Enabling Equitable Access to Public Transport Information to Enhance Hybrid System Use in Cape Town, South Africa

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ABSTRACT

Though previously unscheduled public transport services were often seen as incompatible with equitable mobility goals, emerging cities are increasingly seeking to integrate these with new scheduled services to form hybrid public transport systems. In contrast to the abundance of services available, there is little information available to plan multimodal journeys across the hybrid system, limiting users' abilities to best use the system to meet their needs. This thesis investigated, through mixed research methods framed within Amartya Sen's capability approach, how to enable equitable access to public transport information on the hybrid system through information and communications technology. The research focussed on captive public transport users in the context of Cape Town, South Africa. Using (n=22) semi-structured interviews, candidate passenger information types for planning hybrid journeys across various scenarios were identified. A best-worst scaling study was undertaken (n=413) to gain a representative understanding of the least and most useful information types. A stated preference choice model was applied (n=501) to investigate what minimum information is required to make use of the hybrid network to access mobility opportunities in non-routine scenarios. The most useful information types were represented as different levels of certainty. These information types were: (1) frequency, (2) fare cost, (3) departure time, (4) arrival time, (5) safety walking to/from a station/stop, (6) safety onboard, and (7) safety while waiting at a stop. A further passenger survey (n=536), together with available secondary data, was analysed to gauge access to technologies and skills related to transport information use cases. This research found that none of the information types at the quality level desired is currently evenly available across the hybrid system, and no official information sources have the capacity to equitably reach captive users given current technological capabilities. The combination of gaps in information provision and adequate communication methods hinders users' informational capabilities to plan journeys that best meet their needs and preferences, and consequentially limits their access to opportunities through mobility. Strategies for understanding information needs, collecting the data necessary, and opening this data to the public through portals provide the adaptability and flexibility needed to deliver sustainable solutions.

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LIST OF ABBREVIATIONS

AIC	Akaike Information Criterion
ASC	Alternative-specific Constants
BIC	Bayesian Information Criterion
BWS	Best-worst Scaling
CBD	Central Business District
CoCT	City of Cape Town (government)
DPF	Digital Poverty Framework
GABS	Golden Arrow Bus Services
ICT	Information and Communications Technology
IMTI	Integrated Multimodal Information
MaaS	Mobility as a Service
MBT	Minibus Taxi
MNL	Multinomial Logit
MMNL	Mixed Multinomial Logit
MTI	Multimodal Information
O-D	Origin-Destination
UMI	Unimodal Information
ZAR	South African Rand (currency)

1. INTRODUCTION

1.1 BACKGROUND

Though previously unscheduled, paratransit services were seen as conflicting to equitable mobility goals, cities across Africa, Asia, and Latin America are increasingly seeking to integrate these with new scheduled public transport systems acknowledging the need for both system types to accommodate the flexibility required to respond to rapid growth and changes in urban structures and travel patterns (Ferro et al., 2015). Paratransit, the term used to describe these passenger transport services that do not necessarily follow fixed routes or schedules, in the context of this research excludes privately used modes such as metered taxis, car sharing, and ride-hailing as well as formal forms of paratransit like 'dial-a-ride' buses for disabled persons, and rather encompasses privately-owned public transport services like 16-seater minibus taxis. Hybrid systems – as the result of these processes of integrating scheduled and paratransit systems is referred to - support transportation diversity through multimodality by providing potential users with a mix of modes with various service characteristics. In providing these diverse mobility options, as multimodal systems, hybrid systems have the potential to increase equity and resilience to changing mobility needs (Litman, 2017). While some hybrid systems are intentionally planned early in cases where planning authorities recognised the impracticality of removing unscheduled services entirely and therefore sought to formally integrate unscheduled systems with scheduled ones (or *de jure* hybrid systems), other hybrid systems are a result of failed attempts to replace the unscheduled services with scheduled ones thereby resulting in modified *de facto* hybrid systems (Ferro, Behrens, and Wilkinson, 2013).

While from a spatial planning perspective, the hybrid system's modal mix may theoretically serve a large population and connect them with a wide catchment of opportunities, a discrepancy in knowledge of the network on the users' part may affect their ability to best use the system to meet their needs. Individual knowledge of the system is shaped by both personal experience and the available information on the network. However, information imbalances and limitations across modes create an information deficit, differentially hindering users' ability to access information to harness the opportunities that the complex hybrid network could provide. While ubiquitous in emerging cities globally, paratransit tends to exist in an information vacuum. That is, very little recorded information is available on their services and people rely on word-of-mouth information or experience to navigate them. Furthermore, though some of information across the hybrid system is available to all users through physical formats, other information is exclusively available through technology, creating a divide in information access between those who do and do not have access to relevant technologies.

Increasingly, public and private entities are looking to Information and Communications Technologies (ICTs) to aggregate and feed relevant information to public transport users to simplify their interaction with multimodal mobility networks. ICTs as opposed to information in print mediums are advantageous due to their ability to flexibly respond to and reflect changes in the system (e.g. delays), be user-location specific, open a direct communication channel between the user and the service provider, and collect crowd-sourced data (e.g. messages about incidents, tracking user location to update real-time location of a vehicle) (Austin, 2016). However, the inclusion of paratransit systems in transport ICTs is quite recent and limited, and the effects of such information paired with scheduled systems information on users' ability to better utilise the hybrid network is largely unknown (see the Khwela app in Johannesburg and the MyRide app in Nairobi for example initiatives providing paratransit information to passengers). While ICTs offer new avenues for disseminating meaningful information in hybrid networks, they also come with challenges in the form of relevant content, imbalances in supply across different modes, and barriers to access.

Though several initiatives in recent years have developed technologies to either collect data on paratransit systems (e.g., Digital Matatus in Nairobi), distribute paratransit information (e.g., Lara app in Lagos), or provide multimodal information for hybrid systems (e.g., Gauteng on the Move in South Africa), these technologies have been developed without a deeper understanding of passenger information needs for navigating a hybrid system. In cities with hybrid systems, recorded information is largely skewed in favour of scheduled modes, such as bus rapid transit systems, as opposed to unscheduled paratransit, like privately-owned minibuses. There is a need to understand how lessening this information imbalance may aid users to understand and fluidly move between different parts of the hybrid system. Particularly for captive public transport users, or those without access to private alternative means of travel, access to relevant information could enable them to better understand what journey options are available to them to access different parts of the city. Just as travel information can increase the quality of travel choices in complex networks, "poor information accessibility can pose a barrier to public transport use that is as serious as the potential barriers of physical access to public transport services" (Lyons et al., 2001: 4).

The effects of information for enabling hybrid system use are still relatively unknown as such information has only recently been offered, which leaves an unanswered question for cities globally that have a mix of scheduled and unscheduled public transport offerings (e.g., Accra, Dar es Salaam, Lagos, Istanbul, Mexico City). Though research suggests that access to unimodal information on previously unrecorded systems has the potential to improve users' understanding of the transport system (e.g., Zegras et al., 2015), little research has investigated what information users need to navigate these complex hybrid systems.

Cape Town is an example of such a city. Though initially plans sought to entirely replace the unscheduled paratransit, or the minibus taxis, with a new scheduled, fixed-route bus rapid transit (BRT) system, in response to the failure to remove paratransit competition, its transport strategy has since been re-evaluated to allow both system types, resulting in a hybrid network. While headway has been made to support integration plans through infrastructure, less has been done to integrate the informational infrastructure needed to guide passengers through the system. In the recent decade, there have been several initiatives to integrate the unscheduled system with the scheduled system, from private initiatives to collect data on the services (e.g., GoMetro and WhereIsMyTransport) to government plans to drive integration through technological dimensions such as fare integration and applying e-hailing principles to the paratransit industry (CoCT, 2017). Given Cape Town is like many cities with hybrid systems in that it has limited existing information on the hybrid system, and the metropolitan authority has embraced technology as a pathway for integrating scheduled and unscheduled services (e.g., *2017 Integrated Public Transport Network Business Plan*), Cape Town is an ideal lens through which to explore these issues of information, ICTs, hybridity, and equitable access.

This research proposes to investigate the following primary research question: given the hybrid network is seen as a means of enabling a more feasible and equitable mobility system in Cape Town, then what is the role of ICT in enabling the utilisation of hybrid networks to enhance mobility equity particularly for captive public transport users?

1.2 RESEARCH OBJECTIVES

The objective of information provision in this study is not to incentivise a marked change in modal choice through an information intervention. Rather, in line with the thinking of choices as constrained by perceptions of ease or difficulty in performing a behaviour and expanding people's capability sets, the primary objective is to improve people's understanding of the hybrid travel choices available to them to best meet their needs through information access. The research structure and process are embedded within the theoretical framework of the capability approach, which will be discussed in detail in the literature review. Each of the below objectives comprises its own chapter in this dissertation. The following objectives break down the primary research question into individual, interrelated parts specifically focussed on captive public transport users in Cape Town:

1) To determine what information users need to facilitate public transport journeys and to understand barriers to hybrid public transport use in the current information landscape. *What information is currently drawn on and what information is needed to improve users' ability to use the hybrid public transport network?*

2) To determine users' ICT capabilities within the context of hybrid network-related travel information. *What level of access and ability do users have to use different ICT infrastructures? What are trends in access levels overtime?*

3) To investigate which information types and level of certainty/quality would most enhance public transport users' ability to expand their mobility opportunities through travel decisions that meet their needs and preferences within the hybrid network for non-routine trips. *What is the minimum information required to meaningfully make use of the hybrid network to access and expand mobility opportunities?*

4) To form recommendations for local Cape Town transport planning authorities to enhance users' abilities to access hybrid network information through ICTs and thereby enhance mobility equity for users by improving their capability to use the hybrid network to meet their preferences and needs. *How does an understanding of informational capital deficits and ICT capabilities as barriers to hybrid network use translate into recommendations for better information provision to enable captive public transport users to better access mobility through the hybrid network?*

To assess how ICTs, and thereby information, could enable the utilisation of hybrid networks to enhance mobility equity for public transport users, this research explores these objectives through the lens of captive public transport users, between 18 and 55 years old, who rely on public transport. The segmentation of the transport market into two distinct categories – captive versus choice users – has been debated on grounds that these distinct categories belie the fact that some users are captive to public transport by their decision not to own a car and therefore undermine policy decisions that now confuse chosen captivity for true captivity (Jacques, Manaugh, and El-Geneidy, 2013). Yet whether captive by choice or captive because of no other choice, without access to a private vehicle alternative, captive users are particularly sensitive to volatility and travel uncertainties, and therefore need public transport information (Venter, 2016). Choice users are excluded from this study as they have an alternative choice of private means of travel if their preferred public transport mode does not satisfy their travel needs and would therefore demand a parallel study where the choice to not use public transport would need to be considered. Respondents under 18 years of age were excluded from the study because of ethics approval considerations, whereas the upper age limit is based on life expectancy data. This upper limit is in line with the life expectancy with the target population of captive public transport users who are majority low-income, non-white South Africans. While the life expectancy of South Africans in 2019 at birth was reported at 64 years (World Bank, 2022), when considering the impact of socioeconomic-related health inequalities, then the life expectancy of non-white, low-income South Africans is much lower, ranging from 54 to 62 years (Bredenkamp et al., 2021). Furthermore, travel patterns may differ, as according to the 2020 National Household Travel Survey, those belonging to age groups younger than 55 were most likely to travel, with less than half of those belonging to the age group 55 and older travelling (Stats SA, 2021).

