary travel; Reduce greenhouse gas emissions from university transport sources	✓	✓	✓	✓	✓	
Charles Sturt University	The university developed a Transport Access Guide (TAG) for accessing Charles Sturt University at Albury-Wodonga, Bathurst, Dubbo, Orange, Port Macquarie and Wagga Wagga. The TAG provides information on how to access the campus from the CBD in each regional location using active transport options. The active transport options include walking, cycling and public transport	✓	✓	✓			
Monash University	Developed a net zero transport strategy in 2021, which aims to reduce and eliminate the greenhouse gas emissions from single-occupancy vehicles as well as the university's flights, fleets and commutes.	✓	✓	✓	✓	✓	

Appendix D. Participatory design workshop explanatory statement

Ethics approval #42308

Project: Design workshop of the future Sustainable Mobility as a Service (S-MaaS) platform

A/Professor Selby Coxon

Chief Investigator

Department of Design

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Chenlizhe (Mark) Yang

Student Researcher

Department of Design

Phone: +61 431 230 549

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I am Mark Yang, a PhD Candidate of Monash Art, Design and Architecture. I am currently conducting research into sustainable mobility solutions for the Clayton Precinct. This explanatory statement sets out how this research is being conducted and why it is being done. Please read this Explanatory Statement in full before deciding whether or not to participate in this research. If you would like further information regarding any aspect of this project, you are encouraged to contact me via the email address listed above.

This project is part of the Net Zero Precinct, a 4-year Linkage project funded by the Australian Research Council, ENGIE and Monash University. The study aims to help cities and urban regions reach net zero emissions by taking the Monash Technology Precinct as an optimal scale for urban transition. This research project expects to co-speculate a new mobility solution to net zero transition at the Monash Clayton campus by undertaking participatory research activities with international student community members. The research will consist of design workshops and ethnographic data collection.

What does the research involve?

This research project, conducted by the researchers, involves a series of co-design workshops aimed at enhancing the commuting experiences of international student car drivers from the Clayton and/or Caulfield campuses. The research is structured into two main workshops designed

to fulfill specific objectives in developing and field-testing a sustainable mobility service digital platform that reduces reliance on personal cars.

In order to help us with this research you will be asked to participate in the co-design workshops. You will go through the following steps:

1. Read and sign the consent form when you decide to attend one or both of the co-design workshops (#1 and #2), which will be scheduled on separate dates with an appropriate two-week gap.

[Please note that you are highly recommended to attend both workshops to gain the best understanding and contribute effectively to this project. However, there is no need to feel apologetic if you can only attend one of the workshops due to any reason.]

2. Attend Workshop #1 where you will: (1) tell the story of a behavioural change in your life; (2) share and visualise your routine journey from home to your work or study destinations; (3) imagine and rough sketch potential design solutions to address the pain points or barriers of the routine car journey; (4) map out the future mobility service app in one of your routine journey scenarios.

3. Attend Workshop #2 where you will: (1) gain access to review and interact with the designed interfaces of the mobility service app; (2) test the app interfaces on the Clayton campus using four scenarios; (3) rank the design prototypes and engage in group discussions for further improvement.

4. Respond to post-workshop requests for feedback or interviews, if needed (optional). You may be contacted via email for further interviews or feedback after the workshops.

We expect that you will need a maximum of 2.5 hours for each workshop. The workshop sessions will be audio/video recorded. In addition, photos will be taken during the sessions.

Why were you invited for this research?

Your selection for participation in this study was based on your affiliation with international student cohorts and your utilisation of driving as a primary mode of transportation to the Clayton and/or Caulfield campuses. Your diverse backgrounds and experiences contribute valuable insights into the challenges and opportunities surrounding mobility services. As individuals who navigate new environments and transportation systems, you can offer firsthand knowledge of the user experience and identify areas for improvement. Additionally, your status as an international student brings a global perspective, allowing for considering cultural differences and preferences in mobility solutions. By involving your participation, the workshop aims to ensure inclusivity and

relevance in shaping the future of mobility services for a broad range of users at the future Net Zero Precinct.

Furthermore, students will be recruited from both Clayton and Caulfield campuses to co-design a mobility-as-a-service digital platform, specifically a mobile phone app-based solution. Your contribution will not only enhance the current mobility services but also play a crucial role in the future urban sustainable transition.

Consenting to participate in the project and withdrawing from the research

To accept the invitation to the workshop, you must read this explanatory statement and submit a signed consent form before the workshop. You are under no obligation to participate in this research and have the right to withdraw from further participation at any research stage with no implications to you. You may also withdraw the data you provided at any research stage. If you withdraw data from the study, any visual photos identifiable as your own will be removed from the research. You may be asked to confirm the photos and help identify and exclude identifying features, such as participant faces. However, since data will be collected as part of group discussions, it is not possible to withdraw your individual contributions once they have been integrated into the group findings.

Participants can contact Mark at any stage of the workshops if they have any issues or feedback. He is available for in-person discussions during the workshops or can be reached via the email provided above.

Possible benefits and risks to participants

Your participation in this research endeavour may offer the prospect of informing and inspiring the future of multimodal digital mobility services. By engaging in this collaborative exploration, you have the opportunity to contribute valuable insights and innovative ideas that could shape the evolution of transportation systems toward greater personalisation, comprehensiveness, and sustainability impact. Your contribution as an international student driver from the Clayton campus brings a diverse perspective and firsthand experiences integral to understanding the complex dynamics of mobility needs and preferences.

This potential enhancement holds promise for facilitating the sustainable mobility choices of participants and others and fostering broader transitions toward sustainability on larger-scale regimes. Furthermore, such involvement enriches the knowledge base of university transport planners, governmental agencies, and industry stakeholders committed to advancing community engagement in sustainable transportation initiatives.

It is anticipated that there will be no physical or emotional risk to the participants beyond the risks of daily life. Participation is voluntary, and no financial payment or reimbursement is offered. During consent, it will be emphasised that any concerns or distress can be privately communicated to the researchers during the study and that in case of any issues or complaints about the conduct of the project, they can contact MUHREC.

Confidentiality

By signing the consent form, you consent to the researcher collecting and using information for future research analysis, writing and academic presentations. No personal details will be created in this research. The study results will be published in a PhD thesis and graduate exhibition; if so, no personal information will be included. All data will be de-identified before publication. This may include blurring participants' faces and/or using a pseudonym. Third-party professional services will transcribe audio and video recordings. This company will not have full names, contact details or other identifying information.

Storage of data

Digital data will be stored securely on password-protected drives with access restricted to the investigator(s). The digital data will be deleted after 5 years after the project is complete. Any hard copy records will be stored in a secure cabinet located in the office of the chief investigator and retained for a maximum of 5 years.

Use of data for other purposes

Data from this study may be used to inform other concurrent studies; these are all aimed at promoting sustainable travelling for the future of the Clayton campus. Only summarised, de-identified data will be used to inform other projects where ethics approval has also been granted.

Results

After the two workshops, data collection, and analysis, the results will be shared with participants for feedback (if requested). Selected quotes, audio, videos, and photographs will be used only in a de-identified manner (meaning your name will not be used) unless otherwise agreed upon. Results from the research might be published in the form of a journal article, exhibition film or conference paper, and a copy will be shared directly with participants. If you would like to be notified of such publication, such as (but not limited to) a doctoral thesis or graduate exhibitions, please contact student researcher Mark Yang via the email address provided above. Information and data you share with the research team can be used in future research projects with your consent.

Complaints

If you have any concerns or complaints about the conduct of the project, you are welcome to contact the Executive Office, Monash University Human Research Ethics (MUHREC):

Executive Officer

Monash University Human Research Ethics Committee (MUHREC)

Office of Research Ethics and Integrity

Room 116, Administration Building B (3D)

26 Sports Walk, Clayton Campus

Monash University VIC 3800

Tel: +61 3 9905 2052 Email: muhrec@monash.edu Fax: +61 3 9905 3831

Thank you,

Selby Coxon and Chenlizhe (Mark) Yang

Appendix E. Participatory design workshop consent form

MONASH University

CONSENT FORM

42308 - Design workshop of the future Sustainable Mobility as a Service (S-MaaS) platform

Associate Professor Selby Coxon
Chief Investigator
Department of Design
Email: selby.coxon@monash.edu

Chenlizhe (Mark) Yang
Student Researcher
Department of Design
Email: chenlizhe.yang@monash.edu

I have been invited to take part in the Monash University research project specified above. I have read and understood the Explanatory Statement and I hereby consent to participate in this project.

I consent to the following:	**Yes**	**No**
I am 18 years of age or older and will participate in Study 42308: "Design Workshop of the Future Sustainable Mobility as a Service Platform". This study will include two workshops, each held on separate dates.	☐	☐
I consent for audio/video recording to be taken during the workshop.	☐	☐
I understand that the photos taken, and audio and video recording made as part of this study will be used for analysis. Photos/audio/video where I can be identified will not be published.	☐	☐
I understand that de-identified photos/videos from the workshops might be published.	☐	☐
I understand that the ideas I convey during the workshop discussions will be used for analysis and incorporated into design concepts that might be applied in public spaces.	☐	☐
I consent to be observed during walk-alongs and re-engagements of key scenarios as I use the design concepts of the mobility service digital platform at the Monash Clayton Campus and Monash Technology Precinct.	☐	☐
I understand that the results will be presented through academic reports and journal/conference publications, in a totally de-identified summary form in which I cannot be identified.	☐	☐
I understand that the information and data I share within the workshops will used in future research project(s).	☐	☐
I acknowledge that data, including digital (video, audio, and photos) and physical (sketches, sticky notes, and journey maps), will be sent to a third-party transcription service for analysis after the workshops.	☐	☐
My participation is voluntary; I can choose not to participate in part or the entire study. I understand that I can withdraw at any stage of the project without being penalised or disadvantaged in any way. However, data—both digital and physical—collected during group discussions (any interaction with one or more participants) cannot be withdrawn once integrated, particularly video and audio recordings. Nonetheless, any physical data such as personal journey maps, sticky notes, or sketches that I create independently during the workshop can be withdrawn.	☐	☐
I consent to be contacted for follow-up, which may include extended testing activities and post-workshop interviews.	☐	☐

Name of Participant: _____

Email of Participant: _____

Participant Signature: _____ **Date**:_____

Appendix F. Workshop preparation and pilot activities

The activities of each workshop were designed and tested before the formal action research progress. The researcher started designing progress in early February 2023. To align with the objectives of the action research, the project adopted techniques from participatory and service design. During the process of designing the workshop activities and progress, some design-related toolkits or outcomes were developed. Despite these activities, the designed artefacts were not included in the formal action research involving participants; they remain a part of this practice-based research and illustrate the development of the workshops.

1) Mobility Design Cards

At the beginning of this development process, the researcher summarised the key findings from the literature and a contextual observation study in early 2023, specifically focusing on the transportation conditions at the Clayton campus. And the outcomes of these initial findings were presented as a series of 'Mobility Design Cards' (see Figure A.4). The concept for this card set is inspired by the design cards introduced by (Quilty et al., 2024). The design cards represented the visualised findings from ethnographic research conducted with participants and served as props during ethnographic design workshops with stakeholders.

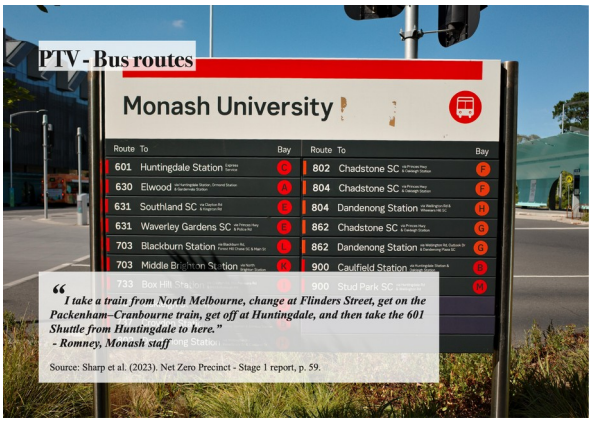
The set of categories for mobility design cards has four themes, including history, travel alternatives, infrastructure, and future options. Each card is double-sided; on one side there is a statement of the card and the findings it refers to, and on the other side an image is paired with a title and quotations from Net Zero Precinct stage 1 stakeholder interviews (Sharp et al., 2023). The images for the most part were either taken during the field observation or gathered from Monash University Archives or related online resources.

The cards were initially designed and used during the first, or kick-off, session of workshops, with the objective of involving and recalling the ideation of participants on their daily experiences around the Clayton campus.



There is no central train station located on the Clayton campus, and the closest railway station is Huntingdale Station. Metro train commuters can transfer to Route 601 at Huntingdale station, which provides express shuttle service to the Clayton bus interchange station within 10 minutes of riding time. Currently, the shuttle buses operating between the Clayton campus and Huntingdale station exclusively use electric power.

HISTORY



Source: Sharp et al. (2023). Net Zero Precinct - Stage 1 report, p. 59.

NZP_Mobility Design Card

The Public Transport Victoria (PTV) provides several modes of public transportation for the Clayton campus, including buses and trains. Ten bus routes connect the Clayton campus to Huntingdale, Middle Brighton, Box Hill, Oakleigh, Croydon, Dandenong, Caulfield train stations, Waverley Gardens, and Chadstone shopping centres. Concurrently, these bus routes facilitate connectivity for the adjacent neighbourhoods, shopping centres and transportation hubs with the Clayton bus interchange station, located at the Clayton campus's second southern entry (S2). This interchange station is conveniently located close to the Learning and Teaching Building and Menzies Building, further enhancing accessibility for commuters.

TRANSPORTATION ALTERNATIVES





Figure F-1. Samples of Mobility Design Card (from top to down display the card-set categories of History, Transportation Alternatives, Infrastructure, Future Options)

2) *“What if?”: Design fiction cards*

As part of the pre-investigation phase preceding workshop #1, a pilot activity titled “What if? Design Fiction Cards” was developed to explore futures thinking among participants. Where the Mobility Design Cards described conditions that already existed at Clayton, this second set was intended to move participants beyond them, by proposing situations that are not yet true and asking what would follow. The approach draws on design fiction, in which a speculative artefact makes a possible future concrete enough to be discussed, and on the experiential futures approach of Candy and Dunagan (2017) referred to in Chapter 3.3.2.

Each card carried a single prompt on the front, phrased as a “What if?” question about the Clayton precinct, with a short set of possible consequences on the reverse intended to open discussion rather than close it. The prompts were grouped into three provocations. Removal took away an element of the commute that participants already relied on, such as all campus car parking. Substitution replaced an element with a different one, such as a shuttle arriving on demand rather than to a timetable. Amplification extended an existing element beyond its current limits, such as a precinct in which every trip is planned and paid for through a single account.

The set was tested in May 2024 with Selby, following the procedure planned for workshop #1. Two observations emerged. Participants engaged readily with prompts that removed or substituted something they already used, since they could reason from their own experience, but they responded weakly to prompts describing a wholly unfamiliar system, tending to restate present frustrations rather than imagine alternatives. The activity also ran longer than the schedule allowed, because each card generated discussion that could not be closed without losing the contribution.

Even though the fiction card set was not formally employed during the workshop with participants, the preparatory development of the “what if?” activity was instrumental in refining the researcher’s understanding of futures-oriented design methodologies and their potential engagement for the participatory design research. The pilot testing and subsequent reflection underscored the value of futures-oriented approaches as a means of moving participants beyond present frustrations, and three decisions in workshop #1 follow directly from it. Futures work was anchored in participants’ own journeys rather than in abstract scenarios, which is why the session opens with the radar journey map. Speculation was bounded to the precinct and to a near horizon rather than an open one. And the future scenario activity was given a fixed structure of journey steps, information channels, thoughts and dramatic arc, so that imagination was supported by a frame rather than left open.