Furthermore, Cape Town is used as a lens through which to explore these four research objectives in the context of an emerging city. Where the Global South loosely refers to regions in the Southern Hemisphere (Parnell and Oldfield, 2014), emerging cities is used for the purposes of this research to refer to a subset of these cities. Emerging cities is a term differentially used - in some cases the emphasis is placed on regions with high economic growth to population growth ratios that currently have a low GDP per capita (e.g., Venter, Mahendra, and Hidalgo, 2019). In other texts, urban areas are classified as emerging based on a current population size of less than half a million, but without the governmental resources to adequately respond to their rapid population growth (e.g., Grijalba Castro and Ramírez López, 2021). Rather than exclude cities on a basis of their current population size or a specific current GDP per capita, emerging cities for the purposes of this research denote cities in the Global South with high fluctuations in travel demand and without necessarily established approaches to managing and responding to growth in urban environments with various institutions and structures characterised by both the planned and legally accepted as well as the unregulated or semi-regulated.

1.3 SUMMARY OF METHODOLOGICAL APPROACH

A research approach can take on one of three types: deductive, inductive, or abductive reasoning (Ruane, 2016; Boylan, 2020). While deductive research tends to start with a hypothesis or set of research questions and test these through research, inductive research does not begin with a hypothesis but begins with specific observations. Inductive research seeks to find generalisations or themes to explain these. The data collected are used to either refine or lend to new theory. Deductive theory, on the other hand, uses existing theory to build the research questions. Abductive research starts with an unexplained phenomenon and seeks to explain this from the information that is available. This research follows the inductive approach, starting with a study of general information needs which is then followed up with research into which specific information needs are in demand and should be pursued in policy and practice to enable access to the hybrid system given the ICT capabilities the study population likely has. However, it combines deductive research in that certain concepts are formed through the qualitative methods and tested through quantitative methods to prioritise information needs and breakdown the population's capabilities to access these needs.

Research paradigms, or how meaning from the research is constructed and thereby informs methodological decisions, take the shape of four main paradigms: positivism, constructivism, interpretivism, and pragmatism. Briefly, positivism concerns itself with the idea that scientific knowledge arises directly out of measurable facts whether that be regarding physical or social phenomena (Creswell, 2011; Johnson and Onwuegbuzie, 2004). In contrast, constructivism is the idea that knowledge is constructed through experience and reflection (Guba and Lincoln, 1989). Interpretivism is closely aligned with constructivism with the notion that, given the world is a social construct, there can be many different interpretations of events based on socio-cultural differences and therefore the events need to be studied through the perspective of those individuals (as opposed to a researcher's own interpretation of those events) (Guba and Lincoln, 1989; Johnson and Onwuegbuzie, 2004). Proponents of constructivism and interpretivism argue that it is impossible to fully establish causality and that the interpretation of phenomena is subjective because the researcher cannot remove their own interpretation from the research process (Johnson and Onwuegbuzie, 2004). Pragmatism maintains that the positivist and constructivist paradigms are not mutually exclusive, and that there are multiple ways of generating knowledge that can be through both subjective and objective means, whereby the research question at hand dictates the qualitative or quantitative nature of the method (Onwuegbuzie et al., 2009; Biesta, 2010).

This research takes a pragmatist approach to addressing the research objectives as it uses mixed methods to develop and guide the research process (Creswell and Plano Clark, 2010). The research objective starts off with unknowns and rather than using assumptions to guide the course of the research, commences with an open-ended problem. Qualitative research was needed to understand the multiple perspectives of captive public transport users and their experiences and need for public transport information. This interpretivist approach allowed the subsequent quantitative research to be directed by the outcomes and learnings of the interviews as opposed to confining the outcomes of the research to preconceived notions of what information transport users in South Africa need. Without a qualitative understanding of the multitude of information needs that a diverse user group has, the quantitative research would have been premised on biased information types. The research would have relied on a subjective rather than objective interpretation to compile a list of probable needs, informed by existing literature which to date comes largely from Western contexts. Commencing the research with an interpretivist approach, more so than a positivist approach, allows for a decolonisation of knowledge, i.e., the rethinking and reframing of concepts embedded in a Western-centric lens, around public transport information needs with an emphasis on the particularity of informational capabilities in a hybrid transport context rather than perceiving these as universal norms (Schwanen, 2018).

A quantitative approach to investigating ICT capabilities and informational needs amongst captive public transport users is useful to understanding what part of the population proportionately may stand to benefit from various information interventions. Quantitative research also helps narrow down and prioritise what can be an unpractically large set of information needs such that the research outcomes can be feasibly translated into practice. This dual qualitative and quantitative approach that pragmatism embraces allows for a richer, deeper investigation of the research objectives than any one approach in isolation would have allowed.

This doctoral research was originally intended to be embedded in the local metropolitan transport and urban development authority and develop through regular feedback with local authorities and engagement in projects, to ensure the research's relevance for short-term and long-term strategic aims. While the ongoing COVID-19 pandemic disrupted the feasibility of working closely with the City to gain deeper understandings of challenges faced around information technologies and information integration, the research objectives and framework were guided by needs within the City given both their feedback during the research proposal presentation as well as supported by their policy objectives as expanded on in the literature review. These have continued to guide the nature of the research.

1.4 OVERVIEW OF THESIS STRUCTURE

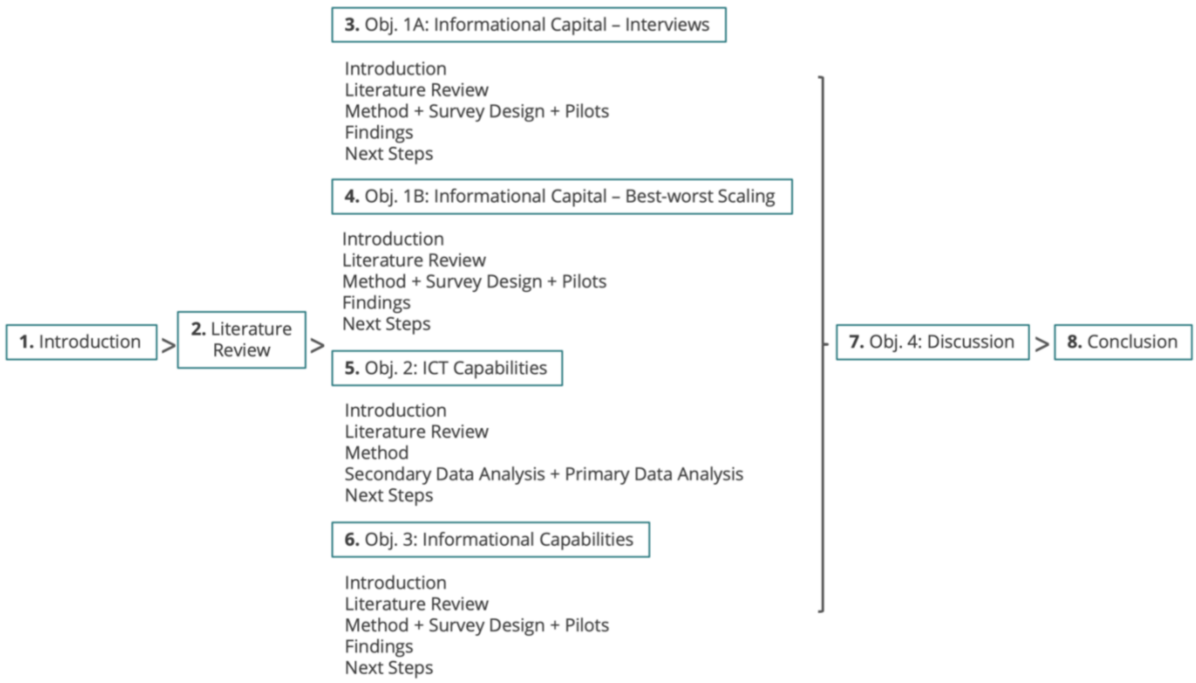

Figure 1.1. Flow of thesis chapters.

The thesis is composed of eight parts and is structured as follows (Figure 1.1). Following this introductory chapter, the second chapter (*Literature Review*) is a literature review that opens with an overview of hybridity and the current state of information in Cape Town, contextualising barriers to its use from an information perspective within the *capability approach* before touching more specifically upon cognitive barriers and facilitators to information use. The literature review wraps up with a summary of gaps in prior research and the resulting detailed research objectives that will guide the following chapters. Rather than a traditional methods chapter where all methods and findings are discussed together, the thesis breaks down the methods chapter into individual chapters for each method specific to each objective. Each of these individual chapters opens with a brief background section to remind the reader of the chapter's position within the larger research, followed by a condensed literature review of prior research done by others specific to the particular thesis objective and the method used to pursue the objective, the study design, and the findings and discussion of results. Chapter 3 (*Objective 1A: Informational Capital – Interviews*) discusses the individual interviews conducted to investigate informational capital needs, which is complemented by Chapter 4 (*Objective 1B: Informational Capital – Best-Worst Scaling*), the best-worst scaling study used to rank and prioritise these needs for use in the Chapter 6. Chapter 5 (*Objective 2: ICT Capabilities*) discusses ICT capabilities of captive public transport users using primary and secondary data analysis. The choice model used to understand informational capabilities is detailed in Chapter 6 (*Objective 3: Informational Capabilities*) and the resulting information needs discussed. Chapter 7 (*Objective 4: Recommendations*) synthesises the findings from the primary research to form policy recommendations for expanding capabilities for captive public transport users through access to informational capital given their ICT capabilities. Chapter 8 (*Conclusion*) concludes the thesis with a summary of the objectives and related findings, how this work lent original contributions to knowledge, and the implications of these conclusions for further research.

2. LITERATURE REVIEW

2.1 INTRODUCTION

The following literature review provides a foundational understanding of Cape Town's hybrid network, and synthesises theoretical writings, to form a theoretical framework to guide the research. It also reviews research from behavioural psychology to create a complementary framework to evaluate public transport user choice and assesses previous research to identify the gaps in knowledge.

The literature review opens with an overview of Cape Town's public transport network and current state of passenger information provision (section 2.1). Drawing on policy documents and transport planning research, the literature review turns to a discussion around equity as a guiding pillar of Cape Town's mobility system to provide justification for deeper research into barriers to people's ability to effectively use the hybrid network, namely information (section 2.2). A theoretical discussion of information's role as an enabler and barrier to hybrid network use follows, drawing from welfare economic theories extended to applications of ICTs to contextualise and evaluate the role of information in delivering equitable mobility (section 2.3). The review then turns to an examination of information's cognitive role in affecting an individual's ability to maximise the mobility potential of the hybrid network to meet their needs through a collection of research done in behavioural economics and travel behaviour (section 2.4.1). The theory of planned behaviour is subsequently introduced to provide a psychological framework to explain how information deficits across the hybrid network affect users' abilities to make use of the full range of journey offerings (section 2.4.2). An overview of research conducted to date into multimodal transport information and paratransit information is presented (section 2.5). The review then closes with a summary of research done to date in understanding multimodal information needs more broadly, before focussing on the gaps in knowledge around hybrid and paratransit information needs (section 2.6).

2.2 SETTING THE SCENE: CURRENT STATE OF PUBLIC TRANSPORT AND INFORMATION IN CAPE TOWN

2.2.1 Overview of Cape Town's Public Transport Network

Cape Town, South Africa is home to an estimated 4.2 million people (Western Cape Government, 2017), with public transport accounting for 38% of all trips made in the morning peak period and private modes of transport for 53% (CoCT, 2019). Of those that use public transport, 95% are in the low and low-middle income brackets, whereas the high-income population accounts for 95% of private transport use. Public transport users rely on several modes operating in Cape Town. The available public transport modes in South African cities (see Figure 2.1) include trains, minibus taxis (MBT), and contracted buses, accounting for 47%, 32%, and 21% respectively of all public transport trips made during peak periods (ibid.). However, since these statistics were reported in 2019, the share of train use is likely to have dropped due to declining service quality and the share of the other modes is likely underrepresented as users moved from train use to alternative public transport modes. Metrorail Western Cape is a national commuter rail service which operates trains since 1994 on five lines that all converge on the main train station in the central business district (CBD). In recent years, Metrorail has been plagued with cancellations and delays, due in part to a shortage of train sets in the wake of recent carriage fires and stolen signalling equipment (Devdiscourse, 2019; IOL, 2019). Golden Arrow Bus Services (GABS) is provincially regulated and is a conventional, scheduled bus service. As a commuter-oriented bus, hundreds of direct service routes are operated primarily during weekdays, largely between lower-income areas and the main economic hubs.

Across South African cities, including Cape Town, MBTs emerged in the 1970s to capitalise on the huge demand for mobility not met by government services (Behrens, 2016). Today they form a vital link between predominately 'Black' and 'Coloured' residential areas on the urban peripheries and downtown commercial areas and affluent suburbs (ibid.). These 16-seater vehicles are owned by private individuals organised into associations. Owners, who do not operate their own vehicles, will hire their MBTs out to drivers. Today, thousands of these MBTs offer services on over 500 routes, but unlike the other public transport services in Cape Town, these services do not have set schedules or designated intermediary stops, and may modify their routes based on external factors (e.g., passenger requests or police blockades). Routes are often designated with a placard in the windshield with the written general end destination, e.g., "Langa." However, oversaturation of the mass transport market has led to violent competition and, in an effort to maximise revenue and minimise operating expenses, vehicles can be poorly maintained putting passenger safety at a risk.

Figure 2.1. Major public transport modes available in Cape Town.
Above photos (clockwise from upper left corner): Minibus taxi, Golden Arrow, Metrorail, and MyCiTi.
Below: Routes served by mode. (Figure to scale, data from WhereIsMyTransport)

Only in the past two decades, with the end of apartheid, has the conversation around South African planning practices shifted towards inclusive urbanism and public transport planning. The

1996 White Paper on National Land Transport marked a shift in prioritising public transport over private car use as the means to achieving desired economic and social development (Van Ryneveld, 2008). In 2007, the national government approved a strategy which proposed the phased implementation of Integrated Rapid Public Transport Networks (IRPTNs), namely introducing Bus Rapid Transit (BRT) systems, in 12 cities by 2014 (Browning, 2017). By 2020, the aim was to ensure that over 85 percent of a city's population would be within one kilometre access of an IPRTN route (ibid.). The *National Land Transport Act of 2009* further aided cities in leading strategies to improve mobility through the devolution of public transport activities from a national to metropolitan level, giving cities the power to contextualise transport initiatives to their unique urban forms, systems and needs (Van Ryneveld, 2008).

The country's winning bid for the 2010 FIFA World Cup spurred the implementation of MyCiTi, Cape Town's BRT system. Though these BRT services were intended to replace existing MBT as indicated in the *2007 Public Transport Strategy*, this strategy has not gone as planned. As a result, the City of Cape Town (CoCT) has since laid out a 'hybrid' strategy to form an Integrated Public Transport Network (IPTN), combining the different modal types wherein MBT are re-envisioned as a part of the full network (CoCT, 2018a). According to the *NLTA Amendment Bill*, an IPTN integrates modes through "appropriate mechanisms [...] to provide users of the network with the optimal solutions to be able to travel from their origins to destinations in a seamless manner" (Amendment of section 1 of Act 5 of 2009, c).

The hybrid system entailed creating a "synergy between, modes of transport, the ticketing system and the relationship between scheduled and on-demand transport" through combined use of a scheduled trunk route service serving 80% of the population living within the 500-metre walking radius of a rail or bus stop and an unscheduled MBT feeder service capturing the rest (CoCT, 2018a: 37; CoCT, 2014a). The *IPTN Business Plan* posits that MBTs will best serve the network, particularly during off-peak periods, as a demand-responsive system, enabled by e-hailing technologies (CoCT, 2017). The goal driving the public transport system planning is to reverse the segregation practices of apartheid and ensure equitable and convenient access to opportunities and facilities for all citizens and visitors – whether for economic, education, health, recreation, or social purposes (CoCT, 2010).

2.2.2 Current Information Landscape

Information is one solution to enabling seamless travel between disparate modes and can be provided in three different ways (see Figure 2.2). By its nature, the least beneficial to a hybrid system context is unimodal information (UMI), which is information on a single mode and would require users to seek out multiple sources if they want information on more than one mode. UMI supports current mode decisions but does little to influence the user in considering alternatives (Kenyon and Lyons, 2003). Multimodal information (MTI) refers to a single source that consolidates information on multiple modes, but still requires the user to look at the discrete information on the different modes and combine these information points if they wish to make a multimodal trip. The third type is integrated multimodal information (IMTI), which is information that is presented on multiple modes at once, possibly even combining them to provide different mode choice options. IMTI can overcome cognitive barriers that impede information use in a complex hybrid system, by (1) making alternatives more transparent, (2) reducing the need to search for different information sources on these alternatives, and (3) compiling and combining information on different modes to provide an overview of the viability of alternatives (ibid.).

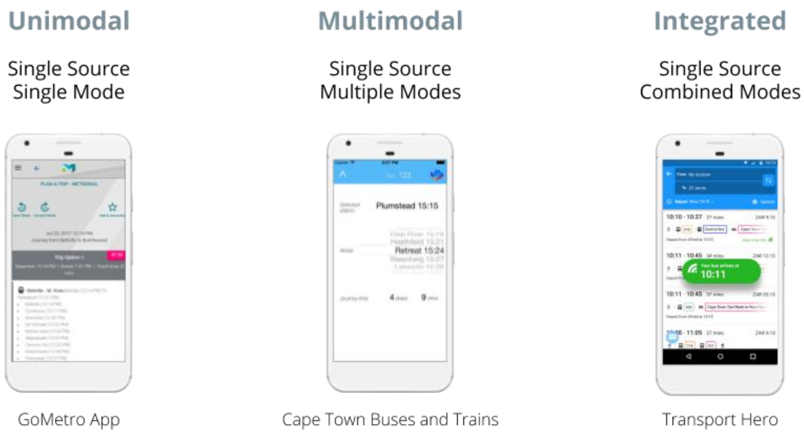

Figure 2.2. Examples of UMI, MTI, and IMTI in Cape Town.

In a city with a train network, two independent bus services, and several thousand MBTs contributing to hundreds of routes, IMTI, more so than MTI and UMI, can better enable people to understand which trip options best suit their needs and preferences by doing the work of finding, extracting, combining and comparing disparate information pieces for the user. And yet despite Cape Town's hybrid system being conceived of as a single, connected web of public transport modes offering choice in movement, accessible information to make that movement choice visible is lacking both in terms of information sources available and balanced information across scheduled and unscheduled networks.

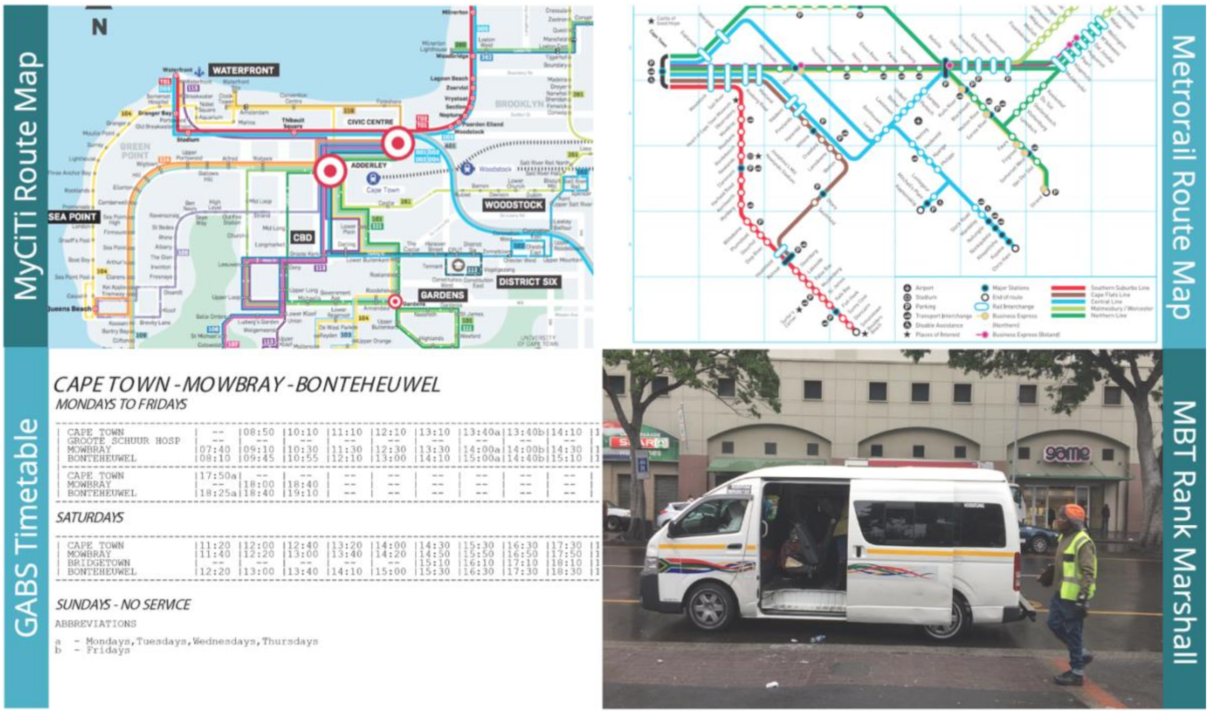

Figure 2.3. Examples of route information on the various modes.
Whereas more traditional route information in the form of route maps is available online and at some stations for MyCiTi and Metrorail services, route information needs to be deduced from the GABS timetable and directly requested from MBT personnel or other passengers.