Figure F-2. Tested design fiction card set

3) Mapping journey: understanding everyday mobility

The third preparatory activity developed a mapping format through which participants could record an ordinary commute in enough detail to be discussed by others. The problem the format had to solve is that habitual travel is difficult to recount. Participants asked to describe how they get to campus tend to name a mode and a duration, which conceals the decisions, waits and small frustrations that shape whether the journey is repeated.

Several layouts were drafted and tested. A linear timeline was tried first, but it invited a sequence of modes rather than an account of experience, and it gave no place to record how a participant felt at any point. A radial, or radar, layout was adopted instead, with the campus at the centre and the journey working outward, so that distance from the centre carried meaning and the first and last stages of the trip were visually separated from the middle. Concentric bands recorded the mode used, the information consulted at each step, and the participant's state of mind, which allowed a single sheet to hold both what happened and how it was experienced.

Testing showed that participants completed the map more readily when it was seeded with a small number of fixed reference points, such as the arrival gate and the departure time, rather than presented as an empty form. It also showed that the map worked best when participants

narrated it aloud while drawing, since the spoken account contained detail, the drawing omitted. Both observations were carried into workshop #1, where journey mapping opens the session and is followed by participants presenting their own map to the group (see Chapter 3.3.2 and Figure 3.15).

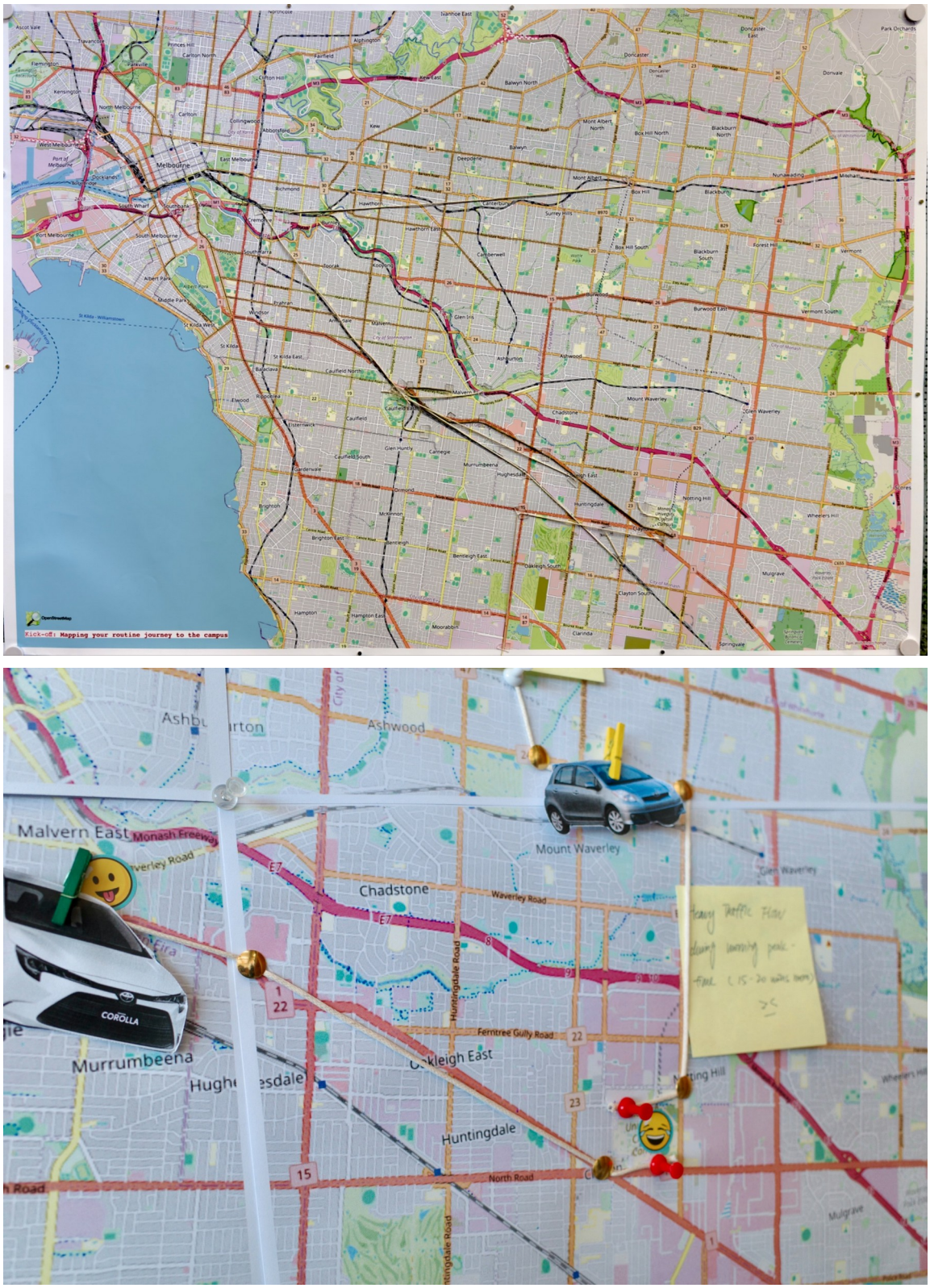


Figure F-3. Sample of journey map workshop activity

4) X-curve: identification of barriers and enablers

The X-curve is a diagram used in transition studies to hold two processes in view at once, namely the build-up of a new practice and the breakdown of the established one. Drawn as two crossing lines across a shared timeline, it shows emergence, acceleration and institutionalisation on one arm, and optimisation, destabilisation and phase-out on the other. Its value for this research is that it treats decline as a subject of design attention rather than an afterthought, which matters when the practice in question is driving to campus.

The activity adapted the diagram into a working sheet on which participants could place barriers and enablers. Enablers were positioned on the rising arm, since they describe what would allow an alternative practice to gain hold, and barriers were positioned on the falling arm, since they describe what keeps car use in place or slows its decline. Placing an item required participants to say when it would matter, which produced more specific statements than a simple list of problems.

Testing indicated that the diagram carried too much conceptual load for a short session. Participants unfamiliar with transition language spent much of the available time interpreting the axes rather than populating them, and the two arms were frequently read as good and bad rather than as build-up and breakdown. The sheet was therefore not used in its full form during the workshops. Its influence remains, however, in the way barriers are treated in this exegesis, since the four barriers reported in Chapter 4.5.3 are presented as conditions holding an existing practice in place rather than as isolated complaints.

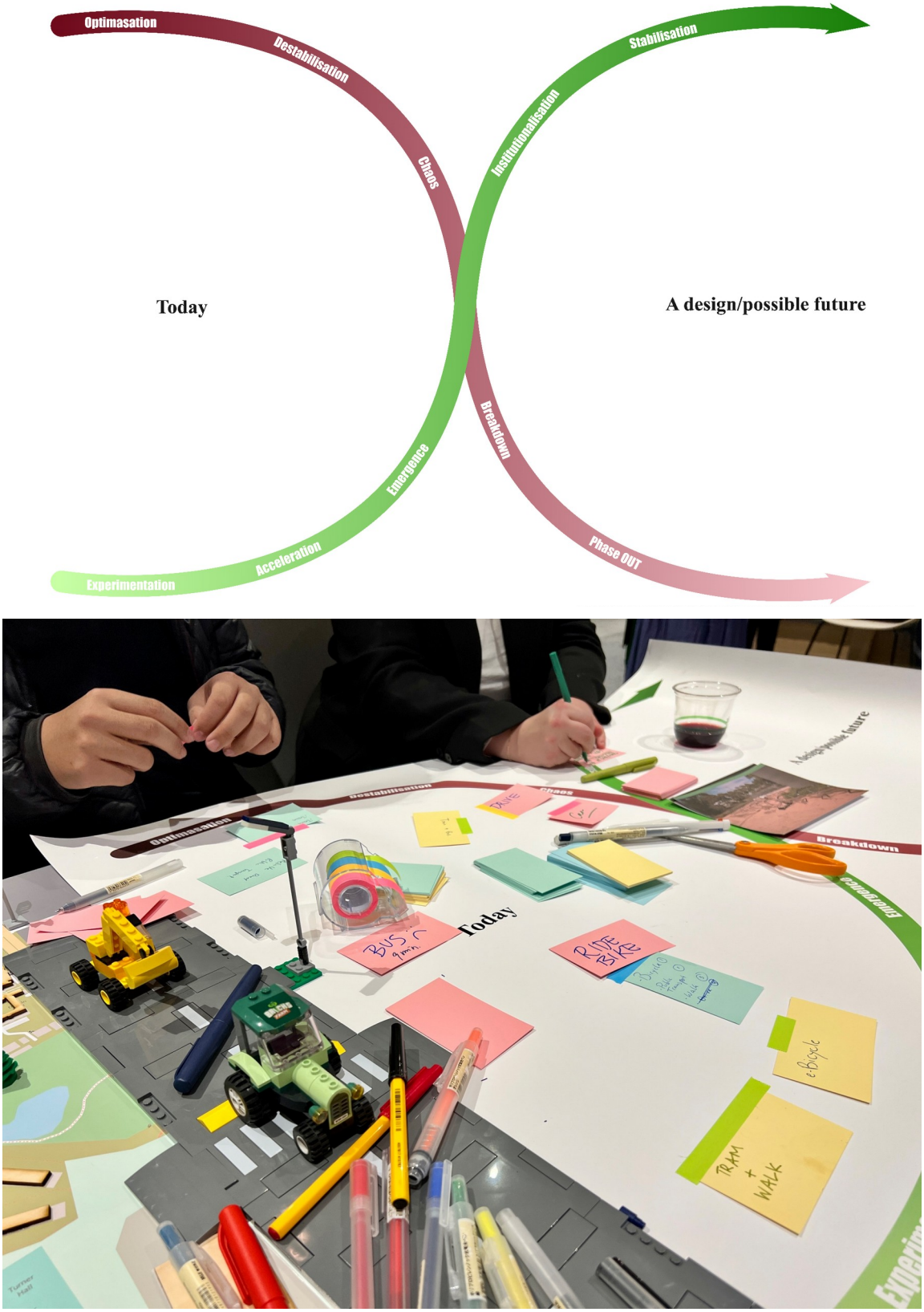


Figure F-4. X-curve analysis sheet (top), testing sessions (bottom)

Pilot testing and method refinement

Prior to formal participant recruitment and data collection, a series of pilot and testing activities were conducted to evaluate the structure, flow, and viability of workshop #1 (see Figure F-5). The pilot testing sessions were crucial in enhancing the interactive techniques and supporting materials, ensuring their clarity, accessibility, and compatibility with the research aims. The testing sessions play an essential role as a formative assessment process to improve methodological rigour and bolster the execution of the design interventions in the next participatory research trajectory.

Pilot testing was conducted in three iterative phases from August 2023 to August 2024. Each round included several volunteer participants, from academic colleagues, postgraduate design researchers, and undergraduate students who were acquainted with or interested in the participatory and design methodologies. Although the participants did not reflect the study's target population, such as international student drivers, their participation was crucial in uncovering procedural ambiguities.



Figure F-5. Testing workshop #1 with visitors from Monash University Higher Degree Research information session on 23 August 2023 (photo was captured by Selby Coxon)

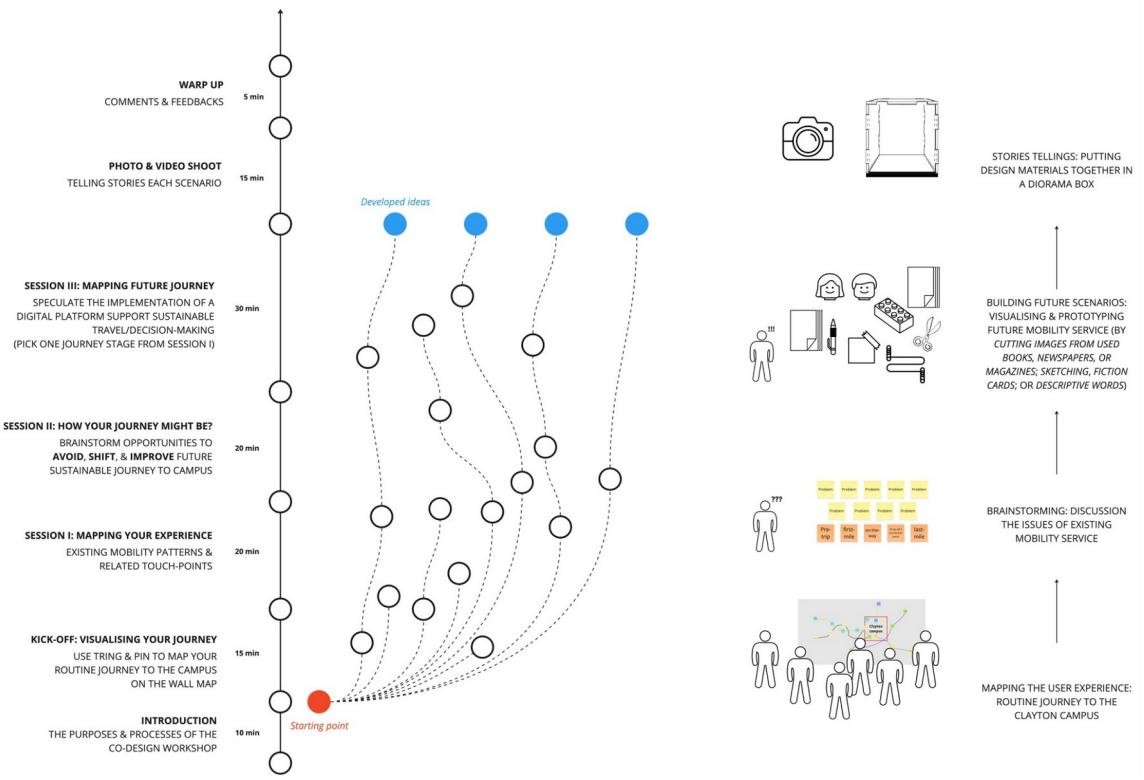


Figure F-6. Initial procedure of workshop #1

A pilot workshop #1 was conducted on 7 May 2024 with undergraduate students from the Faculty of Art, Design and Architecture (MADA) at Monash University Caulfield campus (see Figure A.10). This session served as an exploratory playtest of the complete sequence of participatory activities developed for the formal design workshops with recruited international student participants. With the primary objective of assessing the coherence, timeliness, and engagement levels across all activities of workshop #1, including the visualised journey mapping, commuting challenges analysis, and imagination of future sustainable travelling scenarios (refer to Figure A.11). The designed procedure which tested with the undergraduate students was aligned with the



Figure F-7. Pilot workshop #1 playtest with undergraduate students from the Faculty of Art, Design and Architecture (MADA), Monash University, on 7 May 2024.

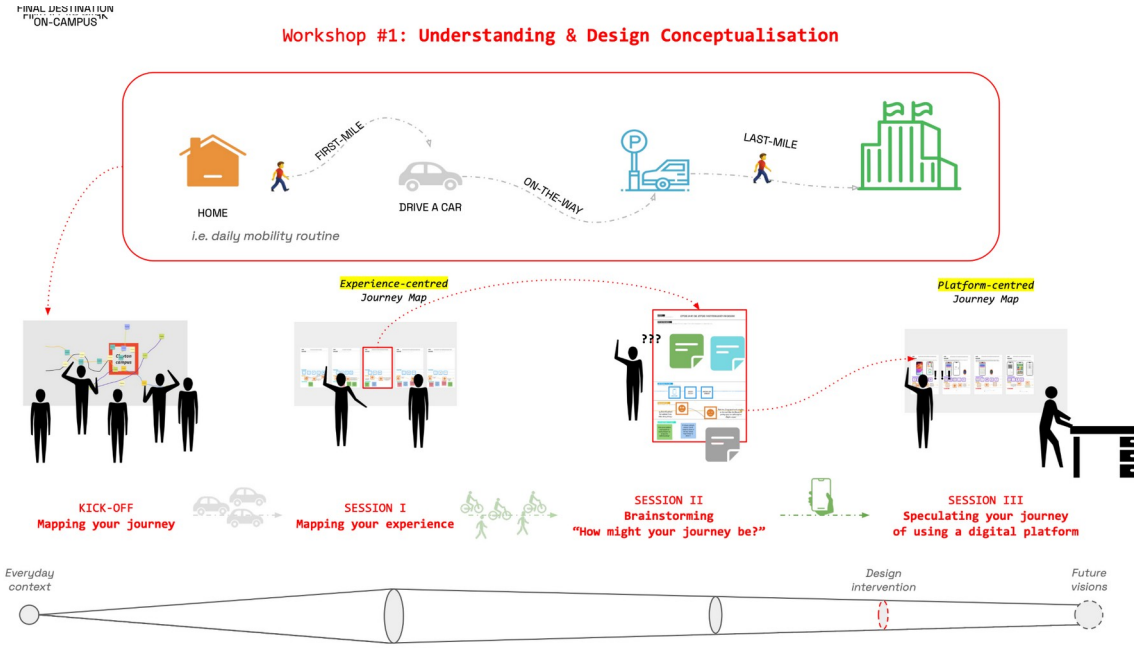


Figure F-8. Designed procedure of the pilot workshop #1

Appendix G. Participatory design workshops selected raw data (images & initial codes)










MONASH University

PAST STORIES ON CHANGE			
Participatory quotes and action	**Initial codes**	**Connecting concepts**	**Selective codes**
I didn't feel like going out, I just wouldn't. I didn't need to go out every week. I could simply stay at home if I wished, so I didn't really care. After getting married, however, I started thinking about going out each week. Maybe going somewhere to buy a few things or visiting a few different places. At that point, you realise the importance of having a car. (C#2_00:24:21)			External factors for behavioural change
(the book) suggests finding an accountability partner. For example, I asked my wife to set a password for the screen time limits on my phone, like a child lock. At first, I didn't stop completely—I could still access social media on weekends. (C#1_00:20:38)	Family care		
Urbanisation affects our capacity to change ourselves and our ideals. Or rather, when people move into a city… When I was very young, just five years old, I moved from my hometown to Shenzhen. (C#5_0:26)			
[researcher: So, getting married had a huge influence on your car usage habits?] Yes, because previously I rarely went out. If I didn't take public transport, I would just take a taxi, and that was fine since I generally wouldn't go very far. (C#2_00:25:08)			
I didn't fully know the traffic laws, I had a translated copy of my licence, so I drove straight home. I learned all the rules on the road through experience. I've been fined before. My biggest fine was AUD 471 for not giving way to a tram. That was in the city, on one of the busiest roads. (C#3_00:05:15)	Security of driving	Barrier Types (BT)	
...where I lived was basically in that area, so everything was pretty close by. If I had classes or anything on campus, I could just walk. Even during my undergraduate years, it took about twenty minutes on foot, which was still acceptable. (C#2_00:25:22)	Living near campus	Travel Motivation (TM)	
To get to campus, I mostly walked, which was a good way to get some exercise. From Clayton, it's actually not too bad to get to other shopping centres. (C#2_00:25:45)	Physical exercise		
"Like you mentioned about seeing the aurora, the car is also a means of earning some extra money for me. I pick people up through Xiaohongshu (a Chinese social media platform) for paid rides. Regarding that aurora event—there have been two major displays since I've been here. (C#3_00:03:34); I drove people twice for these events (aurora). For the meteor shower in Mornington, I also drove people there. It was very crowded. Since my car is just a sedan and can only seat five, I switched to renting a people mover that could seat eight. I rented it through a local car-sharing platform, which is how I earned a bit of side income. I'm very familiar with driving now. (C#3_00:03:34)"	Earning tool	Car-Dependency (CD)	
When I first arrived in Australia, during my first month here, I bought a car. Owning a car has had a huge influence on me. Having a car allows me to get closer to nature, so I often drive out to enjoy myself. Before, in China, I sometimes drove as well, but since I was mostly on campus, I didn't really need a car. After coming to Australia, though, I find myself driving almost every day because my campus is in Caulfield, not in	Driving to suburb areas		

PAST STORIES ON CHANGE			
Clayton, so I drive to university frequently. On weekends, I drive out to distant places (rural areas). (C#3_00:02:29)			
...once you've bought a car, you feel inclined to visit farther places. (C#2_00:26:23), Previously, I wouldn't consider those places because they were too troublesome to get to. For example, when we wanted to see the aurora recently, we needed a place with minimal light pollution, a wide-open area. You can only reach such places by driving. Without a car, you just can't get there. (C#2_00:26:30)	Convenience of driving		Emotional Drivers (ED)
I saw on social media (like Xiaohongshu) that the tram stops near the aurora-viewing spots were packed in the early hours of the morning—crowded with people. It sounded overwhelming. (C#2_00:26:52)	Information from social media		
Like you mentioned about seeing the aurora, the car is also a means of earning some extra money for me. I pick people up through Xiaohongshu (a Chinese social media platform) for paid rides. Regarding that aurora event—there have been two major displays since I've been here. (C#3_00:03:34)		Mobile Usage (MS) - Social Media	
I decided to stop using social media because I realised, I was spending way too much time on it every day. (C#1_00:19:27); Social media often contains repetitive or trivial content. Scrolling through it doesn't really add much value to your life. I find it more rewarding to spend time reading or doing something more meaningful. (C#1_00:22:15)	Waste time on social media		Internal factors for behavioural change
Previously, I never participated in any school activities—no volunteering, no extracurriculars, nothing. I never bothered to look up what was on offer. It wasn't until recently that I discovered our university runs a crochet group—just people with a shared interest getting together and teaching each other. I decided to join and found it quite enjoyable. (C#10_0:03)	Behavioural change on social activities	Social Connection (SC)	
"I think it illustrates that something can seem terrifying if you've never done it before. But once you've done it, you realise…that it's not so bad. (C#7_1:19); Also, I realised that if you don't face something you're afraid of, it will keep haunting you. (C#7_1:36)"	Overcome inner fear	Safety Concerns (SC)	
When I look at this picture (a photo of forest), I recall how, after arriving in Australia, I've really wanted to get out and explore. Australia has many places I like because, compared to China, they're more pristine and less affected by human intervention. I love that feeling, so I often drive to places like that. This reflects a change in my lifestyle from when I lived in China to now living abroad. (C#3_00:03:34)	Natural environments		
Once you reduce your time on social media, you'll find you have more opportunities to connect with nature and adopt a new lifestyle. (C#1_00:20:00)		Emotional Drivers (ED)	
I'm now willing to go out and explore these places. Even though I live in a city, just as I'm willing to visit a zoo that might be located far away or in a remote area, I'm also willing to visit farm stays or these types of places. Now that I'm in Melbourne, even during holidays, I'm happy to travel somewhere with forests. (C#4_1:30)			
(if) back in the countryside, the main work is farming. If I were	Preferred lifestyle	Self-Perception (SP)	

PAST STORIES ON CHANGE			
to go back and farm, I wouldn't know how to do it. The countryside can't offer me the same job opportunities. Plus, all my daily life and entertainment are city-based. I've stayed in the village for a short period—maybe a day or two—but not long term. Life definitely revolves around the city for me. I find that places too small and too quiet are a bit dull. (C#5_1:35)			
Previously, I studied IT, and I used to think programmers were in high demand and coding would be fun. But once I actually started studying it, I felt like I was stuck—it was much harder than I imagined. (C#6_0:06)...It's completely different from what I imagined. (C#6_0:28)	Conflict between anticipation and actual situation		
If we're just talking about this random jumble of code, then I'd say it's not great. But seeing this gibberish reminds me of those happy times in my childhood when I was exploring computers, so in that sense, it's good. (C#8_0:16)	Childhood experiences		

EVERYDAY COMMUTING EXPERIENCE			
Participant quotes and action	**Initial codes**	**Connecting concepts**	**Phases of journey**
My wife wanted me to get a license, so she scheduled the test for me. Otherwise, I might've kept procrastinating. (C#2_5:24)	Family caring	Family caring	***Pre-trip***
Every morning, I take my wife to the station for work, so it's really convenient to stop there. (C#2_0:03)			
I primarily use Google Maps or the built-in Apple Maps, and they usually provide accurate navigation. Occasionally, there might be inaccuracies, but they're rare. I've only encountered one or two instances where the destination couldn't be located, so I rate this stage quite highly. (C#1_0:05)	Mobile-map apps	Digital platforms	
...every day, since the roads near my house are under construction, I never know which road will be closed today or tomorrow. So, every time I head out to school, I have to rely on GPS. If I don't use navigation, the road I took yesterday might be closed today, and I'd have no way to get around it. That's why I now always use GPS—it's unavoidable. (C#2_0:10); I live in an apartment with a parking lot on the second basement level, there's no signal down there. So, I have to plan the route and start navigation at home (C#2_0:43)	Road construction		
I have to plan the route and start navigation at home. Once I'm in the car, it connects and works. Otherwise, I'd have to drive up to the surface to get a signal and set it up there, which is really inconvenient. That's why I docked some points here—it's not as seamless as it used to be. (C#2_0:43)	Avoid Traffic congestion		***First-mile***
But leaving the parking lot can be tricky. The parking lot's exit has cars parked on both sides of the gate, which blocks your view. (C#2_1:31)...It's hard to see oncoming cars, and it can be dangerous. (C#2_1:56)	Blind spot	Road safety	
"It's very frustrating, especially if I'm running late. On top of that, my car is old and has a six-cylinder engine, so it's very fuel-inefficient. You can literally see the fuel gauge dropping while I'm driving around the parking lot. It's so wasteful. (C#3_1:00)"	Searching for a parking lot	Cost of fuel	***On-the-way***

EVERYDAY COMMUTING EXPERIENCE			
For “on the way,” the main issue is road construction. There’s constant congestion, with two or three lanes merging into one. It’s frustrating. But at least I drive a hybrid, so it’s not fuel intensive. (C#2_2:35)	Road construction		
I might as well ride a bike. I could park anywhere and save all that time. I’ve even considered cycling when the weather gets warmer. (C#1_4:05)	Try to cycle	Active mobility	
...as pedestrians, the experience can be quite strange in Australia. For example, the cars here drive very fast, and at crosswalks, there aren’t many pedestrians. When you’re crossing a major intersection, you feel like all the cars are watching you from every direction. It’s like being on a stage with all eyes on you as you cross. (C#3_3:52)	Anxiety at crossings		
"I enjoy the driving experience more than walking. (C#3_2:35); I enjoy driving more because you just sit and relax (C#3_3:28); Sometimes (listen to music), but often I prefer silence. I just drive quietly and let my mind wander. (C#3_3:35)"	Enjoy driving	Comfort of driving	
"Mainly my laptop—it’s old and heavy. Carrying it on my back while biking is tiring. Also, the wind and weather here are extreme—it’s often very windy or cold. Driving is just more comfortable. (C#1_4:31); Driving is just more comfortable and gives me a better experience. (C#1_5:00)"	Carrying laptop		
...so what I was saying is, as long as there's an engine making noise, it bothers me. So I'm thinking about switching my car to a fully electric one. Anyway, that's unrelated. (C#2_0:03)	Quiet driving experience		
Every morning, I take my wife to the station for work, so it's really convenient to stop there. (C#2_0:03)	Family caring	Family caring	
Whether I park at the N1 car park or the Woodside Building car park, it's usually okay. At the N1 multi-level car park, even the blue permit spots aren’t usually full. (C#2_1:39)	Off-peak time parking	Parking on campus	***Drop-off***
Sometimes when I arrive late, parking can be difficult. Occasionally there's no space at Woodside or N1, and then I'm stuck. (C#2_3:09); If there are no spaces near Woodside when I arrive, it’s pretty much hopeless. I just keep circling around the N1 car park, going up and down, until eventually, a space opens up and I quickly park and rush to my meeting. (C#2_3:51)	Peak-time parking		
"Every time I arrive, the parking is usually full. I have to drive from the ground floor all the way to the fifth floor or rooftop. (C#3_1:00); It seems like the driving skills of students at Caulfield or Clayton aren’t great. The turning areas near the pillars are very narrow, so people often stop and inch their way around. It’s quite annoying. (C#3_2:07)"			
"It depends on luck. On a good day, you might find a spot on Ground 2 within five minutes if someone just stepped to leave (C#1_3:21); (if on a bad day) You might search the entire structure and find nothing, then have to move to a different zone. That can take much longer. (C#1_3:28); The longest was when I had plans to meet friends at the sports			

EVERYDAY COMMUTING EXPERIENCE			
centre. I tried the parking structure there, couldn't find a spot, search the surface lots, and eventually had to come back to N1. It took me half an hour. (C#1_3:39)"			
After parking in N1, I still have to walk to my lecture buildings —usually Woolside or LTB. It's quite far. Walking to LTB takes at least ten minutes.	Long-walking distance	Walking on campus	***Last-mile***

IMAGINATION OF FUTURE MAAS			
Participant quotes and action	**Initial codes**	**Connecting concepts**	**Selective codes**
For me, monetary rewards would be ideal. For instance, if driving emits a certain amount of carbon, and using this platform reduces that, I'd want a cash reward for the carbon savings. (C#1_0:05)	Financial rewards	Sustainable Trade-offs (STO)	Design Enablers (DE)
The rewards could come in many forms: digital credits, e-vouchers, or discounts usable within the university. If this project is rooted in a university setting, the rewards could encourage campus spending, further promoting the app. (C#3_1:51)			
there's the idea of rewards for low-carbon travel, whether they're financial or psychological...you need a mix of incentives. (C#2_0:06) I wrote down the idea of a "digital wallet," a centralised credit system (C#2_0:53)... For example, if you meet certain goals, you could receive badges or rankings to boost a sense of achievement. Some people don't care about small cash rewards, like $5 or $10, but psychological rewards can be effective. (C#2_0:29)			
if you've accumulated enough credits, you could reserve a parking spot...or exchange creidts for parking discounts. (C#2_2:02)	Parking permits		
...for instance, collecting enough credits could get you a lunchbox. (C#2_1:23)	Physical rewards		
Based on my personal experience, when I use Google Maps to find parking, it usually directs me to paid public parking areas. It rarely shows free parking options (C#3_0:02)...If this route planning feature could differentiate between paid and free parking options, that would be very helpful. (C#3_0:23)	Route planning		
The first is route planning, which is crucial. The plan must be reliable—if I have 30 minutes before class and the app estimates a 25-minute journey, it must actually take 25 minutes, not longer. (C#1_1:36)			
For me, the two most important aspects of travel are convenience and speed. If there's a method other than driving that can get me to my destination, I'd be happy to use it—as long as it's convenient and reasonably comfortable. (C#1_0:07)	Convenience	Lifestyle Alignment (LA)	
I started using it when I didn't have a car, and I've used it for about a year. But I don't need a car every day. (C#5_6:00); It's usually for longer trips, like going to the beach or when I need to transport equipment for filming. For example, I need a car for carrying my camera gear. (C#5_6:34)	Owing a car		