Limited IMTI is offered in Cape Town and where it is, this information is unevenly distributed and in different formats (Figure 2.3). Complete information is primarily accessible online, with the exception of MBTs (Figure 2.4). Information accessible through non-ICT mediums is largely discretely provided on isolated scheduled modes. The MyCiTi services have wide information coverage across their major and intermediary stops. Major interchanges and BRT stations are staffed, have route maps and timetables, and wayfinding signage for boarding the bus bound to the correct end-destination. User guides are available to understand the payment system and the different fare options available. Intermediary stations have a route map, timetables for routes that service that specific stop as well as stops along the routes. Metrorail has some information available at the central station in the CBD but other intermediary stations have faded timetables and partial route maps, at best. Kiosks and ticket counters outside of the central station are not routinely staffed. Information for GABS can be acquired at the kiosk at the main terminal near the central train station for basic route, fare and payment inquiries, though information can vary dependent on the staffs' knowledge. Signage for end destination and in-rank departure locations is provided at the main terminal. No timetables or route maps are available. Intermediary stops, indicated usually by a yellow bus stop structure, do not have any information on the services available. Similarly, end destinations are indicated at major MBT ranks (major points of boarding and alighting, either built structures or informal convergence points on the street) at the different vehicle boarding points, but no timetables, route maps, or additional recorded information is available. Rank personal and MBT drivers can provide additional information on request.

Figure 2.4. Information types on modes provided by different publicly accessible sources in Cape Town and the ICT needed to access these sources.

Where information does exist across multiple modes, this information is inaccessible without technology. Two mobile apps (Transport Hero and Public Transport App) for iOS and Android provided IMTI across all four main modes in Cape Town, but due to limited active marketing have limited downloads and have since been removed from the app stores after no longer being updated. The official MyCiTi website provides limited information on where to find the modes other than the MyCiTi buses in the CBD, and also points to toll-free phone numbers for further information on Metrorail and GABS. The Transport Information Centre can be reached via a toll-free number and offers information on MyCiTi, Metrorail and GABS. Otherwise, MyCiTi's public transport map (available online and at stops and stations) indicates approximate locations of train stations to give some indication of transfer points.

However, the ability of existing sources to provide information across the full hybrid system is undermined by the lack of necessary information to enable multimodal trip planning. Recorded information availability is skewed in favour of scheduled modes. There is very little recorded information openly available on MBT services, though in recent years private companies, such as GoMetro on behalf of the CoCT, have collected route, frequency, operating hours, stops, and fare data. Some such data has been made available through trip planning apps (e.g., Public Transport App), though these have not been actively marketed and have few active users. These existing trip planning tools for hybrid systems are limited to information on estimated fares, approximate trip duration, departure and arrival estimates, transfer points, an indication of where the route runs through the city, and vehicle-route identifiers for MyCiTi. As research has not been done into user needs for paratransit systems nor on combined paratransit and scheduled mode trips in a context like Cape Town, rife with volatility and large discrepancies between modes, the current information types that are provided cannot be taken as the only types of information that are necessary for people to navigate Cape Town's hybrid system.

2.3 BACKGROUND TO HYBRIDITY IN CAPE TOWN – THE PLANNED AND UNREALISED

Underlying Cape Town's IPTN plan and an integrated transport system are principles of equity - that everyone has the right to a high-quality, equal public transport experience (CoCT, 2018a; CoCT, 2012). Given the City's commitment to delivering an equitable public transport system (CoCT, 2012; CoCT, 2014b; CoCT, 2018a) that reverses the exclusive urbanism planning practices of apartheid and ensures that all citizens and visitors have convenient access to opportunities and facilities, ensuring accessibility is key to realising more equitable mobility (CoCT, 2010).

Accessibility can be defined from the perspective of the individual public transport user as a combination of (1) the distribution of mobility resources, (2) the opportunities services connect to, and (3) the individual's capability to utilise these services (Pereira et al., 2016). While infrastructure is the layer that physically connects different points, it is the information layer that enables the users to understand how those points connect. Part of an equitable mobility system then is equitable access to information, or the fair and just distribution of public transport information, such that different user types can meaningfully use information to make high quality journey choices to suit their travel needs given the options the hybrid network provides.

It is important to draw a distinction between the terms 'equality' and 'equity' which will be a central component to the theoretical framework guiding this research proposal as expanded upon later in the paper. If inequality is the "differential appropriation of wealth (income and assets) by different individuals and social groups, relative to each other", then equality is defined by the uniformity of wealth (Castells, 2010: 70). However, in highly unequal societies such as in South Africa, equality and uniformity of public goods are not enough to enable a better future for historically disadvantaged groups. Though equality means the same distribution and access to income or resources, it does not imply that everyone has equal ability to use these goods to achieve a good quality of life nor is perfect equality a determinant of fairness (Rawls, 1999). Equity, on the other hand, is concerned with fair and just distribution of opportunities, and is about creating an even footing by enabling disadvantaged groups to draw on public resources to offset disparities in societies (UN Habitat, 2008; Vasconcellos, 2011). When assessing equity, Vasconcellos (2011) emphasises the tension between the social and economic types of equity, where the economic concept places more weight on 'willingness to pay.' Measurements of social equity, however, need to be understood in terms of individuals' needs and the division and use of goods and resources amongst different individuals and user groups (ibid.). In the context of public transport, equity can be defined in terms of accessibility, where the key concern is enabling ease of accessing opportunities and places, taking into consideration individual economic, social and physical needs (Pereira et al., 2016). In line with this understanding of equity, the hybrid system offers people a choice of modes of varying quality, service attributes, and coverage from which they can better match to their mobility needs and individual constraints as opposed to what a unimodal system might offer.

Despite the CoCT's strategic plans for an IPTN, integrated information across modes to communicate to users how disparate systems interlink is limited. According to national legislation, the responsibility to adequately provide information to enable people to use the integrated public transport network sits at the metropolitan level. The *National Land Transport Act 2009* (NLTA) mandates that municipal governments are responsible for ensuring that people can get maximum benefit from the integrated public transport network, by specifically making municipalities obligated for: “encouraging and promoting the optimal use of the available travel modes so as to enhance the effectiveness of the transport system and reduce travelling time and costs” (NLTA, 2009: c.2. s.c. vii.). The Act further delegates the responsibility of “providing information to users or potential users of public transport” to municipal governments (ibid.: c.2. s.c. xii.). The NLTA also stipulates that municipalities must establish a transport call centre to handle inquiries and complaints. To this end, the CoCT offers the 24-hour Transport Information Centre (TIC) with information services (e.g., routes, schedules, ticket prices, etc.) on MyCiTi, Golden Arrow, and Metrorail available in English, Afrikaans and Xhosa. However, the information that the TIC can feasibly provide on the hybrid network is limited by what data is available to them from the different operators, as not all sit at the municipal level. The CoCT’s IPTN Business Plan acknowledges that the efficiency of an IPTN is reduced if modes are fragmented, and that information technologies and a centralised platform can be used to stitch these together to create a seamless passenger experience while still accommodating entrepreneurism in service provision (CoCT, 2017).

Though intended to be developed as an integrated system (e.g., NLTA, 2009), Cape Town’s hybrid network has several barriers that reduce passengers’ ability to seamlessly move through the system reducing the potential for the hybrid network to better meet their needs. While studies have investigated hybrid networks in Cape Town from the viewpoints of operational compatibility (e.g., Stoy, 2015; Behrens et al., 2017; Behrens et al., 2018), service quality (e.g., Ugo, 2014 investigated service quality as a barrier to BRT uptake in Cape Town), and fare integration (e.g., Venter et al., 2020), research has not delved deeper into how information can aid, at least partially, the integrated use of the different modes. Though the hybrid network is planned as a network with a wide coverage of routes, there currently is little information accessible, or in some cases even available, to passengers to make it clear how the discrete modes and independent vehicles composing the network are interlinked or how to combine the different services to best meet individual journey needs. Information is unevenly distributed - information in non-ICT mediums is largely discretely provided on isolated scheduled modes and where it does exist across multiple modes, information is inaccessible to non-ICT users. How this inequitable access to information – or the fair and just distribution of public transport information – affects different users’ ability to meaningfully use information to make high quality journey choices to suit their travel needs given the options the hybrid network provides is poorly understood.

2.4 A THEORETICAL FRAMEWORK FOR ICT ASSESSMENT

2.4.1 The Capability Approach

Grounding the discussion within a theoretical framework, the following section looks at the role of information technologies in facilitating the realisation of the equity goals set within the CoCT's vision for the hybrid network. Rather than considering this role in economic terms, or ability to pay, Vasconcellos (2011) argues that transport equity and accessibility to services must be considered in social terms, or ability to use. The implementation of information, and, more explicitly, ICTs to further transport policies and equity goals central to these policies should be evaluated through people's ability to meaningfully use the new information to improve their well-being. As opposed to addressing inequalities through the fair distribution of social and natural primary goods (e.g., Rawls, 1999), Amartya Sen (1980) argues that social primary goods can be used differently and may not lead to increases in personal welfare, in part because of variations in individuals' abilities to make use of the goods. According to Rawls, natural primary goods are those that relate to mental and bodily abilities whereas social primary goods are the things people need to be free and equal as members of society, e.g., liberties, prosperity, and self-respect (Martens, 2017).

Sen introduces the concept of *capabilities* (see Figure 2.5) as an alternative way to approach individuals' well-being – what people are effectively able to do and be. The term *capabilities* refers to the collective set of options a person is free to choose from, whereas *functionings* is a subset of these capabilities that are achieved and "reflects the various things a person may value doing or being" (Sen, 1999: 75). Social context and past behaviour influence an individual's choice of realised functionings, though it is important to note that not all capabilities are achieved out of choice but out of obligation because of some sort of restriction (Beyazit, 2011). Freedom of choice and agency are affected by personal, social and environmental characteristics that do not necessarily lead to well-being (Frediani, 2010).