IMAGINATION OF FUTURE MAAS		
I'd learn how to use the app and understand local transportation options. As I add more information, the app could offer better suggestions. (C#4_4:34)		
I think it could add personalised recommendations. For instance, if I often choose to bike or use public transport, it could prioritise suggesting those options. (C#6_0:32)		
What we need is an app that provides similar information: the benefits, the challenges, what to expect. For example, Google Maps won't tell you how tough a cycling route will be or whether it's suitable for a beginner. (C#6_4:01)	Personalised suggestion	
A voice assistant could announce nearby parking options and guide you to the most suitable one. For example, if you're attending a 2-hour class, the assistant could suggest a 3-hour free parking spot, which would be just right. (C#3_0:44)		
...you need a mix of incentives. I wrote down the idea of a "digital wallet," a centralised credit system. (C#2_0:53)	Digital wallet	
...encourage people to park further away in suitable spots and then walk... (C#3_2:33), although parking is limited, we could optimise usage by allocating spaces smartly. For example, in residential areas where residents leave for work during the day, cars could park there temporarily (C#3_2:52)	Active Mobility	
Once I've fully adapted, my reliance on the app would decrease. After I become familiar with routes and options, I wouldn't need it daily. (C#4_5:13); ...it would have already helped me build a habit. (C#4_5:18)	Training sustainable travel habits	
...these options are currently separate, but it would be ideal if they were all accessible and payable through one app. (C#1_0:34); Another feature would be the ability to pay after the trip, similar to Uber, so you can just get off without worrying about payment at that moment. (C#1_2:11)	Payment	
Overall, the app acts as a centralised medium. (C#2_3:28)... like MyGov, which connects users to multiple services like the ATO or Centrelink. (C#2_4:05)	Centred medium	
...if this system could integrate all available transport options into one app, it would be great. For example, short trips could be solved with a scooter, while longer journeys could combine a car and a scooter. (C#1_0:34)		
...you could convert more spaces to be dedicated to these smaller cars. And even though it's a vehicle, it still gives you a better range, speed, and climate control compared to a bike or scooter. And because it's fully automated, it can connect to smart devices, like your app, and integrate all the information needed, which can be used in these mini electric vehicles. (C#5_0:39)	Integrated multimodal transportation options	Perceived Accessibility (PA)
I'm thinking that if there's an app designed to assist us, it could help in multiple ways. (C#6_0:01)		
Driving, public transport, walking, or cycling. I didn't include driving here, but I might add cycling. Cycling might have more restrictions compared to the other options. Cars, however, aren't necessarily a traditional or straightforward mode of		

IMAGINATION OF FUTURE MAAS			
transport; it's more complex. So, I'd need an app. (C#4_0:27)			
...and maybe you'd cycle or take public transport for the first few days of the week to save up for driving on Friday when you have an important event. (C#2_2:18)			
(the digital platfiorm) could collect credits that can be redeemed for tangible rewards or other benefits. (C#2_1:05)	Visualised benefits		
...with GoGet, the car conditions aren't always guaranteed. For example, the car I got was quite old, and some cars don't even have reverse sensors or decent maintenance, so you can never be sure about the car's safety. (C#5_4:12)	Safety	User Trust (UT)	Adoption Drivers (AD)
I feel that before arriving on campus, we don't know where we need to go for classes or how big the campus is. There's no real plan. That's why I think this app should help by telling me how to get from where I live to campus. (C#4_0:00)	Navigation on campus		
It could also display this data visually, making it easier to compare progress over time. (C#2_3:17)	Data visualisation		
...the app should offer alternative language options for people who don't speak English and cater to the needs of older users. (C#1_2:22)	Multi-language		Barriers to Change (BTC)
The worst part is that this route from Carnegie to Clayton overlaps with part of the Caulfield-Clayton commute. If someone decides to cycle between Caulfield and Clayton, they'd suffer too. But no app currently tells us how tough a cycling route is or what to expect in advance. (C#6_2:37)	Lack support of cycling		
...about the voice assistant, some people may be close to their destination but it's unsafe to check their phone while driving. (C#3_0:29) A voice assistant could announce nearby parking options and guide you to the most suitable one. (C#3_0:44) The focus here is on driving security, reducing unnecessary risks. (C#3_1:09)	Voice-guide	Barrier Types (BT)	Design Enablers (DE)
For example, if you're attending a 2-hour class, the assistant could suggest a 3-hour free parking spot, which would be just right. (C#3_0:44); although parking is limited, we could optimise usage by allocating spaces smartly. For example, in residential areas where residents leave for work during the day, cars could park there temporarily. (C#3_2:52)	Parking on campus		
...but tailored to individual preferences and conditions like the weather. For example, if it's likely to rain, the app could recommend I take public transport instead of biking. Also, for local students, there are concessions like half-price fares, but international students might not be aware of these benefits. (C#6_0:42)	Personal preferences		
...but here's the story. We took a taxi from Clayton to Carnegie, about 10 kilometres, because we didn't know there was a train or shuttle bus option. The journey required walking over a kilometre in some parts, so we chose to take a cab. On the way back, we realised it was a painful 10+ kilometre trip. (C#6_2:10)	Familiar with local transportation	Emotional Drivers (ED)	
...at least (the digital platform) help me decide where to live based on a reasonable distance and suggest the most suitable			

IMAGINATION OF FUTURE MAAS			
transport options. (C#4_1:02); This would apply before I move here. I'd need to estimate my commute time. My personal experience is that during my first year, I lived in Boronia, which you know is far. I had to take the train to the city (CBD), and from the station, it was a 5-kilometre uphill bike ride. Should I take the bus or cycle? It was very challenging. (C#4_1:23); I want this app to help me quickly develop similar strategies here. (C#4_4:31)			

EXPERIENCE ON PHYSICAL PROTOTYPES			
Participant quotes and Action	**Initial codes**	**Connecting concepts**	**Selective Codes**
"The safety concern probably arises from a gender perspective. Girls might particularly worry about it. If it became a kind of social or friend-making app, I might avoid it because I'd be concerned about harassment or unwanted interactions. (C#7_1:33); ...maybe this social feature might appeal more to guys looking to date or something. But for most girls, apart from those who really want to socialise, it might just increase anxiety around safety. (C#7_2:40)"	Security of female travellers		
"The app gives me a sense of belonging. After exploring it and finding it useful, I feel more inclined to provide personal details, like confirming my identity as a student. (C#7_1:00); The app feels distinctly Monash-focused. For instance, integrating your student pass into your wallet or Apple Pay feels personal and useful. (C#7_1:55); If it was just an app (without Monash logo, or identification elements), I probably wouldn't notice it, and even if I did, I wouldn't download it. But because I'm a student here and it's our university's app—... (C#7_4:17); I trust the app because the uni acknowledges me as their student and created something specifically to make travel easier for us. (C#7_4:36)"	Belonging	Identification	
(the notifications, like promotions for transport or schedule updates are helpful), like reminders about upcoming bus schedules or new routes. It's also nice if it integrates with Monash systems, like linking to school emails or course schedules. (C#7_2:44)	Notifications on promotions	Information Display	"Adoption Drivers (AD) Design Enablers (DE)"
I think the app is helpful for viewing daily schedules and suggesting efficient travel options based on my timetable. (C#7_3:54)	Daily schedules		
...if it (the digital platform) shows options like walking or cycling and their time estimates. It could attract users by integrating exercise into commuting. (C#4_2:13)	Details of each alternative		
(the "Direction" feature) should be more accessible from the main screen. (C#10)	More easy access to the function of direction		
I'd rate it (the functions of journey planning) low for planning because it doesn't provide enough detailed information. It's hard to account for uncertainties like weather changes or unexpected challenges (C#4_3:30)....An example, if I plan to	Weather conditions and unexpected challenges		

EXPERIENCE ON PHYSICAL PROTOTYPES		
cycle but the train service is down, I might end up cycling 10 extra kilometres on poor roads. These complexities make planning difficult. (C4#_4:05)		
(I propose) Users wouldn't need to search through menus. For instance, if there's an AI assistant integrated, like Siri, I could just say, "Hey Siri, help me plan my trip to Monash. (C#9_0:23)	Facilitated with AI	
It could consider time, money, calories burned, and carbon emissions—multiple dimensions (C#9_3:03)...and users could choose which dimensions matter to them. If it's AI-based, users could simply talk to it instead of manually selecting options. (C#9_3:15)		
For navigation, I'd like the app to connect with other tools I use, such as cycling trackers or wearable devices, to provide seamless guidance. (C#4_5:24)	Connection with relevant hardware	Integrated with external contexts
"Based on my experience using navigation apps, I prefer a minimalist design where the main features are easily accessible on the home screen. (C#8_0:01); If users can customise it, adding more personal features, it would be even better (C#8_0:36)...allowing users to add their own content, like notes or visual changes within the interface, would be great. (C#8_0:52)"	Simplism of design of home page	Simplism design language
For design, I believe "less is more." The best designs simplify things. On the home page, I'd suggest adding a feature like "Tap to Talk," allowing users to interact with an AI assistant. For example, I could say, "I want to go to the Caulfield campus by a certain time," and it would recommend the features I need. (C#9_0:00)		
I'd recommend modularisation. For example, on the first use, users could select which features they care about, like planning trips, and skip others like subscriptions. This customisation could reduce server load too. (C#9_1:20)	modularisation of multi-functions	Personalised design
If I only care about planning and not subscriptions, I don't want to see unnecessary notifications. (C#9_1:54)	Unnecessary notifications	
If it includes robust features like a planner or reminders, I would use it consistently. These features are useful to me, but I wouldn't want the pricing for per-use plans to be too high. (C#8_3:48)	Personalised journey planning & reminders	
I'd prefer if it saved my preferences so I wouldn't need to adjust them every time I use the app. (C#3_2:01)	Saved personal preference	
I go to the "Plan" section of the app. Initially, I thought it was like Google Maps, where you could plan a trip. But it turns out this "Plan" is linked to a calendar event. If I have an event in my calendar, I can see options like public transport or driving. (C#2_1:28)	Personalised journey planning	
non-driving options depend heavily on weather conditions. For example, if it rains, I may wait for a taxi or reconsider cycling. (C#4_2:44)	Dynamic or personalised travelling route	
...but the issue is, if I don't have a calendar event, I can't just randomly plan a trip. For example, if I suddenly decide to go to	Unscheduled travelling requires	Adjustable options

EXPERIENCE ON PHYSICAL PROTOTYPES			
university, I can't input the start and end points directly. (C#2_1:50)... I think it should allow users to input a start and endpoint for immediate navigation. (C#2_2:15)			
(Unscheduled events, or off-semester periods travelling) It depends, as my schedule changes frequently (C#8_3:18), for example, during exams, I only plan specific trips, not daily ones. (C#8_3:23)	Frequency of accessing campus		
...because when you open the app, you immediately understand its purpose, which helps you decide whether to use it. Also, this page is visually appealing and engaging. (C#7_0:23)	Easily understand		
It (the founction of social connecting/networking) doesn't have much meaning for me. If I wanted to meet people, there are plenty of other Chinese students in the apartments or classmates. You can easily chat on campus if you really want to. (C#7_2:00)	Less requirement of social networking	Social network	
my view is that people you meet online aren't very reliable. (C#7_2:21)	Unreliable on online social network platform		
"Initially, it's about helping me plan. But after using it a few times, I'd value its rewards system, which might encourage me to keep using it. (C#10_1:32) The rewards make it more appealing than just providing directions. (C#10_2:48)"	Attract to use	Sustainable Travel Decision	Nudging & Rewarding Mechanisms
Another feature could involve setting goals, like calorie burns or carbon emissions. For instance, I could aim to burn 100 calories, and the app could suggest walking between stops instead of driving or taking the bus. (C#9_2:32)	Goal-setting		
When reaching the destination, I'd like the app to track points or credits for sustainable choices. These could translate into tangible rewards, like discounts or cashback, encouraging good habits. (C#4_0:00)	Tangible rewards		
If the pricing mechanism is appealing, like discounts or partnerships with schools, it could be more attractive. (C#3_3:28); [researcher: Would rewards or cashback systems increase its appeal?] Yes, something like Woolworths' cashback system could be very engaging. (C#3_4:24)	Discount on campus		
"(the planning function) For example, it provides a schedule, and suggestions based on preferences like travel distance. However, I find this section a bit complicated. (C#3_1:08); [researcher: Do you think this app could help reduce your driving frequency in the future?] Yes, it could. (C#3_0:31)"	Reduce-car-dependency		
[researcher: Would it reduce how often you drive if the app were integrated into your daily life?] Possibly, yes. (C#2_5:06)...I'd say about 30 to 40%. (C#2_5:16)			
...that would show whether my habits are improving or becoming less sustainable, and it could adjust plans accordingly. (C#4_1:21)	Regularly reports for sustainable commuting habits	Feedback	Gamification
The app's real-time feedback is key. For example, if I change plans mid-journey, it should adjust and help me adapt. Seeing my points increase at the end of the journey would be	Gamification elements		

EXPERIENCE ON PHYSICAL PROTOTYPES			
motivating. (C#4_3:23)			
(arriving at the bus loop Clayton)...then I check my total carbon emissions. It feels quite rewarding to see the impact. (C#2_4:00)...(due to the) ranking system (C#2_4:07)...It's somewhat helpful because it shows my emissions, encouraging me to take public transport or walk instead of driving. (C#2_4:15)	Visualised of carbon emissions in the ranking pages	Data visualisation & Leaderboards	

DIGITAL EXPERIENCE ON MAAS PLATFORM (INTERVIEWS)			
Participant quotes and action	**Initial codes**	**Connecting concepts**	**Selective codes**
Honestly, that would be tough. I don't ride a bike, so cycling or e-scooters aren't really options for me. That means I'm left with either walking, driving, or using public transport. But my place is far from campus—walking takes 40 to 50 minutes, which is too much. Plus, the terrain is uphill. (C#2_18:51); Time is definitely number one. Cost isn't a huge factor—ironically, public transport can sometimes be more expensive. I've already bought a car, so a lot of those costs feel "sunk" to me—registration, insurance, etc. (C#2_22:24); Yes—convenience and time are deeply linked. If you don't have to wait or transfer, that's when public transport becomes competitive. (C#2_38:37)	Time sensitivity	Transport Decision-making factors	Barriers to Sustainable Mobility
...so I feel like I should use it (drive a car). If I live a bit further out, rent's cheaper, so I keep driving. (C#3_5:06)	Cost considerations		
Yeah, my previous place got sold, so I had to move. Now it takes 30–40 minutes with traffic. I'm planning to move again soon, closer to uni. Rent is expensive closer to campus, but if I lived nearby, maybe I'd stop driving. (C#3_4:19)	Accommodations		
Suppose I'm going from Clayton to here, then I want to know how many people at this time are going from Clayton to here, and how many people have a similarity of over 90% with me, and have chosen the same travel method as me, using the same software. (C#4_37:42); ... (for example) if 90% of people on the same route - with the same endpoints and starting points - all choose to use the desert bus, and only you choose to cycle, would you want to try switching to a desert bus? (C#4_40:10)	Trip complexity & flexibility		
This activity (detective wall) made me notice things I'd usually ignore, like commute time, distance from university (Clayton campus), whether I drive, etc. Most issues were already on my mind, but this made me think more deeply. (C#3_2:59); [researcher: So after reflecting, do you feel it's changed your attitude or travel behaviour in any way? Or are you still driving?] Still driving. (C#3_4:13)	"Yes, but no"	Post-workshop behaviours	
the main issue was how far some houses are from train stations. There's also the problem that many residential streets are small and buses don't go into them. So you often have to walk out of your neighbourhood just to catch a bus—or sometimes you just walk all the way to the station. (C#2_31:28); A rental scheme (shared bikes/e-scooters) would help, but pricing would be important. And then there are safety concerns. E-scooters go fast, and there's not much protection for riders. (C#2_32:58)	Fiest-/Last-mile challenges	Public transport system limitations	Barriers to Sustainable Mobility