A focus on capabilities rather than functionings places emphasis on what an individual is able to do or be, rather than a subset of these capabilities which is what an individual does end up valuing and doing. For example, an individual who chooses to walk to work rather than using their bicycle has a wider range of mobility freedoms than an individual who has to walk to work because they have no other choice. Though both individuals walk, both do not have the same freedoms, or capability set to choose from. Expanding capability through the removal of obstacles to well-being is key to enabling freedom for people to lead the lives they choose (Robeyns, 2005).

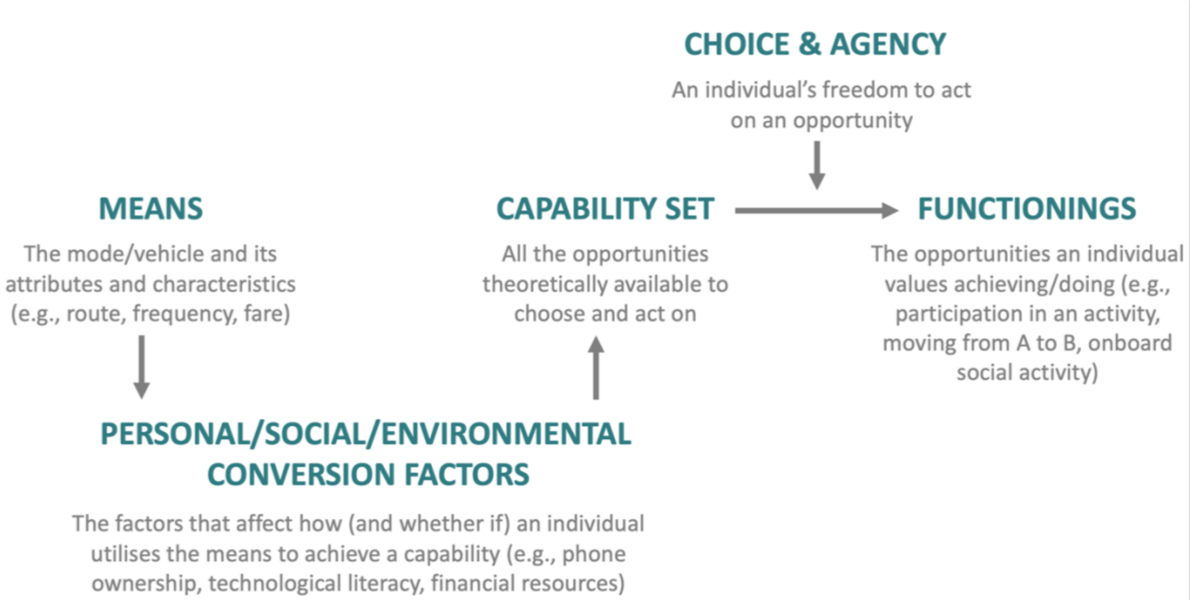

Figure 2.5. Capability Approach applied to transport.

The *means* are goods and services, like the availability of physical commodities or social support structures. However, these are not the ultimate ends of well-being. Mediating between the means people have access to and the capabilities they can achieve are an individual's *conversion factors*. These can be personal, social and environmental in nature, limiting or enabling what functionings might be available to a person for any given means. Conversion factors such as financial means to afford the fare, physical ability to board the vehicle, and shelter for when it rains while waiting are aspects that determine whether an individual is able to make use of public transport to achieve desired outcomes. While the means are important, they are not in and of themselves indicators of whether well-being can be positively affected. Though individuals may have identical capability sets, they may choose to pursue different functionings depending on their unique choices and agency (Sen, 1992). Sen (1999) stresses that it is important not to limit what life options people choose to pursue. Rather, emphasis should be on providing means that do not present unmanageable barriers and are complementary to the personal, social, and environmental conditions present so that individuals can realise functionings that those means theoretically could enable.

2.4.2 The Capability Approach Applied to Transport

The capability approach has been applied in transport studies to understand social equity issues (Lira, 2019) and has been mainly focussed on the conceptual applications from a perspective of access (e.g., Beyazit, 2011; Hananel and Berechman, 2016; Pereira et al., 2016; Martens, 2017). According to Beyazit (2011), from this perspective, the *means* are the transport system in its totality, while the *capabilities* are defined as mobility, or the physical, social and financial ability to move around. The *functionings* are then the various trips an individual has access to, to achieve a desired outcome, whether that be to travel for work, or simply for the experience of the journey itself. Which mode at what time of day at which locations for what travel purpose are *choices* individuals make that are influenced by their collective set of *values* (e.g., financial and time constraints, lifestyle preferences, etc.).

Accessibility is viewed as a mediating factor between the greater means available and an individual's capability set. Transport accessibility is determined by a combination of two factors: the external environment and personal abilities (Pereira et al., 2016). In terms of the external environment, while a transport system may be available, it does not necessarily connect and thereby improve an individual's ability to access desired places and opportunities. Service traits like operating hours, frequencies and connections may limit where and when mobility is possible. According to Pereira et al. (2016), personal abilities are comprised of personal (e.g., physical fitness, cognitive skills, financial resources) and external factors. These include the limiting and enabling aspects of a social and physical environment that affect individual ability to access a system, such as perceived personal safety onboard a vehicle and availability of travel information. Furthermore, as demonstrated in Cao et al.'s (2019) study of a low-income neighbourhood in Being, socio-economic disparities, amongst other personal factors, can act as barriers to transport accessibility by creating a gap between actual and desired mobility. To assess the relationship between transport accessibility and social inequalities, in their Bogota, Colombia-based study, Oviedo and Guzman (2020) suggested that focussing on non-mandatory trip purposes, rather than routine trips, leverages the capabilities approach to reveal barriers to opportunities people may have reason to realise through mobility.

Building upon these applications of the capability approach to transport studies and mobility accessibility, the capability approach can be extended to transport information as a way of harnessing the mobility potentials of a hybrid network. Like Beyazit's (2011) conceptualisation of transport within the capability approach, the hybrid network is the means that individuals in theory have access to, to take a range of journeys across the hybrid system. If the hybrid system offers different combinations of modes to traverse the city to get from point A to point B, then it can be said to offer increased choice as opposed to a unimodal system which may only offer one option for fares, travel times, etc. Information on the hybrid system enhances personal abilities to mix and match these modes to meet their travel needs and preferences by illuminating the different travel means available to access different opportunities in the city. Differential personal abilities (e.g., ability to read timetables, access to the internet to see service alerts, mobile apps to journey plan across multiple modes) act further to filter what information is accessible to an individual. In turn, barriers to personal ability to access information affect individual choice and agency in cognitively limiting the mobility opportunities an individual may consider.

In the context of Cape Town and the implementation of a more equitable hybrid transport network, information, or a lack thereof, affects people's understandings of the larger public transport network (Chorus et al., 2007) and aids in assessing the different combinations of journey options available to them (Kenyon and Lyons, 2003) to best achieve their desired functionings. Transport information that is packaged in ICTs, while potentially powerful as a source of information across multiple modes, may not be equally accessible to all public transport users. Technology is not only a means or object, but also plays a transformative role, in that technology can modify the capabilities an individual is able to theoretically attain through a given object, in this case, the hybrid system (Haenssgen and Ariana, 2018). To better understand how people's differing abilities to access and use ICTs affects their individual capacity to meaningfully harness ICTs to leverage the hybrid system to meet their mobility needs, ICTs for transport information should be evaluated with a consideration of how information-related abilities affect access to use.

2.4.3 Information and ICT in the Context of the Capability Approach

According to Heeks (1999), ICTs are tools that can be used to achieve something, so when applied to the capability approach, ICTs can affect what capabilities and functionings an individual can achieve. Because, as according to Sen (1999), individuals have different ways of transforming a means into a functioning, it stands to reason that the utility of ICT would be equally diverse. ICT access relates to three components which differ in their utility dependent on individual differences: the infrastructure; the service; and the content (Alampay, 2006). Individual differences may influence ICT access including education level, gender, income and age. Similarly, the quality of access itself, such as broadband speeds that affect Internet connectivity, differences in quality of hardware, and availability of ICT infrastructure can impact an individuals' ability to use ICTs.

Due to these differences, access must be evaluated beyond ownership to take into account the needs and reasons for using ICTs (Mann, 2003) and individuals' abilities to make use of various ICTs to achieve intended functionings (Garnham, 1997).

While the variety in travel choice that Cape Town's hybrid system offers could foster a more equitable mobility system, barriers to information access may limit knowledge of choices available and thereby access to these journey choices. Moreover, the information available through ICTs on the hybrid system is not evenly distributed across modes (or, for that matter, not even via non-ICT mediums such as route maps at stops, e.g., route information) and information tends to be biased in favour of scheduled modes. ICT can act as an enabler between the hybrid network and people's ability to navigate across its many travel options, if it is accessible to the user and its information content is relevant to the user's needs.

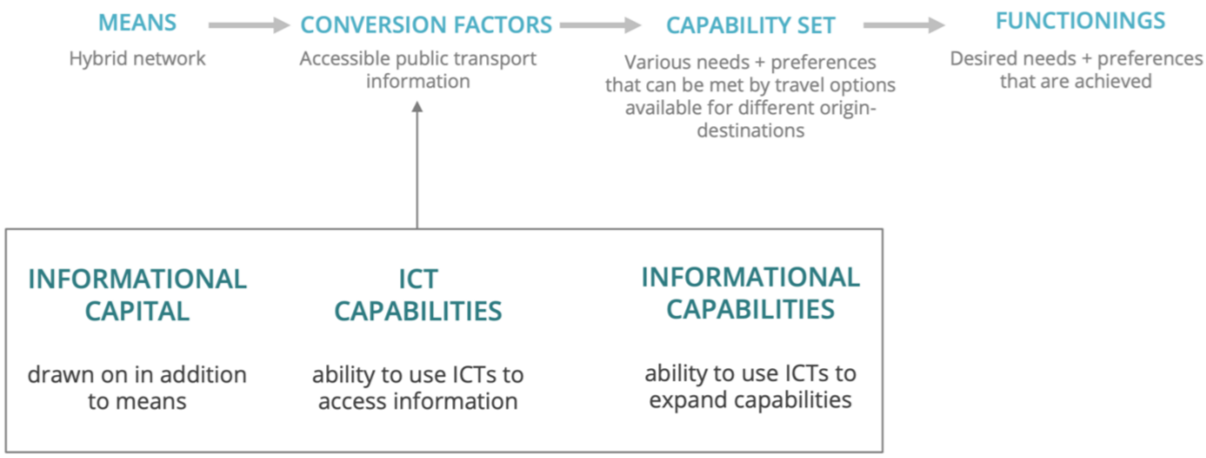

Figure 2.6. Sen's capability approach applied to the hybrid system and Gigler's application of the approach to ICTs.