DIGITAL EXPERIENCE ON MAAS PLATFORM (INTERVIEWS)			
Public transport isn't much better either. I don't need to travel across suburbs or take trains—it's mostly buses, and the service is pretty poor. I have to transfer, wait a long time, and it still ends up taking me around 40 minutes. So even though the total time is about the same, driving gets me there in 10 minutes. (C#2_19:40)	Negative experience with bus		
"In the morning, I'd open the app and it'd tell me the best way to get to uni—what saves the most time or money. I don't need too many options—just a few that are clear: cheapest, quickest, most sustainable. (C#3_14:52)"	Planning of the day		
...I mean - in the software, don't display money, just display points. Because when I see the amount of money, I think differently. I think I have this money, and I can buy whatever I want. (C#4_12:09); Using (rewards) points would be better. Because I think money makes me think it's not just for use on campus. (C#4_12:29)	Rewards	Potential of digital design interventions	
[researcher: So what kind of features do you think would attract more users?] Earning money or rewards. (C#3_16:32); For me, the app has to be clean and efficient. I care about saving time and money. (C#3_19:56)			
I hope if I open my phone, the upper half displays whatever looks good, and it might be an animation, might be a... might be a review, and it shows how much I have in total this month or this year or now. It's a short animation, the lower half is also an animation, it might be a usage version animation. It says you can now buy several hamburgers, several drinks, call a car. Yes, and it's a cycle, saying these are the things you can do with your current savings - quite a lot. (C#4_33:22)			
Eventually, it could support all aspects of student life, not just transport; It (the digital platform) could show info on lectures, exhibitions, or events too. (C#3_34:22)			
[researcher: So you'd want clear proof—like data or visuals showing how much time or money you've saved?] Yeah, like a progress tracker showing the savings. (C#3_24:21)	Money savings		
I want to say I don't want to see this accurate number. Because I feel whether my carbon emission is 3 kg or 30 kg, I'll still think it's high. What I want to see more is whether I'm above or below average. (C#4_14:16) [researcher: You mean the specific position? Which average are you comparing with? Definitely the city's average.] Yes, I'm not comparing with the school students' average. Because since I've used this software, if I compare with other users of this software, I definitely won't have an advantage. I want to know how much lower I am than the city average after using this software. (C#4_14:42); I prefer a percentage-like ranking. Like if I'm in the numerator or denominator in this city, that kind of feeling. Then I hope I'm on a certain side with a certain proportion. (C#4_15:16); I don't think this (inner-platform ranking) is very attractive. I prefer comparing with people who don't use this software. Because the more I use this software, the more I discover the benefits, and the more willing I am to recommend it to non-users.	Persuasive information display		
And it could show how that saved time could be used—like a list of what you could do in 30 minutes. (C#3_25:02) [researcher: Like "30 minutes = go to the gym" or "read a			

DIGITAL EXPERIENCE ON MAAS PLATFORM (INTERVIEWS)			
chapter of a book"?] Yeah, make it relatable with examples. Quantify it with everyday activities. (C#3_25:38)			
Suppose I'm going from Clayton to here, then I want to know how many people at this time are going from Clayton to here, and how many people have a similarity of over 90% with me, and have chosen the same travel method as me, using the same software. (C#4_37:42); ... (for example) if 90% of people on the same route - with the same endpoints and starting points - all choose to use the desert bus, and only you choose to cycle, would you want to try switching to a desert bus? (C#4_40:10)	Route sharing		
[researcher: but what about expanding the idea to be more than just transport? Like a campus life platform?] Like a message board? (C#3_33:02); [researcher: Yeah, something like Xiaohongshu or Reddit.] That's where the social part helps—it becomes more than just functional. (C#3_33:32)	Social networking	Cultural & behavioural dimensions	
For international students, they might need to set up their transport cards, like the Myki. Maybe they could apply for it digitally through the app. (C#3_21:39)	New international students		
Yeah, I think that stuff is pretty appealing. But road conditions around Clayton campus aren't ideal for cycling. It's surrounded by high-speed roads, and you end up riding in the same lanes as fast-moving cars. (C#2_41:06); [researcher: Are there no bike lanes?] Not consistently. In some spots, you'd have to go out of your way just to avoid the highways. (C#2_41:32) [Researcher: So no direct, safe route?] Exactly. For example, Wellington Road right outside campus is a 70–80 km/h zone. People ride e-scooters there too, which is kind of terrifying. (C#2_41:44)	Safety of cycling	Infrastructure & policy constraints	

Appendix H. Summary of Themes, Sub-themes, and Illustrative Codes Derived from Participant Transcripts

Overarching Theme	Sub-themes	Descriptive codes	Illustrative data context (participant codes)
THEME 1 (*past*): Life course transitions and evolving mobility dependencies. The evolution of personal motility needs as dictated by changing life circumstances, psychological stressors, and environmental exploration	1.1. Psychological shifts and habitual replacement	Economic pressures forcing lifestyle changes Mobility as a coping mechanism for academic/urban stress Forced exposure overcoming psychological barriers	The high cost of living in Australia forced a cessation of smoking; grocery shopping mobility became the replacement source of dopamine (#9). Joining campus knitting clubs to socialize and relieve the stress of IT studies (#10).
	1.2. Urban conditioning and economic necessity	Deep dependency on urban convenience Professional necessity of personal cars in suburban areas (Melbourne) Private cars as “production tools”	A lifelong "passive" conditioning to mega-cities (Shenzhen, London, Melbourne) making rural return impossible (#5). Operating a suburban renovation business necessitates a personal vehicle due to the lack of transit to remote sites (#8).
	1.3. Life events and the “escape” to nature environments	Marriage triggering increased weekend mobility Relocation sparking interest in outdoor exploration Vehicle acquisition to mitigate "IT burnout"	Transitioning from a "homebody" to an active explorer post-marriage (#2). Moving to Australia triggered a new desire to access beaches and forests, driving the need for personal vehicle ownership (#3, #6).
THEME 2 (*contemporary*): Spatial inequities and infrastructural frictions in daily commuting at the Clayton precinct.	2.1. The core-periphery transit divide	2.1.1. Seamless transit at urban hubs 2.1.2. Severe suburban transit service delays (over 30 minutes) 2.1.3. Unreliability of public transport services	Living at a major urban transit hub (Southern Cross) provides seamless, reliable commutes (#7). Conversely, suburban commuters experience crippling delays, or watch multiple delayed buses arrive simultaneously and bypass stops (#8, #9).
	2.2. Spatial disorientation and cognitive burdens	2.2.1. Digital map failures in spatial orientation 2.2.2. “Awkward” mid-length commute distances (e.g., around 2 km) 2.2.3. Incomprehensible campus parking signage	Digital maps display bus stops as 2D "dots" without orienting the user, resulting in repeatedly boarding transit in the wrong direction (#10). Navigating the 2km distance where walking is slightly too far, but buses are too inefficient (#9).
	2.3. Hostile micro-geographies and the “last-mile” connectivity	2.3.1. Pedestrian vulnerability and aggressive vehicle behaviours 2.3.2. Extreme spatial competition for university parking 2.3.3. Weather-related degradation of active mobility	Drivers refusing to yield and braking aggressively close to pedestrians on campus roads (#7). The intense temporal competition for campus parking, requiring arrival by early-morning to secure a spot (#1, #2,

Overarching Theme	Sub-themes	Descriptive codes	Illustrative data context (participant codes)
			#3).
THEME 3 (*prefer futures*): Proposed conceptions of future mobility service and digital integration.	3.1. hyper-personalised and orienting navigation	3.1.1. Context-aware routing incorporating user identity 3.1.2. Predictive difficulty mapping for active mobility options 3.1.3. Augmented physical orientation cues	Route planners that automatically apply international student transit discounts (#6). Algorithms that map the physical "hardship" (hills, weather) of a cycling route for novices, rather than just the fastest time (#6, #4).
	3.2. market adoption of privately-owned micro-mobility	3.2.1. Rejection of public shared-hardware (e.g., e-bikes/scooters) 3.2.2. Subsidisation of micro-EVs (electric tricycles/mini-cars) 3.2.3. Tailoring vehicle size to specific demographic needs	A strong distrust of shared mobility hardware due to hygiene and resource waste (#1). Proposing affordable, easy-to-park Micro-EVs as the ideal solution for international students to navigate "awkward" distances and transport groceries (#5).
	3.3. gamification and behavioural economics in everyday commuting practice	3.3.1. Centralised digital wallets for carbon tracking (road-transport) 3.3.2. tangible financial rewards for sustainable mode choices 3.3.3. bidding for priority infrastructure	Designing platforms where adopting active or public transport earns digital credits. These credits can be directly converted into cash (#1) or used to bid for exclusive priority parking spaces on campus (#2).

Appendix I. Follow-up semi-structured interview questions

Follow-up Interview Questions (30-45 mins)

The interview will be conducted in three sections: ***workshop experience***, ***design insights & feedback, and reflecting on change***

Introduction:

Thank you for taking the time to participate in this interview. The purpose of this session is to gather deeper insights into the potential implementation of the conceptual Mobility as a Service (MaaS) application at Monash University's Clayton campus. This application is designed to support sustainable travel choices and enhance decision-making for international student drivers.

During the interview, you will have the opportunity to interact with the mobile app prototype via Figma, exploring its key features, navigation, and functionality. Your feedback on the interface, usability, and overall experience will help refine the design to better align with student mobility needs.

In addition to evaluating the digital platform, this session will also reflect on your overall experience in the previous design workshops in 2024. Your insights on the co-design process and the feasibility of the proposed solutions will be valuable in shaping the next phase of development.

I appreciate your participation and encourage you to share honest feedback, including any challenges, expectations, or concerns regarding the app's implementation and adoption.

** Confirm that the interview will be audio/video recorded and ask for consent.*

1. **After attending both workshop #1 and #2 (Aug - Sep 2024)**
    - Can you share a specific moment or activity you still remember from the workshops that was particularly impactful for you?
    - How did the workshop activities influence your perspective on sustainable mobility?
    - Did the workshop format allow you to express your views effectively? If not, what would have helped?

2. **Introducing the updated digital platform interface design, sharing the interfaces of the digital platform with interviewee. Invite them to interact with the digital platform.**
    - You will now have the opportunity to test the updated digital platform interface on the smartphone. Please interact with the buttons, navigation bar, and core functionalities.
        - Based on your interaction, how do you feel about the conceptual application introduced during the workshop?
        - Were there any aspects of the interface that felt intuitive or confusing?
    - Features and Functionalities
        - Are there any specific features or functionalities you believe should be added to improve the user experience?
        - How well do you think the proposed solutions align with your daily mobility needs? Specifically, consider: Personalised mobility suggestions and planning, Visual design and ease of use, Real-time transport-related data (ETA, cost, carbon emissions, etc.)
    - Campus Impact and Implementation Feasibility
        - In what ways do you think this application could benefit the Clayton campus community?
        - Do you foresee any challenges in implementing this platform effectively? If so, what are they?
    - Concerns and Acceptability
        - Do you have any concerns regarding the adoption of this digital platform? Consider aspects such as:
            - *Privacy - How comfortable are you with data sharing in this app?*
            - *Feasibility - Do you think the app's suggested mobility solutions are practical and easy to follow?*
            - *Other Concerns - Are there any other barriers that may discourage students from using the platform?*
    - Behavioural Changes and Support Needs
        - Since participating in the workshops, have you taken any steps to make your travel more sustainable? If so, what changes have you made?
        - What support, incentives, or changes in infrastructure would encourage you to shift away from driving to campus?
    - Encouraging Adoption and Trust

    - How do you think this app could encourage more students to consider alternative mobility options?
    - What aspects of the app would make it more appealing or trustworthy for international students?

3. **Broader perspective & Wrap-up**
    - Are these societal or institutional challenges you think this project should address to be successful?
    - What role do you think international students can play in promoting sustainable mobility within Monash University?
    - What changes or additional functionalities could make the app more engaging for a broader demographic at the Clayton Precinct?
    - Any questions?

That's all the questions for today.

Thank the participants again for their time and valuable contributions

Explain the next steps in the research process and how their input will be used

- Offer the participants the opportunity to ask any questions they may have
- Invite the participants to attend the final design exhibition
- Confirm the ways they can contact me should they think of anything else later (researcher's email address and contact number)

END OF INTERVIEW

Appendix J. Fieldnotes with reflexive accounts

This appendix summarises the five field observation points, providing contextual observations and reflexive accounts. Each observation point corresponds to a specific location on the Clayton campus map (refer to Figure J-1), aims to provide an additional perspective as design researcher for understanding of commuting behaviours and infrastructure implementation on campus.

- **Fieldnote 1. N1 car park**
- **Fieldnote 2. Clayton bus interchange**
- **Fieldnote 3. James Gormley Bike Arrival Station**
- **Fieldnote 4. Train + Bus journeys**
- **Fieldnote 5. Inner Clayton campus commuting**

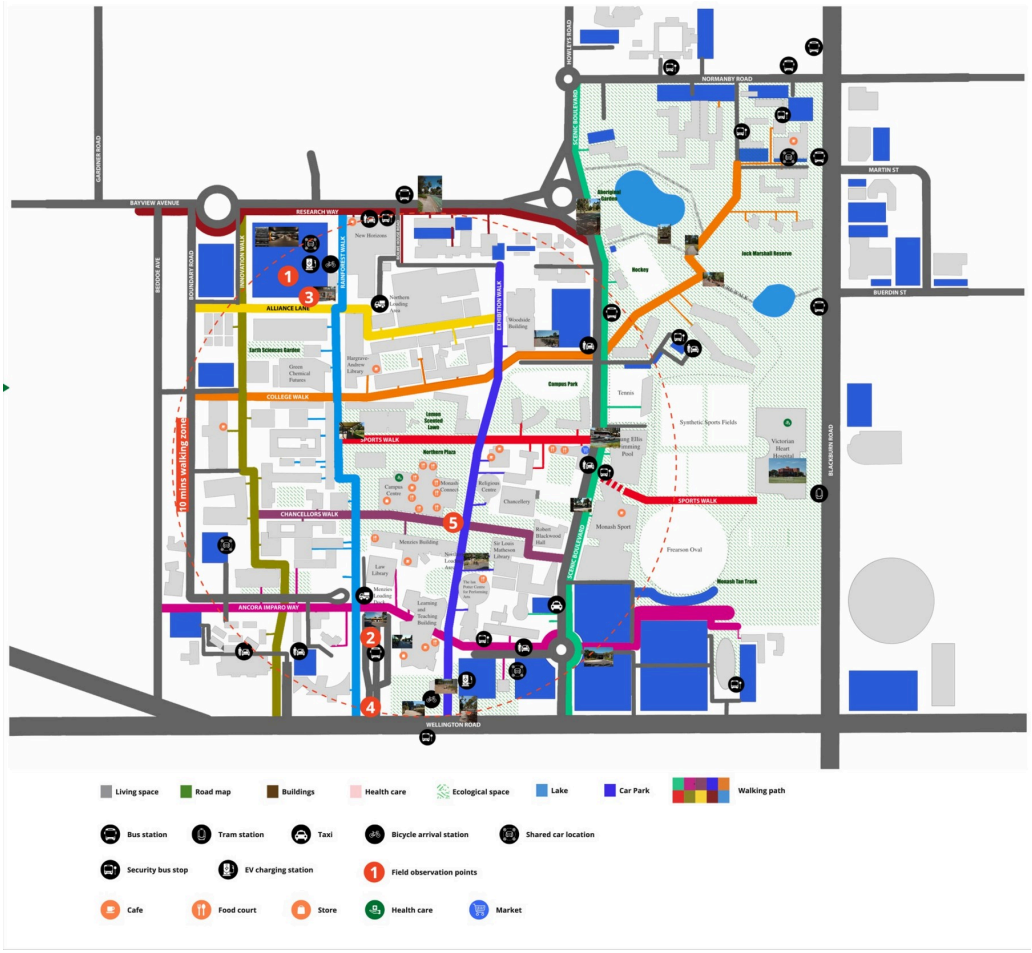


Figure J-1. Clayton campus map with field observation points, author redrawn from Monash University.

Fieldnote 1 - Private car dependency at N1 car park

Fieldnote ID: FN-08-MAR-2023-CLAYTON-N1

Date: 08 Mar 2023

Time: 08:05 AEST

Location: Multi-level car park building (N1), Monash University Clayton campus

Weather: Clear skies, ~18°C

Contextual Observation:

Single-occupancy cars made up most of the morning peak arrivals at the N1 car park. There was a steady flow of people entering, and all levels of the car park were almost full. The researcher drove own car from ground level to the roof over 40 minutes, and did not find a free car park. And there were not many active mobility commuters during this time, only few bikers were seen.

Reflexive account:

As a researcher who spent a lot of time in the Clayton precinct, I kept coming back to the problem of convenience versus sustainability. At the start of my field observations, I frequently visited the campus in the morning to observe a stream of cars entering the multi-level car park building (N1), most of which contained only one person. This pattern of single-occupancy vehicle usage was a visible sign of the auto reliance that characterises much of the Clayton community's mobility culture, like most suburban areas of Australia.

Despite my research on sustainable transportation and my intention to model the behaviours I seek to promote, I have found myself heavily dependent on driving to campus. Private car usage often provides convenience and time efficiency, particularly given my research commitments and irregular working hours, which frequently outweigh my aspirations to consistently adopt more sustainable commuting modes, such as public transport or active mobility. This self-observation highlights the complex interplay between individual circumstances, infrastructural conditions, and the behavioural changes required to transition towards more sustainable mobility practices.



Figure J-2. Full N1 car park - level 1, at 8:10am.



Figure J-3. Stream of cars entering N1 car park at 8:15am.

Researcher notes:

- Supports Chapter 4.2.2: Private car dependency and campus road hierarchies
- Supports Chapter 5.6.3: Participatory investigation finding #2: suburban transport infrastructure limits mode shifts

Fieldnote 2 - Inner-campus shuttle service bus stop (Southern Bus Interchange)

Fieldnote ID: FN-08-MAR-2023-CLAYTON-BUS-SOUTH

Date: 08 Mar 2023

Time: 10:35 AEST

Location: Southern bus interchange, Monash University Clayton campus

Weather: Clear skies, ~18°C

Contextual Observation:

During morning and mid-afternoon peak observational sessions, I saw many students being left behind as buses reached full capacity at the Clayton bus interchange. On one occasion, while I was waiting in line for the Caulfield service (one of the highest demand inner-campus shuttle services departing from the Clayton campus), I noticed several students leaving after estimating that their waiting time would exceed 30 minutes (referred from the fixed timetable). They instead went to bus route 900, a PTV service that costs around $3 AUD for the journey from Clayton to the Caulfield campus.

Reflexive account:



Figure J-4. Informational sign at the Clayton bus interchange, captured on 8 Aug 2023.

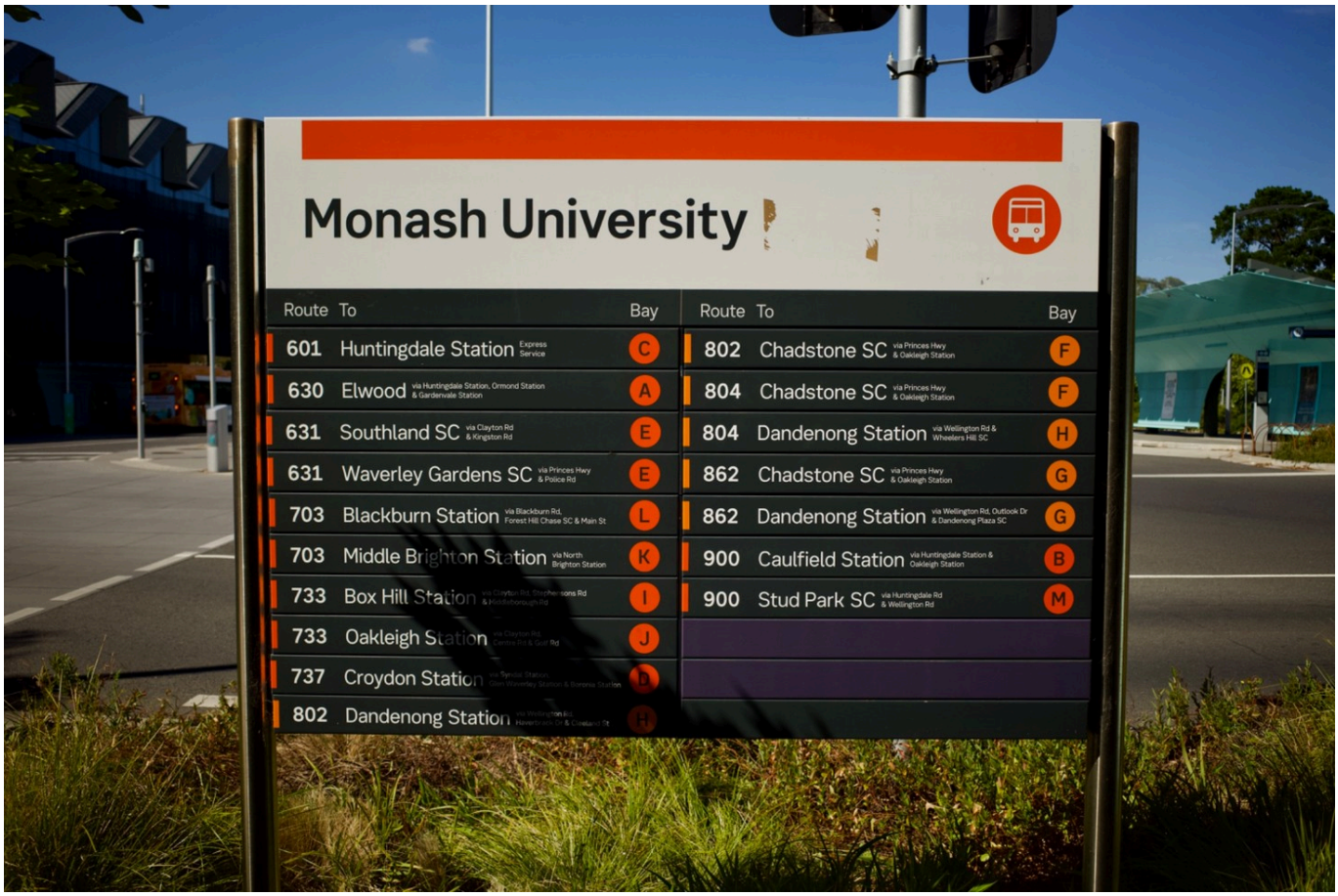


Figure J-5. Informational sign at the Clayton bus interchange, captured on 8 Feb 2023.



Figure J-6. Informational sign at the Clayton bus interchange, captured on 5 Jul 2025.

Researcher notes:

- Supports Chapter 4.4: Public Transport Access and Weather Resilience
- Supports Chapter 5.6.3: Participatory investigation finding #2: suburban transport infrastructure limits mode shifts
- The change of interface design of the informational sign at the Clayton bus interchange, compares 2023 and 2025 versions

Fieldnote 3 - James Gormley Bike Arrival Station (Northern)

Fieldnote ID: FN-08-MAR-2023-CLAYTON-BUS-SOUTH

Date: 07 Mar 2023

Time: 11:15 AEST

Location: James Gormley Bike Arrival Station, Monash University Clayton campus

Weather: Clear skies, ~21°C

Contextual Observation:

The James Gormley Bike Arrival Station is located near a key pedestrian and cycling corridor on the northern edge of the Clayton campus. At the time of observation, the surrounding area is active but not crowed. Several cyclists arrived in short intervals, dismounting and pushing their bikes toward the station entrance by scanning their M-Pass (digital wallet or physical card).

Reflexive account:



Figure J-7. Quiet entry of the James Gormley Bike Arrival Station at 11:15am.

Fieldnote 4 - Home to Clayton campus commute via Train + Bus

Fieldnote ID: FN-11-MAY-2023-CLAYTON-PT-COMMUTE

Date: 11 May 2023

Time: 09:15 AEST

Location: Clayton Campus via Huntingdale Station and 601 shuttle bus & Glen Waverley Train Line

Weather: Clear skies, ~16°C

Contextual Observation:

Reflexive account:



Figure J-8. Southern bus interchange at Monash University Clayton campus.



Figure J-9. Train interior during the home-to-campus commute.

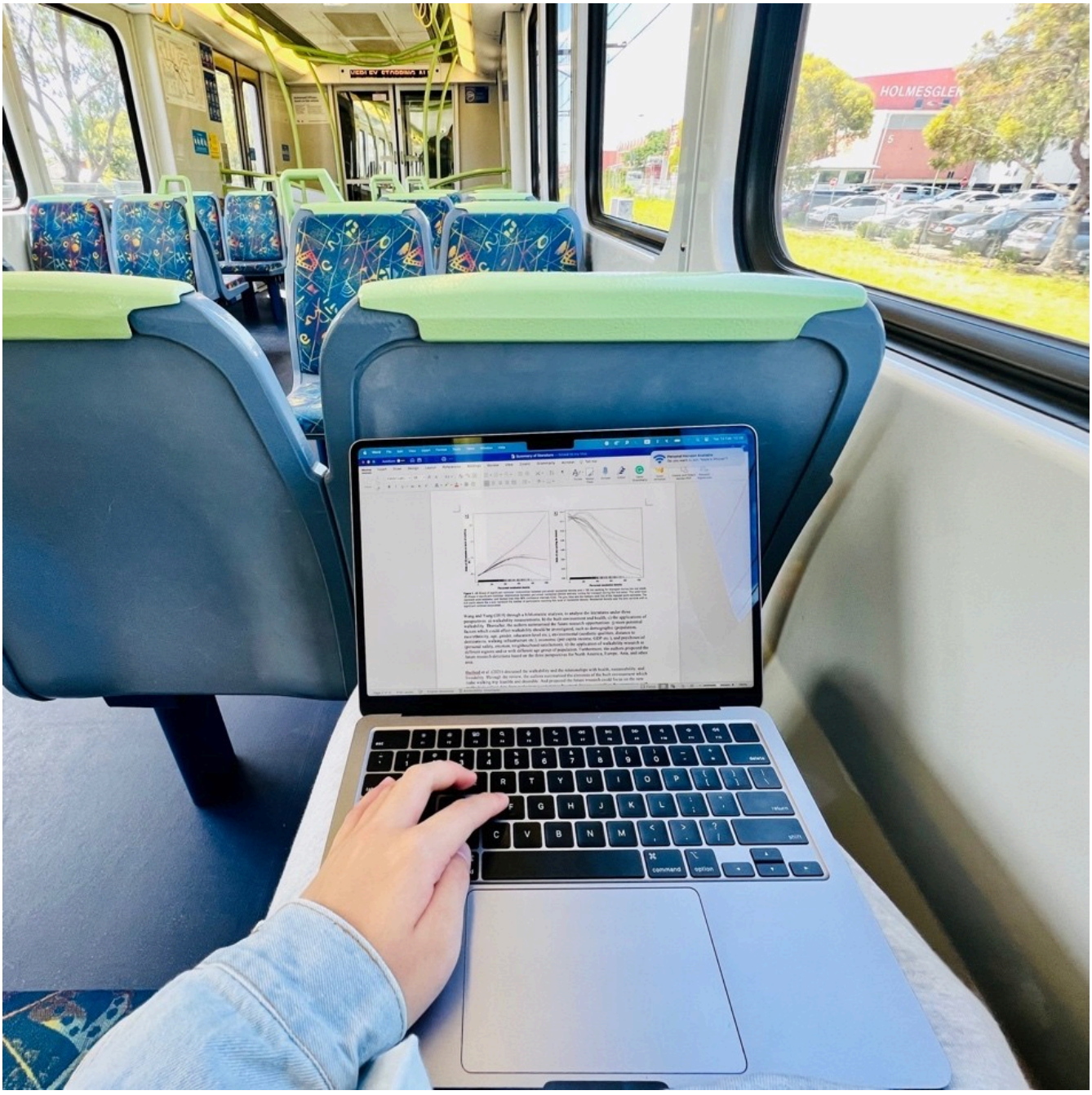


Figure J-10. Researcher working during the train journey to the Clayton campus.

Fieldnote 5 - Inner Clayton Campus Commuting: Walking, E-scooter, and Cycling

Fieldnote ID: FN-20-SEP-2024-CLAYTON-INNER-MOBILITY

Date: 20 Sep 2024

Time: 12:10 AEST

Location: Inner campus pedestrian and micromobility corridors, Monash University Clayton campus

Weather: Clear skies, ~15°C

Contextual Observation:

Walking is the most common form of inner-campus movement. Regardless of the mode of transport used to arrive at the Clayton campus, commuters still rely on walking to reach their final destinations whether from car parks, bus stops, bicycle arrival stations, campus shuttle bus stops, or pick-up/drop-off points.

Although there are two main bicycle arrival stations on campus (South and North) offering secure bike storage, lockers, and shower facilities, cycling remains an uncommon choice for most Clayton commuters. Nearly all buildings on campus feature their own bike parking areas and lockers, designed to encourage cycling both for commuting and for movement within the campus.

E-scooter is an emerging mobility option around the campus and suburbs. A few were observed during the study period; however, the campus currently lacks dedicated infrastructure such as parking stations, storage, lockers, and charging columns to support e-scooter users.

E-golf carts are used primarily by cleaning and maintenance staff, enabling them to transport tools and equipment under 100% green energy power. Electric street sweeper vehicles were observed operating along the scenic boulevard for street cleaning tasks.

Human-powered trolleys are a common tool for last-mile cargo delivery within the campus, supporting logistical activities between buildings.

Reflexive account:

During morning peak observational sessions, I noted that motorcycle parking areas were rarely filled beyond half capacity at the G-floor of N1 carpark and C12 carpark, where the car parking lots were at saturation. This discrepancy between supply and actual usage prompted a reflection on the allocation of campus transport resources. The allocation of underused motorcycle parking spaces may be reassessed to prioritise enhancing more outdoor bike parking spaces or future micromobility docking stations (refer to Figures J-11 and J-12). From a perspective of design researcher, this observation emphasises the potential opportunities to question whether existing spatial and regulatory frameworks really correspond with the mode-shift ambitions outlined in campus sustainable transportation strategies.



Figure J-11. A student cycling near the campus centre, captured on 8 Feb 2023.



Figure J-12. Limited bicycle parking space at the campus centre during peak time (teaching semesters), captured on 16 Aug 2023.