In studies of ICT's impact on socio-economic development, Bjorn-Soren Gigler (2011) examined the ability of people to make use of ICT to achieve functionings. Though his discussion is from the viewpoint of enhancing collective informational capabilities amongst rural communities, he lays out a useful approach to applying Sen's capabilities to ICTs that can be applied more generally. Gigler introduces the terms *informational capital*, *ICT capabilities*, and *informational capabilities* to place ICT's role for development within the framework of the capability approach (see Figure 2.6). *Informational capital* relates to the resources or assets a person has access to through the availability of information. It should be relevant and specific to the local context and circumstances and respond to information needs.

ICT capabilities and *informational capabilities* loosely refer to people's "freedom to use ICTs within the institutional and socio-economic setup of society" (Gigler, 2011: 8). What sets access to ICTs apart from meaningful use of ICTs is the difference between simply distinguishing between the 'haves' and 'have-nots', and going further to unpack ICT proficiency and ability to translate technology into beneficial outcomes. *ICT capabilities* are an individual's abilities to access and use ICT in various ways. The relevance of available information and individual capability to contextualise the content within one's own socio-cultural context is what Gigler refers to as *informational capabilities*. This underscores the increasing importance in identifying missing information bits that are critical to decision making processes in a particular context but not traditionally recorded on paratransit. In short, informational capability is the "combination between a person's existing livelihood resources in terms of information (information capital) and his/her agency (ability) to strengthen these assets and to use them in such a way that the use of information can help a person to transform his/her options in life in order to achieve the 'beings' and 'doings' a person would like to achieve" (ibid.: 8). Access to ICT, in and of itself, does not translate into positive outcomes. Access to ICT that meaningfully enhances people's informational capabilities is needed to impact well-being.

It is within this framework of understanding ICTs in the context of capabilities that access to hybrid public transport information is investigated to understand how to deliver information via technologies most equitably.

2.5 TRAVEL INFORMATION AND BEHAVIOUR

2.5.1 Information as an Influencer

Individuals' decision-making processes mediate between what capability set can be obtained given individual informational capabilities and how functionings are selected. Understanding how behaviour is influenced to seek out information is important in the context of Cape Town's current information landscape in which disparate information sources segregated by mode can be a barrier to individuals' capabilities to consider and utilise different opportunities the hybrid public transport system affords. Information behaviour, a field of information science research, refers to these behavioural processes as related to information and encompasses the concepts of information need, information-seeking and acquisition, and information use which are discussed as related to mobility (Wilson, 1997).

There is an assumption that individuals make rational decisions based upon information and would choose the mode most fitting to their personal needs (Kenyon and Lyons, 2003). Rather than considering all alternatives to make a rational choice that maximises utility (Ben-Elia and Avineri, 2015a), given the complexity and unreliability of transport networks that makes such a thorough consideration of alternatives cognitively exhausting, an individual's knowledge of the network is limited and therefore rationality is bounded (Simon, 1982; Chorus et al., 2007). Individuals will make choices that minimise regret and seek information where knowledge limitations could result in an unsatisfactory choice (Chorus et al., 2008). Individuals will go through an effort-accuracy trade off decision strategy before seeking information, balancing the accuracy of attaining a specific goal against effort to obtain information to increase perceived accuracy (Farag and Lyons, 2008). The individual will search for an alternative until they find something that satisfies their goals rather than maximises them.

Cognitive effort is the level of mental exertion required to complete a task, or in the case of information, the effort to process information, and affective effort is the emotional energy a task uses and, in the case of transport, is affected by uncertainty (Kahneman, 2013; Grotenhuis et al., 2007). Cognitive effort decreases with familiarity (Kahneman, 2013). Complex trips can increase the level of cognitive effort and affective effort required to complete the trip by public transport. Trip complexity increases with trip chaining which is when several trips are tied together rather than a return trip to the original origin. In the case of non-routine trips, it has been found that if people regularly rely on a mode for their routine trip, they will use this mode for other trip purposes (Aarts et al., 1997; Verplanken et al., 1994). Habitual behaviour, or the repetition of past behaviour without necessarily forming an intention so that there is no deliberate decision made, can save both cognitive and affective effort (Grotenhuis et al., 2007).

Though habit is a strong influencer of behaviour (Aarts et al., 1997; Verplanken et al., 1997), information can act as an influencer on behaviour if it promises a viable alternative to the routine method of travel (Bamberg et al., 2003; Kenyon and Lyons, 2003; Lyons et al., 2001; Pronello et al., 2017). It is important to note that habit is in part developed because it is functional in achieving some sort of goal (e.g., convenience) (Verplanken and Aarts, 1999). But, in line with prospect theory, travel situations where there is a potential strong loss will drive information acquisition to minimise regret (Kahneman and Tversky, 1979). The effects of satisficing and habitual behaviour are weaker in situations where the individual is unfamiliar with route and travel options and where there are volatile travel conditions (Lyons, 2006). Occasional public transport users are more likely to seek pre-travel information than people who make frequent trips (Yeboah et al., 2019).

Public transport users do tend to seek public transport information except in cases where time is not a constraint, there are frequent services and the trip is short (Farag and Lyons, 2008). Sensitivity to certain travel constraints (e.g., time) result in mode, frequency and route choices being more sensitive to uncertainties thereby promoting pre-trip public transportation information seeking (Farag and Lyons, 2012). Information needs vary based on mode and journey stage (Mulley et al., 2017), with individuals more likely to seek information on unreliable services than reliable services (Yeboah et al., 2019). However, for information to help reduce travel uncertainty it must be reliable (Chorus et al., 2007), otherwise the traveller will be less likely to trust the information (Schooley et al., 2011) and use it to make future decisions (Bifulco, Pace, and Viti, 2014). This information-seeking process and the capability of a traveller to transform information to make relevant travel decisions is captured in figure 2.7.

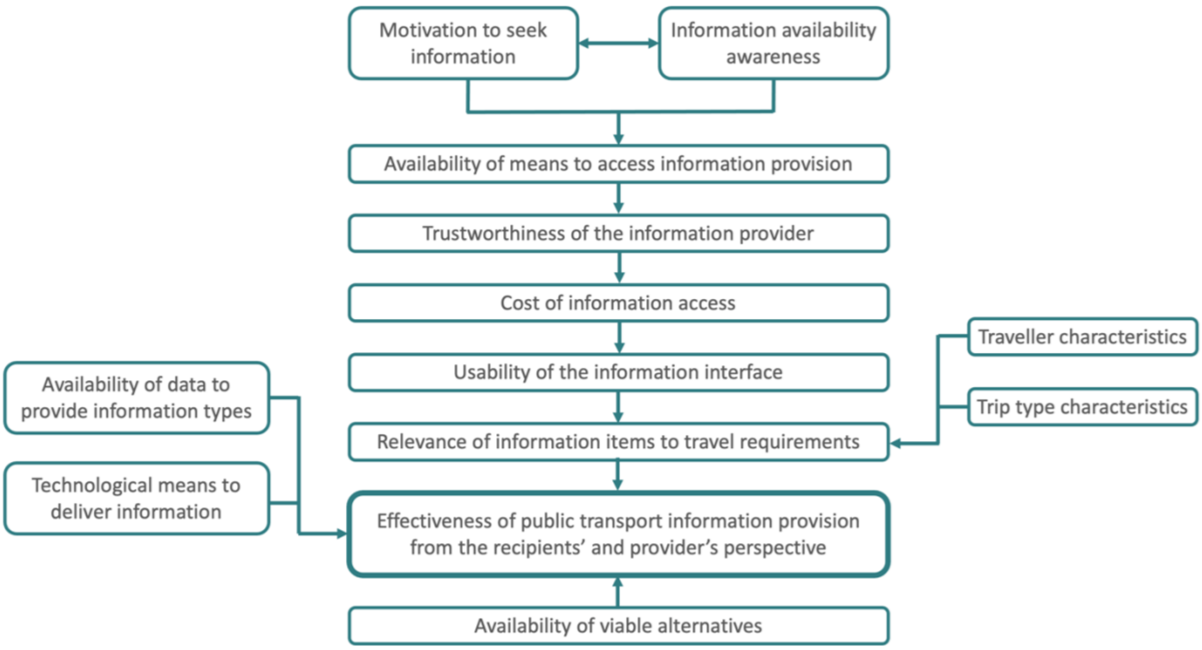

Figure 2.7. Factors that affect the capability of a traveller to use information to make travel decisions. (Adapted from Lyons, 2001)

2.5.2 Information as a Cognitive Barrier

It has been found that information awareness alone can be a barrier to information use (Farag and Lyons, 2008), and the demand for information is further reduced as individuals mistake their subjective attitudes to be true knowledge (Kenyon and Lyons, 2003). The *theory of planned* *behaviour* presents the concept of perceived behavioural control that can help conceptualise how information barriers in turn affect journey decisions.

The theory of planned behaviour (see Figure 2.8) is an extension of the *theory of reasoned action*, which sees *intentions* (comprised of *subjective norms* and *attitudes*) as a predictor of *behaviour*. It differs from the theory of reasoned action because it does not assume that the choice-maker has full control of factors affecting behavioural choice (Ajzen, 1991; Adjei and Behrens, 2012). In the theory of reasoned action, individuals have an intention to act on a specific behaviour. This intention is composed of their attitudes – how favourable a person feels the behaviour is – and subjective norms – the social pressure a person feels to act on a behaviour. In the theory of planned behaviour, the new element, *perceived behavioural control*, adds that intention is also affected by an individual's perception of ability to control that behaviour. That is, perceived behavioural control refers to how easy an individual believes it is to perform a specific behaviour (as opposed to material constraints limiting the actual ease or difficulty), which varies across situations and actions and is influenced by past experience and any anticipated obstacles (Ajzen, 1991). This confidence in ability to perform that behaviour influences whether an individual acts on that behaviour.

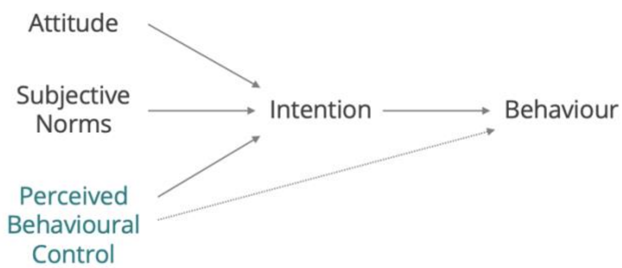

Figure 2.8. Theory of Planned Behaviour. (Adapted from Ajzen, 1991)

In theory, if an individual has limited information across a public transport network, they would more likely make decisions using the services and routes that they have the most knowledge or experience around, and therefore believe would most successfully fulfil their trip purpose. Though the individual may be aware of other services that exist, that individual would not necessarily consider these modes in their journey planning.