Figure J-13. E-bike and E-scooter parked at the Clayton campus, using conventional bicycle parking hoops that lack specific security-locking and charging facilities. Captured on 8 Feb 2023.



Figure J-14. Human-powered trolley used for last-mile cargo delivery on the Clayton campus.

Researcher notes:

This fieldnote informed the final design by recognising inner-campus movement as an essential part of the overall commuting journey rather than the endpoint, leading to integrated walking and last-mile navigation within the future MaaS platform. It also emphasised design opportunities to better support emerging micromobility through features that connect users with existing facilities while informing future campus infrastructure improvements, including e-scooter docking and expanded bike parking.

Appendix K. Design features catalogue

Visual language of the designed MaaS digital platform interface is regarded as one of the most essential components to the service experience, as it influences how users might perceive options, comprehend system status, and make decisions in the future commuting scenarios. The interface needs to be clear and consistent for international students who encounter unfamiliar local regulations, diverse transportation information, and demanding daily schedules, while also supporting everyday travel scenarios. This design project establishes a visual language as a unified "reading system" across screens, ensuring that essential actions, messages, and mobility modes are readily identifiable and accessible during future MaaS-based commuting journeys.

In a MaaS context, visual language is not only about aesthetics. It serves as a functional layer that fosters user trust in the platform, alleviates cognitive burden, and facilitates the comparison of travel modes without extensive textual elaboration. The platform uses uniform icons, a regulated colour scheme, and consistent page layouts to facilitate rapid scanning, prompt decision-making, and assured navigation. These elements assist the connection between the digital interface and the overarching service logic outlined in the service blueprint (see Section 7.1), as they illustrate how the user-facing
layer interacts with and directs the future commuting experience at each stage of the MaaS-based journeys.

1. Iconology in the digital platform

The icons in the designed platform serve as immediate representation of transportation modes, service action, and platform statuses, as icon convey meaning rapidly when users are in motion or multitasking. In future MaaS-facilitated commuting scenarios, users might verify a route while getting to a stop, accessing a parking facility, or awaiting a transfer. In these conditions, icons of the digital interface function as concise visual indicators that minimise reading requirements and reduce the possibility of overlooking essential information. In this project, the election of icons of the digital platform also serves as visual facilitators which make the essential transport-related information and navigation easy to understand by international students, who might be unfamiliar with local transportation system and facing language barriers.

The platform icon set is selected to achieve a balance between familiarity and specificity (refer to Figure K-1). Recognisable symbols facilitate rapid identification, including basic icons for bus, train, walking, cycling, or carpooling. The icons need to simultaneously depict campus-specific and service-oriented concepts that are uncommon in generic navigation applications, including inner-campus shuttle services, drop-off and connection points, reward or carbon-saving points systems, and community-based security bus services. This is achieved by maintaining a uniform iconography throughout the interface system, ensuring that new symbols seamlessly integrate into the existing interface language.

The utilisation of icons is also associated with interaction design. Icons are positioned at decision-making points, including navigation bars, transport mode selections, route summary widgets, and alters. Icons linked with actions are designed in a manner that conveys “tap to do”, whereas icons related to information convey “scan to know.” This differentiation aids the platform in preventing ambiguity regarding symbols that appear clickable yet are not, which is crucial for user trust and usability. Labels are positioned adjacent to icons when the meaning may be ambiguous, particularly for infrequent service features, as the user demographic with different levels of English confidence and various levels of experience with local transport systems.

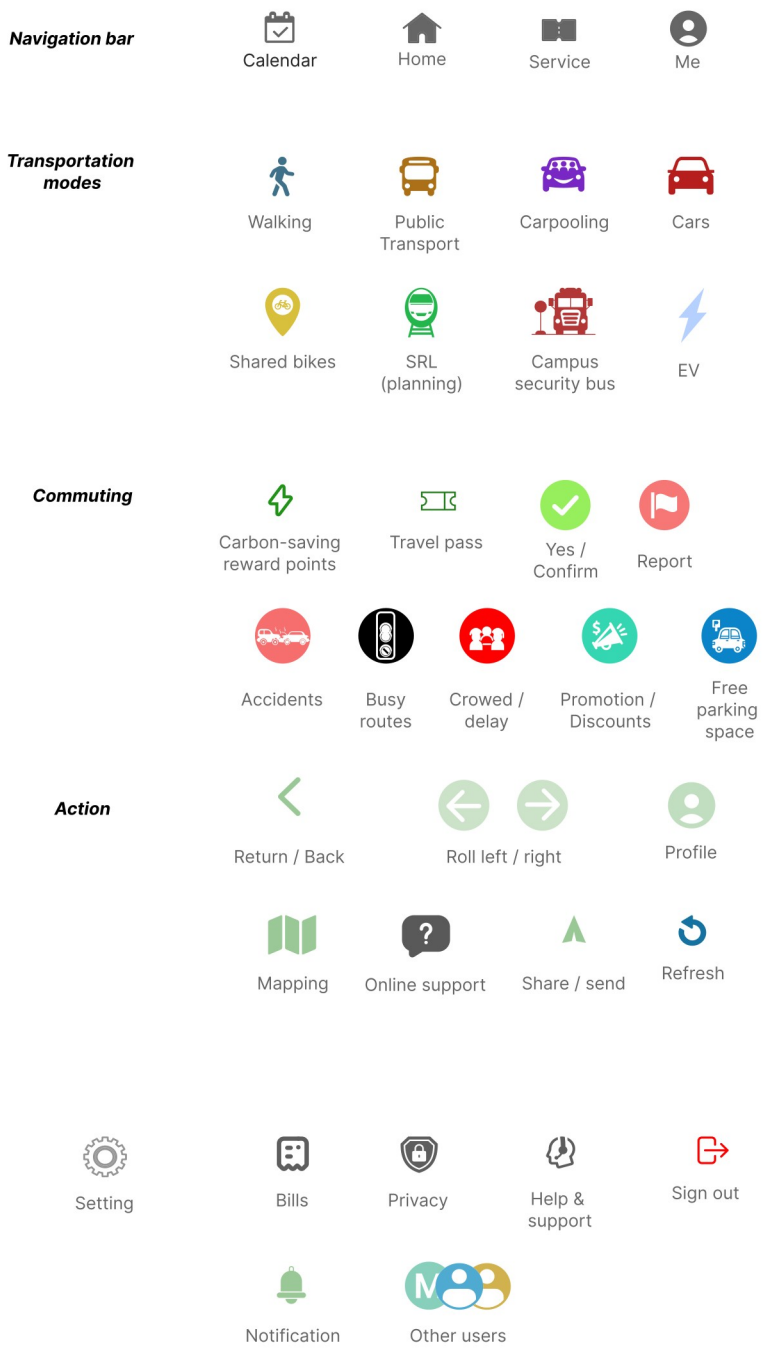


Figure K-1. Icon set of the platform

2. The principles of colour selection

Colour selection of this digital platform is regarded an approach to enhance meaning, structure, and focus. In domain of human-computer interaction (HCI), colour is a semiotic instrument that communicates meaning, defines hierarchy, and guides user attention on a screen (Ware, 2013). The purpose of the colour selection methodology is to transcend aesthetics by incorporating functionality, accessibility, and emotional engagement. In the designed MaaS digital platform, colour selections directly affect users' perception of information and interaction with the MaaS platform.

The colour selection in the MaaS digital platform user interfaces is informed by four interconnected factors (in the following discussion) that facilitate practical commuting applications, instead of aesthetic considerations. In a future MaaS-based commuting scenarios, the interfaces might frequently check in short intervals, sometimes while walking, waiting, or switching modes. In these circumstances, colour need to facilitate rapid reading, convey priority, and instil confidence in the system's stability and reliability.

- **Contract and legibility**

The high contrast between foreground and background hues enhances readability and accessibility. Text, icons, and key controls are designed to be prominent against background surfaces, enabling users to discern information under varying lighting conditions and across diverse phone displays. This is crucial for route summaries, departure times, and alters, as even a minor reading delay can result in missed connections. Colour enhances readability, while spacing and typographic weight contribute significantly, ensuring the interface does not depend solely on colour.

- **Consistency and hierarchy**

A cohesive colour palette enhances the visual hierarchy across interface pages and widgets of the designed MaaS platform. The consistent implementation of primary, secondary, and accent hues facilitates intuitive navigation and reduces cognitive load for the users. (Contini et al., 2025) highlighted that high-contrast colours could improve the readability and accessibility of information, reduce visual fatigue, and enhance the user experience and usability. Additionally, utilising colour hue, value, and saturation (see Figure K-2) can structure an effective visual hierarchy and guide users' attention to make navigation more intuitive (Griffin & Pupedis, 2020).

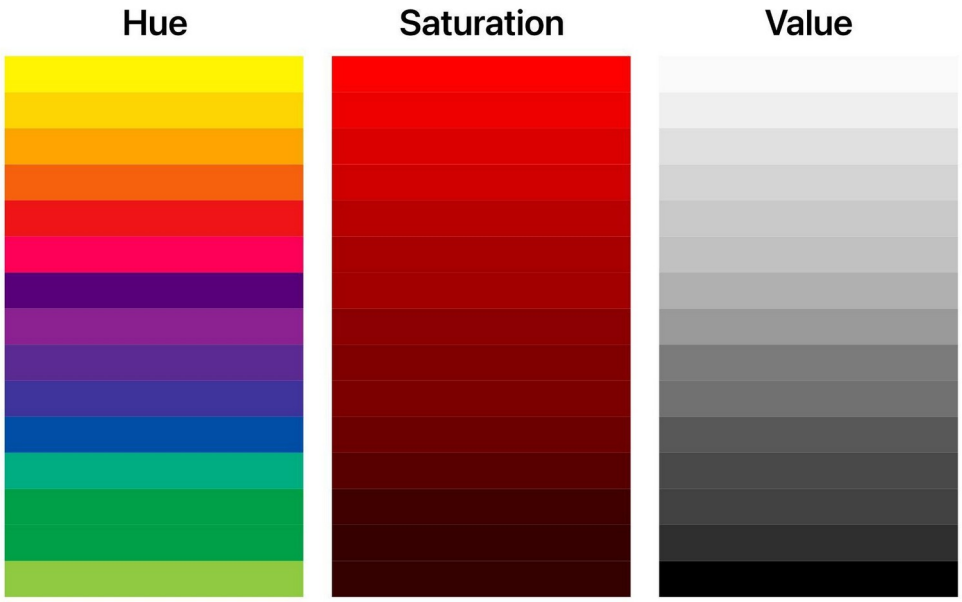


Figure K-2. An example of colour hue, saturation and value (author's own)

Figure K-3 presents the colour system developed for the *Go Green! Monash* MaaS interface, showing how colour is selected and applied to established hierarchy, communicate status, and differentiate mobility information.

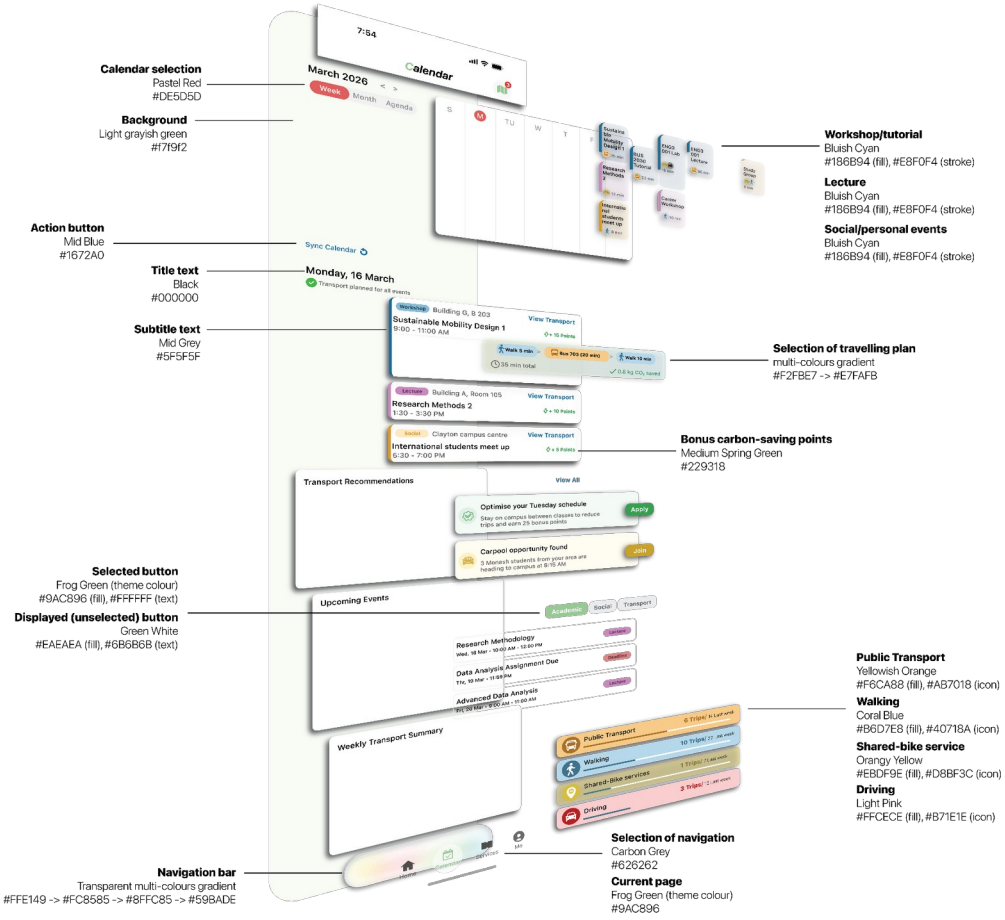


Figure K-3. Colour selection and hierarchy of the MaaS digital platform

For instance, in the design of the travel planner widget, each selected option is highlighted using gradient variations of the platform's theme colours (see Figure K-4), demonstrating the highest level of functionality within the widget. In contrast, unselected options are presented in black text, accompanied by bonus reward points displayed in light green. This visual hierarchy is intended to draw the user's attention towards sustainable travel alternatives, thereby subtly encouraging the selection of the most environmentally responsible option.

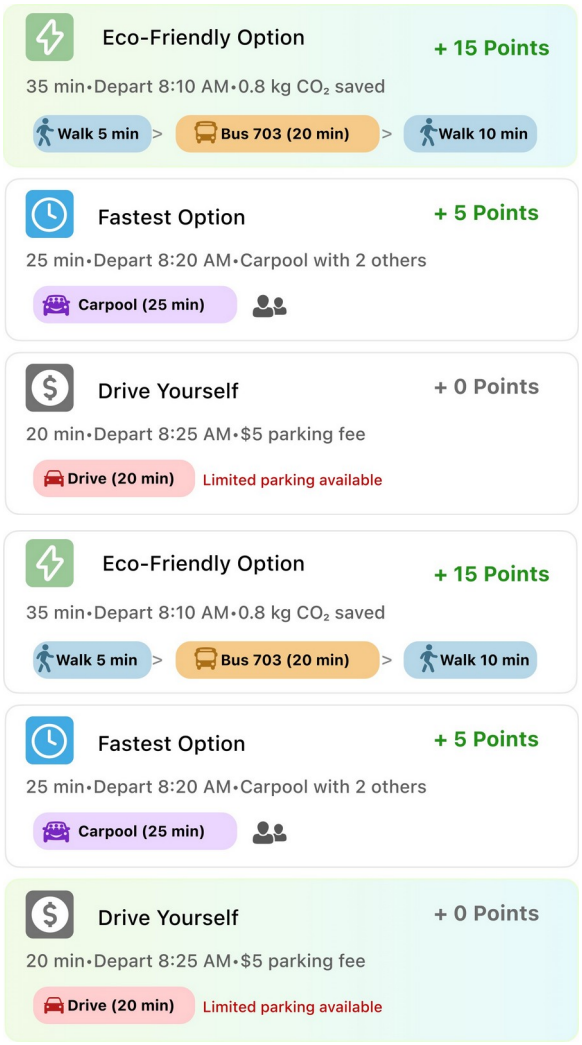


Figure K-4. Interface colour design comparison between (a - left) selected option of eco-friendly travel, and (b - right) selected option of driving alone in the journey planning widget

❖ Symbolism and meaning

The symbolism delineates how colour conveys concepts associated with mobility options and platform identity. The palette is centred on the principal theme colour (*Dark Sea Green #9AC896*), which is selected to represent environmental care and "greener choice" as the primary objective of the platform. Green is commonly associated with public messaging on sustainability, facilitating rapid recognition for users who may not engage with lengthy text or are still acquiring local transportation terminology. In Figure K-5, the green background of the platform icon serves as a consistent identity marker, ensuring that the platform maintains a unified service perception despite incorporating various transport services and mobility modes.