The theory of planned behaviour has been applied in transport studies to assess the effect of new information on private to public mode shifts (e.g., Bamberg et al., 2003; Donald et al., 2014), but not explicitly to study the effects of an intervention on public transport mode choice wherein information about the public transport network itself is increased or decreased (e.g., Guillen et al., 2013 investigated commuter dependency on different public transport modes but assumed respondents had complete knowledge of alternatives). Travel mode choice is an action based in reason, and therefore mode choices are affected by interventions that change attitudes, subjective norms and perceived behavioural control (Bamberg et al., 2003). If there is no intervention that affects travel circumstances, past behaviour is a predictor of later behaviour (ibid.). Thogersen (2006) found that transport behaviour for public transport users is less stable than it is for car-owners, which has implications for how receptive a public transport user may be to altering their choices and changing their future behaviour. New information can affect intentions and perceptions of behavioural control so long as it is relevant and persuasive (Bamberg et al., 2003). In a study of factors that effected whether people chose to drive or use public transport to get to work, Donald et al. (2014) found that while attitude, subjective norms and perceived behavioural control all have positive indirect effects on public transport use by influencing intention, perceived behavioural control was the greatest predictor of intention to use public transport. To study how higher quality public transport services might satisfy and thereby retain and attract users, Fu and Juan (2017) combined the theory of planned behaviour and the customer satisfaction theory in an empirical study. They found that satisfaction (expectations compared to perceived experience) precedes attitude – a strong predictor of information use (Farag and Lyons, 2010), and that, with regard to transport, the level of satisfaction is determined by service quality, availability of public transport information, subjective norm, and perceived behavioural control. A user-friendly public transport system leads to increased perceptions of perceived behavioural control, and in turn increased satisfaction with the service. Andersson et al. (2018) applied the theory of planned behaviour to an investigation of ICT to incentivise behavioural change through ICTs and found that to shift travel behaviour, ICTs need to provide content that is both customised and relevant to the user's needs.

Though this doctoral research focuses on captive public transport users, or people without alternative means of private transport, the theory of planned behaviour is important to understanding potential barriers to hybrid system use. To affect intentions and thereby influence behaviour, in the case of this research study – incentivise use of the hybrid system – public transport information needs to be of high quality, accurate, and relevant to users. Moreover, it needs to be multimodal in nature to break down barriers to perceived difficulty of using multiple modes to complete journeys. Within a multimodal system, it is plausible that even captive public transport users exert a level of agency over their mode choice and trip combinations with access to information. In the absence of information, the limitations of individual knowledge and experience restrict the extent that an individual can freely make choices over which public transport journey to take and the degree to which their needs and preferences can be met. Whereas it would follow from the theory of planned behaviour, access to information can enhance an individual's agency and ability to make decisions around public transport journeys that meet their needs and preferences.

2.6 PRIOR MULTIMODAL AND PARATRANSIT INFORMATION RESEARCH

2.6.1 Multimodal Transport Information

Multimodal information, as compared to disparate information on single modes and services, has the most potential for affecting public transport users' behaviour (Grotenhuis et al., 2007; Kenyon and Lyons, 2003). Access to multimodal travel information affects a traveller's ability to make quality choices, which increases with completeness of knowledge and decreases with uncertainty of attributes attached to alternatives (Chorus et al., 2007). Though previous studies have not investigated the effect of hybrid public transport information on use, numerous studies have explored various aspects of multimodal transport information. Studies have used pre-defined information needs to investigate which information types are most important (e.g., Abdel-Aty, 2001), how information preferences vary across different journey planning stages and socio-demographics (e.g., Grotenhuis et al., 2007; Mulley et al., 2017), and the effect of multimodal information on decision-making (e.g., Gan, 2015; Chorus et al., 2007; Skoglund and Karlsson, 2012).

In terms of multimodal information-seeking behaviour, Kenyon and Lyons (2003) investigated whether information on multiple modes can overcome barriers of habit and instrumental-reasoned attitudes towards mode choice and better encourage individuals in seeking, accepting and using information. 'Instrumental-reasoning' refers to the idea that choice makers aim to make decisions that maximise utility, such as choosing the option with the least fare cost or shortest travel time. The assumption is that in limited information circumstances the choice maker is unable to fully weigh the costs and benefits of all the options available and therefore makes choices based on what they believe to minimise costs and maximise benefits. When given full information, the choice maker then may decide that their current journey choice is not the optimal utility-maximising choice and may opt for an alternative they would not have previously considered. While information on a single mode does little to influence alternative travel behaviour, it does facilitate or support usual modal choice (ibid.). However, integrated information on multiple modes accessed at a single source (such as a website) is believed to make information about multiple modes more easily accessible, thereby exposing the individual to multiple travel options with less effort to the individual (ibid.). In turn, an increased awareness of alternatives may influence an individual's perceptions of alternatives, revealing a gap in the individual's knowledge and heightening their awareness of their knowledge limitations in the face of a complex multimodal system (Chorus et al., 2006). Given this, information acquisition may lead to further information acquisition as the perceived benefits of an information search increase.

Importantly, information needs differ based on the stage of the journey (Grotenhuis et al., 2007). People most want to gather multimodal journey information prior to making the journey in order to better plan the journey, but on wayside want information to help them catch the right vehicle, and on-board desire information to help them understand their arrival times at a transfer point to connect to onward travel. These three travel situations are stages where travel patterns can change (Kramers, 2014). Pre-trip, habits can be changed by the introduction of a new variable – such as a new piece of information. During the trip, disruptions to the service will cause a person to alter their journey. Post-trip, the traveller may rethink their trip choices when the daily trip did not meet their utility requirements. As these travel situations and associated information needs are not treated homogenously by users, information needs at various stages need to be treated separately in information research (Mulley et al., 2017).

Related to the concept of multimodal transport information, is the growing idea of thinking not only about information as an integrated service, but the full experience of transport use itself as an integrated experience instead of piecemeal one to reduce cognitive effort around use of publicly available transport modes. MaaS, or Mobility as a Service, is used to varying degrees to describe a transport model wherein users' transport needs are catered to through a single point, such as a technology interface that integrates the physical transport infrastructure with information and data infrastructure (Jittrapirom et al., 2017). What exactly MaaS is is debated, but in their review of existing definitions Jittrapirom et al. (2017) found that MaaS can be thought of as a concept for thinking about differing components of the transport experience as a single experience, a phenomenon that has come about with ICTs, or as a solution to simplifying complex transport services. How MaaS has materialised in reality varies considerably, but some of the core features of these services include aspects such as the integration of transport modes to facilitate multimodal trips, a single digital platform, a tariff option to accessing the services, and the extension of mobility services integrated to include demand-responsive services, amongst other common features (Ibid., 2017). Information integration and provision on various public transport services is just one small, but essential component to enabling MaaS solutions to enter a market (Watkins et al., 2021; Jittrapirom et al., 2017). However the lack of data, particularly in easily formats compatible with one another or with different quality standards, in low-income regions and cities with paratransit acts as a barrier to integrated transport tools and services such as MaaS (Yanocha, Mason, and Hagen, 2021).

2.6.2 Recent Developments into Paratransit Systems User Information and ICTs for Hybrid Networks

The effects of information for enabling hybrid network use are still relatively unknown, which leaves an unanswered question for not only Cape Town's hybrid network but also other cities across the continent that have a mix of scheduled and unscheduled public transport offerings (e.g., Accra, Dar es Salaam, Johannesburg, Lagos). Though research suggests that access to unimodal information on previously unrecorded systems has the potential to improve users' understanding of the transport system and thereby use (e.g., Zegras et al., 2015), the implications of multimodal information for public transport users across scheduled and paratransit systems are less understood. While some of these cities offer multimodal information on their scheduled systems (e.g., the Gautrain website provides separate information on buses and trains in the Gauteng province, South Africa) or even experimented with integrated multimodal information with paratransit systems (e.g., the Gauteng Metropolitan Authority's Gauteng On The Move app), information continues to be in short supply across cities with hybrid networks, potentially limiting the integrated use of the scheduled and paratransit systems.

There is little research that has been conducted to investigate user needs for hybrid networks in emerging cities. The same can be said for the lack of investigation into user needs on scheduled systems. Public transport information is disseminated with the assumption that user needs in the Global South mirror those in the Global North. Public transport information provision in the Global North tends to extend to routes and schedules, fares, trip disruptions and service changes, onboard amenities like Wi-Fi access, disabled access points, and other customer service information like travelling with special items (Halpern, 2021). Research concerning information needs in the Global North has tended to focus on fare and travel time elements, albeit these studies looked at information preferences given existing information provisions rather than gathering an understanding of needs through an open-ended approach (e.g., Chorus, Arentze and

Timmermans, 2007; Maedo et al., 2021; Mulley et al., 2017). For example, based on a pre-determined set of information needs, Grotenhuis, Wiegmans, and Rietveld (2007) found that Dutch respondents most desired information types that reduced information search time and travel time including types such as total travel time, trip alterations and cancellations, and real-time information on delays. However, it is not clear if these same provision requirements are adequate for public transport users in cities with public transport with dissimilar service characteristics (e.g., non-fixed stops and routes), quality of vehicles and operations, or high-crime rates around public transport use (Peters and Bhusal, 2020). Furthermore, public transportation information provisions tend to strictly conform to information captured in General Transit Feed Specification (GTFS) formats (e.g., agency, routes, trips, stop times, stops, and calendar of operations, and optionally fares) or current mobility trends like real-time information. The CoCT's IPTN Business Plan (2017) is an example of these assumed needs driving decisions to implement certain types of ICTs to meet pre-determined information needs. The policy document makes assumptions about the passenger information needed to lend to a more integrated system and enable informed decision-making (i.e., real-time information encompassing fares, routes, modes, total trip time). While no surveys have asked Cape Town public transport users explicitly about their information needs, there have been surveys that asked respondents to rank or rate various challenges related to public transport use that do hint at information gaps (e.g., Teffo et al., 2018; Stats SA, 2013).

In the preparation of paratransit data collection projects, most did not conduct research on user information needs prior to collection, with the exception of a project in Dhaka (Zegras et al., 2015), which collated previous surveys to provide a theoretical list of user information needs. These projects limited the data collected to basic route shapes and stops (e.g., Zegras et al., 2015), and in some cases, the additional frequency, travel time, and fare data needed to create a GTFS file (e.g., Accra Mobility, Digital Matatus, and Transport for Cairo) were collected. Though GTFS is regularly used in journey applications in Western contexts with predominately scheduled systems, without research into information needs, it is important not to conflate the information that GTFS provides with the information that people need to navigate hybrid systems. Information needs may be over and above those that are captured in GTFS files.