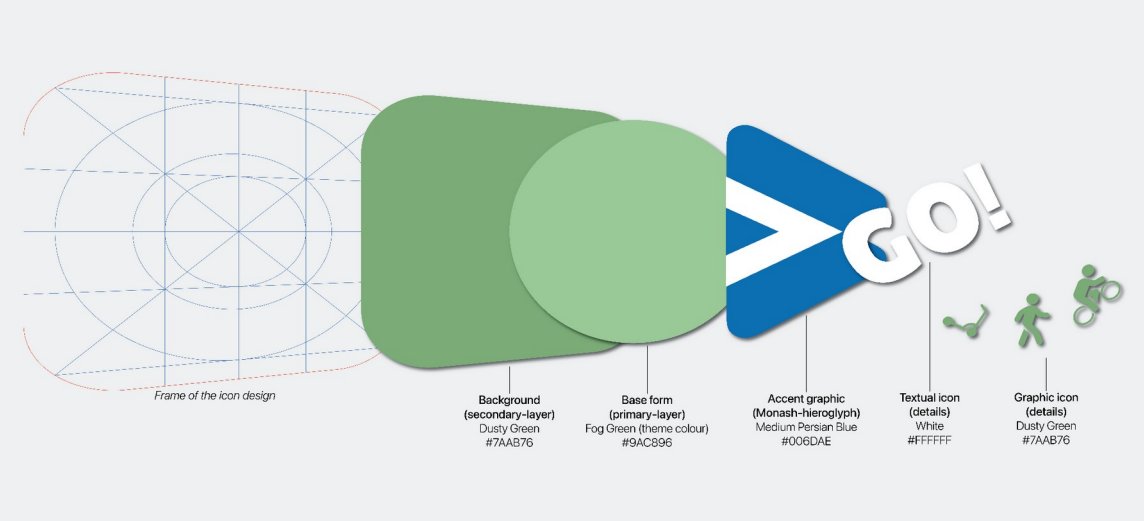


Figure K-5. Icon composition and colour symbolism of the designed "Go Green! Monash" MaaS digital platform

Colour also provides meaning functionally when the interface depicts various mobility modes. In the palette layout illustrated in Figure K-6 , each mode is associated with a unique colour family which visually connect to the theme colours of each transport service in real-context, enabling users to quickly recognise options when comparing routes, reviewing a trip schedule, or transitioning at connection ports. The mode colours function as semantic labels facilitating repaid orientation, whereas the platform

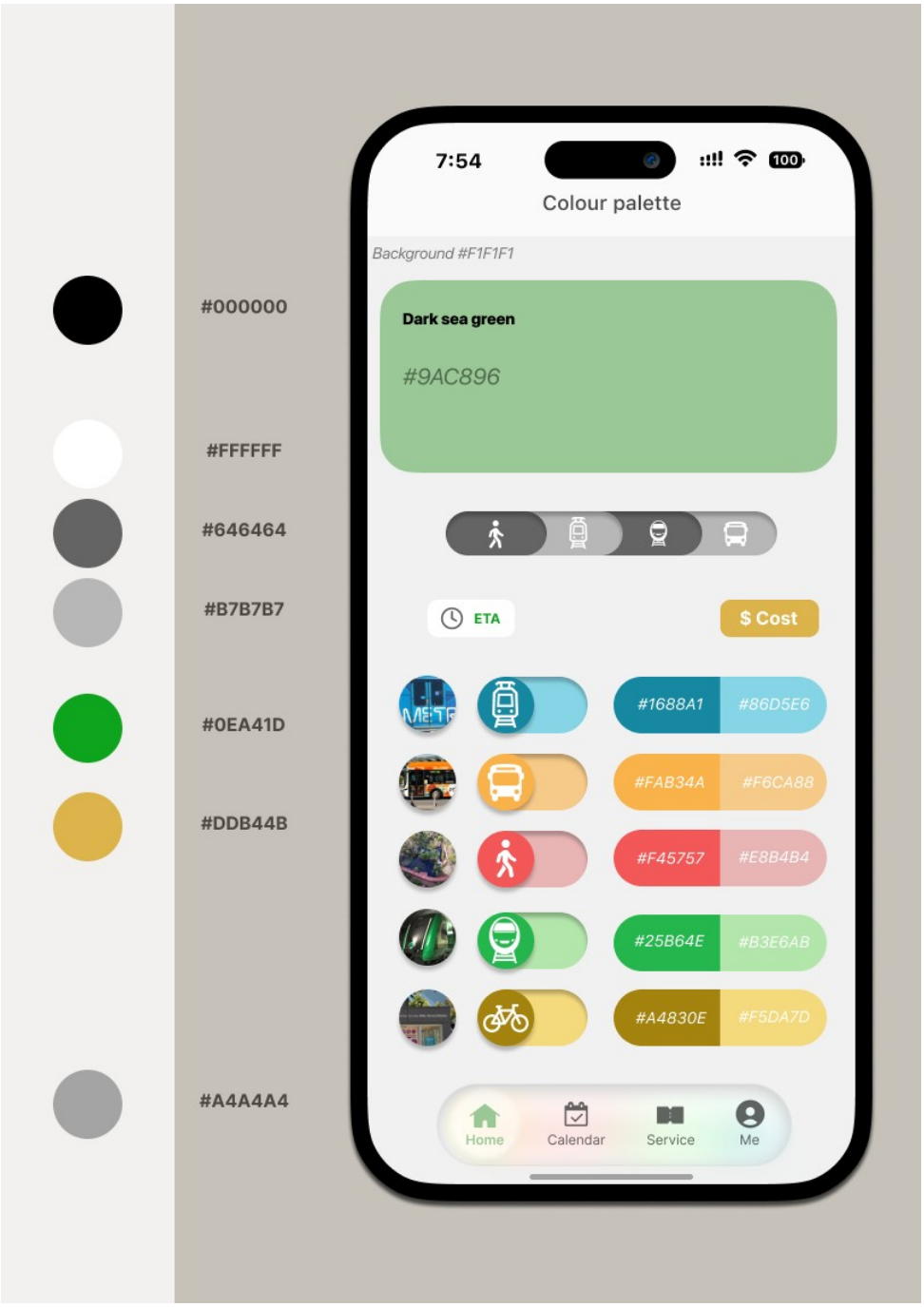


Figure K-6. Colour palette of the MaaS platform

Through the integration of these principles, the MaaS platform utilises colour as a visual design element and, most importantly, as a communicative medium that fosters trust, inclusivity, and behavioural change. The strategic application of colour enables student users to perceive low-carbon transport options as attractive, reliable, and socially desirable, thus advancing the primary objective of the sustainable mobility strategy within the Clayton precinct.

3. Page layout design

The MaaS platform adopts a block-based layout, organised through modular widgets that structure each page in a consistent manner. This design approach embodies modern digital

interaction design principles, wherein modularity enhances usability, scalability, and adaptability across diverse user contexts. The platform uses widget-based blocks to enable international student users to access essential functions, including journey planning, service selection, payment, and personal settings through visually separate and self-contained modules. This design style also matches the current layout of the Monash University student homepage (see Figure K-7), which organises access to various Campus services, such as Moodle, library loans, M-Pass balances, and assessment information are presented using a block of widgets. Such alignment creates a visual and interactional continuity with students' prior digital experiences, therefore reducing the learning curve, enhancing usability, and fostering trust in the MaaS platform as a reliable and institutionally connected mobility service.

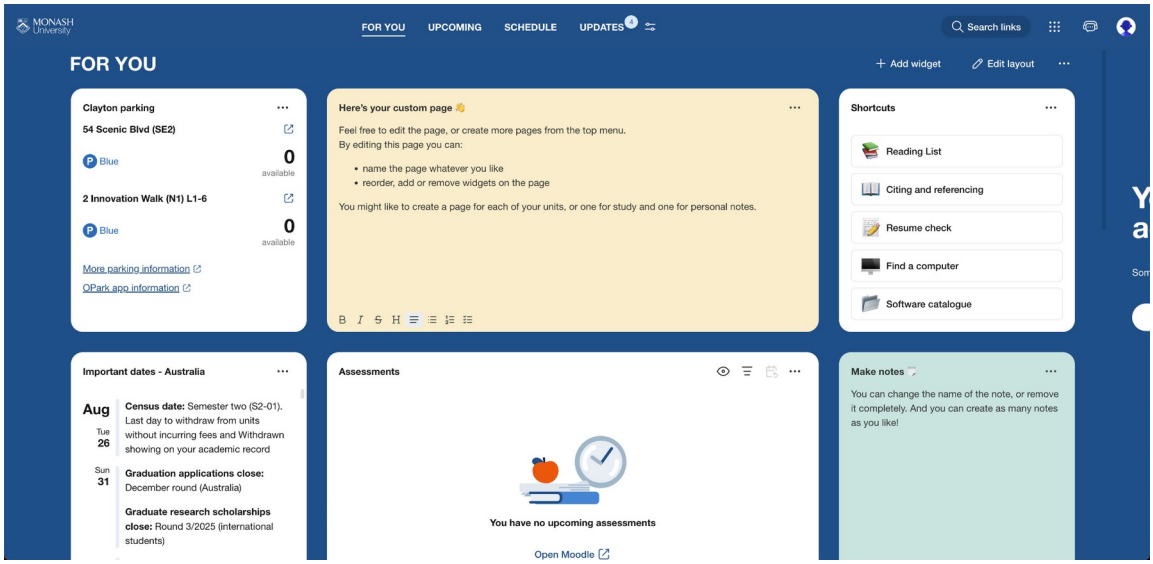


Figure K-7. Monash student dashboard webpage, screen captured by the author

From a design perspective, block-style layouts reduce cognitive load by graphically segmenting complex information into manageable components (Norman, 2013)From a design perspective, block-style layouts reduce cognitive load by graphically segmenting complex information into manageable components (Norman, 2013). In the designed MaaS platform, each block functions as an independent interface element that maintains a clear hierarchy, enhancing navigational intuitiveness. For instance, the journey planning widget (see Figure K-8) prioritises real-time route recommendations, including eco-friendly and fastest options, while the supplementary layers present contextual information, such as travel times, reward points, estimated carbon emissions, and arrival times. This modular arrangement prioritises the most relevant information at the top of the interaction, thereby facilitating users' timely mobility choices.

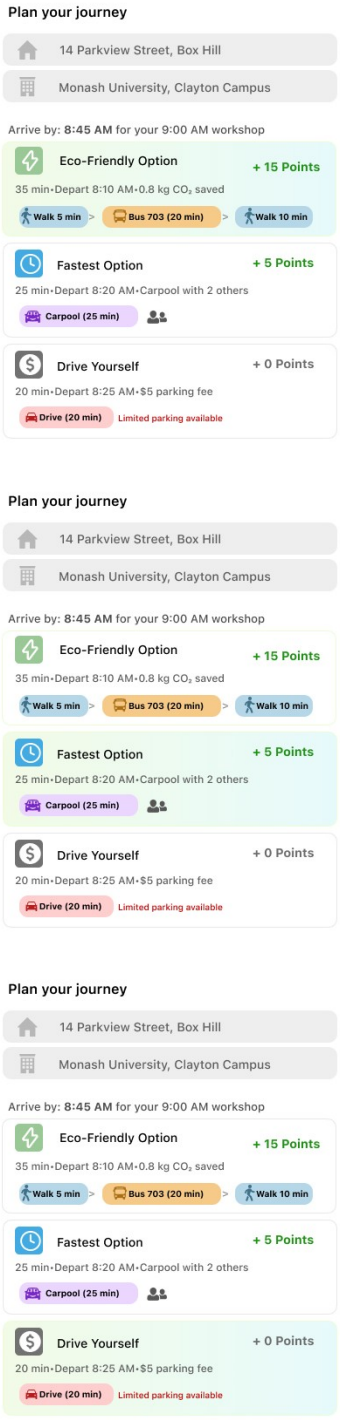


Figure K-8. User interfaces of the journey planning widget

Additionally, the block-based design aligns with the principle of responsive user interface development. Blocks can be dynamically rearranged or reordered by users' personal preferences and various screen sizes or orientations, ensuring functional continuity throughout different devices. Moreover, widget modularity enables iterative development and future service integration, enabling the incorporation of new mobility services, such as e-scooter sharing or new public transport routes, as independent modules without disrupting overall system architecture.

The widget-based page layout significantly enhances personalisation and inclusivity. According to the participatory investigation of international students from the Clayton campus, most of the participants expressed that a more personalised or on-demand mobility service platform could support their behavioural shift from driving a private car to a multimodal commute (refer to Chapter 5). Within the design of the MaaS platform, users can prioritise, remove, or reorder blocks based on their mobility requirements or preferences, thereby customising their MaaS platform interface (see Figure K-9). This adaptation supports international students in managing cultural and infrastructural unfamiliarity within a new transit context, ensuring clarity and accessibility. The block style paves the way for multilingual overlays in the future, facilitating the application of various widgets into multiple languages and thereby increasing accessibility for new international students.

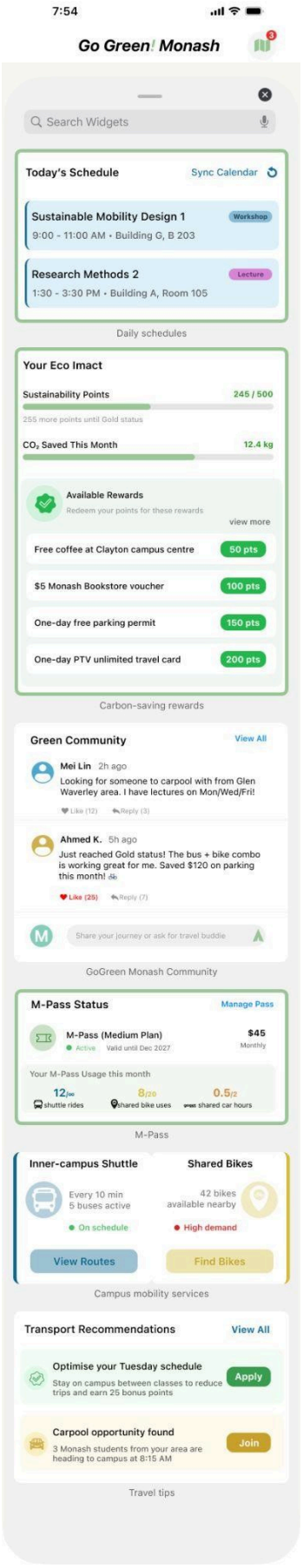


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