Previous data collection projects seeking to map paratransit systems have primarily done these to test data collection methodologies and with the intention that local authorities would likely be the end users of the collected data. The Digital Matatus project aimed to investigate whether mobile technologies could be used to collect data on paratransit systems, and whether this data could be captured and distributed as GTFS, which is typically used by formal transport agencies, or if a new standard would be required (Williams et al., 2015). Because GTFS is a file standard for encoding public transport information, the data collected was limited to the pre-defined GTFS data requirements (i.e., agency, service schedule, routes, stops, stop times, and trips). A final objective of the project was to understand, by making the data openly accessible, who might have use for such data and how it would be used. To accommodate the flexible operations of paratransit, several changes to GTFS were found to be necessary (e.g., continuous stops to compensate for no defined stops). While the data was used by policy and decision-makers in transport planning processes, there was less evidence of commuter demand for the data. Similar to Digital Matatus, the objective of the Accra Mobility was to test smartphones as a methodology for collecting data on paratransit routes in Accra, Ghana and to use this data to aid local transport authorities in regulating and planning the network (Saddier et al., 2016). A data collection project in Maputo, Mozambique limited data collected to routes and stops to create a map that could be used to persuade local authorities to include chapas in local transport masterplans (Klopp and Cavoli, 2017). A secondary goal of this project was to create a readable map for users who might not be familiar with the city or with chapas, and to improve the practicality and image of the minibuses.

Despite a lack of deeper understanding of information needs for journey planning in a hybrid public transport, technological innovations for data collection and information provision for hybrid systems have been growing. Several private and public initiatives have collected data on paratransit systems for transport planning and passenger information purposes, though this data has been largely limited to what was needed to create GTFS files (e.g., Allyrider, Digital Matatus, GoMetro, Jungle Bus, Transport for Cairo, WhereIsMyTransport). Navigation tools aimed at paratransit systems (e.g., Afta Robot, Khwela, Lara, Ma3Route, MyRide) aim to consolidate and provide passenger information on previously unrecorded systems. Very few navigation tools however provide complete and reliable integrated multimodal information across the full hybrid network, offering instead partial information largely in favour of scheduled systems (e.g., GoMetroTransport App, Google Transit, Moovit).

Though the body of literature into the potential of ICTs for responding to information challenges in the Global South is limited, several have explored information provision in relation to perceived service quality of paratransit services finding that current information services inadequately address the needs of users. In Indonesia, Kubota and Joewono (2007) looked at factors influencing user satisfaction with paratransit services to understand how paratransit ridership might be sustained given competitive modal alternatives and found that to improve service quality, operators and the government should invest in improving comfort, customer service, safety and security in addition to the provision of information. Siahaan et al. (2020) investigated paratransit information services specifically, particularly in the context of ICTs as a solution for improving perceived reliability of services through the provision of real-time information. Using questionnaires from ICT-literate paratransit users in Indonesia, they found that real-time information provision could improve service satisfaction and that users would even be willing to pay a minimal fee to access these services to improve their travel experience using paratransit. Tiglao et al. (2020) investigated paratransit users' perceptions of service quality based on seven factors including information given the larger issue of declining paratransit use in Manila, Philippines, and found that of the seven factors explored to explain service quality perceptions, information was one of the factors that significantly affected perceived quality of paratransit services (where information was measured based on visibility of the operator details, signage on the paratransit, and information about available routes). In a study of paratransit in Ibadan, Nigeria, Olowosegun, Moyo, and Gopinath (2021) found that while paratransit service quality was poorly perceived, the services are essential to enabling mobility access and as such warrant governmental support and attention for strengthening its weaknesses.

The sharp increase in penetration of e-hailing services in emerging cities in response to the rise in technology ownership and access to the internet highlights the potential for ICT-based solutions to mobility, such as ICTs for hybrid public transport information, to find ground in emerging cities (Boutueil and Aguiléra, 2019). Particularly regarding users' safety and security and reliability concerns around paratransit services, evidence from the Global South has shown ICTs are a potential avenue to responding to these challenges (Joewono and Kutoba, 2007). Medeiros et al. (2018) found that ICTs have the capacity to influence travel behaviour of paratransit users: as compared to paratransit use without ICTs, ICT-enabled travel positively influenced safety and security perceptions as well as overall satisfaction of paratransit users in Jakarta, Indonesia. Beyond positively influencing perceptions towards services, improved access to information can also impact travel behaviour by exposing travel opportunities. In a study where a bus route map was introduced in Dhaka, Bangladesh, users reported that this information would enable them to access routes that they were previously unfamiliar with and visit new parts of the city (Zegras et al., 2015).

To implement ICT-based solutions to mobility, emerging cities need to have certain conditions in place including that transport operators be willing to share data, potential users are open to use the technology-based services, ICT infrastructure is available to support the system, diverse transport services are already available in the city, and policies and legislations that facilitate the implementation and operations of such a system (Dzisi et al., 2022; Goulding and Kamargianni, 2018). Due to the nature of the splintered ownership and variable operations, integrating paratransit services into information systems with scheduled public transport systems presents multiple challenges. Beyond the aforementioned issue of data availability, how to capture these services as data pieces, given GTFS data standards designed for scheduled, fixed-route services, and ensure the data is reliable is an ongoing challenge (Williams et al., 2015). Furthermore, given the competitive environment where information sharing might jeopardise competitive advantage and lack of trust in governments, paratransit operators are reluctant to transition to formalised and integrated operations (Asimeng and Heinrichs, 2021). In a comparative study of the implementation of an integrated ticketing solution in Souel and Bogota, Audouin and Finger (2018) found that technological solutions targeting integration should be implemented only following system-wide institutional reforms that have integrated the various services that are included in the technological integration implementation. Stakeholder engagement early on in the process of integrating paratransit into technologies and adaptation of these technologies to local conditions is paramount (Behrens, McCormick, and Mfinanga, 2012).

2.7 SUMMARY OF GAPS IN PRIOR RESEARCH

The existing body of literature currently examines hybridity from the view of transport planning and the effects of information provision on complex system use, but these two concepts – hybrid network use and information as an influencer – have not been linked, leaving a gap in knowledge about how information could enable hybrid network use in an emerging city. This is further complicated by inequalities in ICT capabilities that add additional complexity to access hybrid public transport information. Applying the capability approach to ICTs for hybrid networks provides a theoretical framework for investigating this linkage. Though the capability approach has been applied separately to both public transport and ICTs, the capability approach has not previously been used to assess ICTs' potential to enable more equitable mobility through access to information. In transport systems where there is a significant imbalance in publicly available information, such as across a hybrid network composed of dynamic parts, there is a need to better understand how closing the information gap can affect users' access to mobility in hybrid networks, particularly through ICTs that can integrate information across complex systems. The research objectives discussed in the following four chapters explore these gaps in the literature, drawing on the capability approach as a framework to assess access to hybrid information in Cape Town to better understand information needs, information barriers, and how to equitably deliver meaningful information across a hybrid system to public transport users via ICTs.

3. OBJECTIVE 1A: INFORMATION CAPITAL – INTERVIEWS

3.1 INTRODUCTION

This chapter aims to investigate what informational capital is currently drawn on and what information is needed to improve users' ability to use the hybrid network with a focus on objective 1:

> To determine what information users need to facilitate public transport journeys and to understand barriers to hybrid public transport use in the current information landscape.

In line with the capabilities approach, this part of the research starts from a blank slate of information needs as opposed to an evaluation of the importance of information that is currently on offer. Without any prior investigations of user needs in Cape Town or around the hybrid system, assumptions cannot be made that what is currently on offer is sufficient. The chapter opens with a brief literature review of previous research conducted around information needs (section 3.2) before discussing the study design for the semi-structured interviews to gather a comprehensive qualitative understanding of informational capital (section 3.3). The chapter then discusses the findings of the interviews with captive public transport users around their information needs for making combined use of scheduled and unscheduled modes to complete routine and non-routine trips under various scenarios, in addition to sources of information that they currently access (section 3.4). The chapter closes with the implications of the findings and the additional research needed to gain a statistically representative understanding of information needs (section 3.5).

3.2 PREVIOUS RESEARCH METHODOLOGIES INTO INFORMATION NEEDS

While multiple studies investigating ICT interventions for transport have limited their scope to pre-determined information needs (e.g., Abdel-Aty, 2001; Grotenhuis et al., 2007; Farag and Lyons, 2012; Mulley et al., 2017), existing information provisions cannot be taken as sufficient (Lyons et al., 2001). Given that information needs surrounding trip planning entailing scheduled and unscheduled modes have not been investigated, particularly in a heterogeneous transport environment like Cape Town, information requirements need to be reassessed within the context of hybrid systems, to gather a grounded understanding of needs.

A qualitative, open-ended approach allows an understanding of the complexity of needs and reveals needs rather than measuring the importance of predetermined needs. Several studies have leveraged qualitative interviews to gain an exhaustive overview of information needs. Papangelis et al. (2016) focussed on real-time passenger information needs for rural public transport users in Scotland in the event of service disruptions. Through 52 semi-structured interviews with rural passengers, they investigated the effects of service disruptions on passengers and what information passengers require to respond to disruptions. Similarly, in their investigation of information use for pre-trip planning purposes, Farag and Lyons (2008) employed semi-structured interviews in addition to focus groups. This approach enabled them to uncover nuances in differential information-seeking preferences by demographic group.

Furthermore, this research objective is intended to support the third objective's choice model with the identification of information needs for further testing. In their health studies in rural locations in sub-Saharan Africa, Mangham and Hanson (2008) conducted semi-structured interviews and group discussions with health practitioners to determine key attributes for use in their subsequent choice model.

3.3 STUDY DESIGN

The study was limited to captive public transport users, between 18 and 55 years old, who rely on public transport to move from A to B, and thereby may be more sensitive to volatility and travel uncertainties as they do not have access to a private vehicle alternative (Venter, 2016). Choice users were excluded from this study as they have an alternative choice of private means of travel, if their preferred public transport mode does not satisfy their travel needs and would therefore demand a parallel study where the choice to not use public transport would need to be considered.

Heterogenous purposive snowball sampling was used to select participants until saturation was met. Through snowball sampling, initial respondents were recruited through contacts at an office in the Cape Town CBD, including student workers and cleaning staff, who then referred other friends and colleagues to participate voluntarily in the study. Finding saturation is a process wherein further data collection no longer yields new and insightful results (Saunders et al., 2018) and is expected to be met with about 15 to 31 respondents per group surveyed (Mason, 2010). Heterogenous purposive sampling means that while the sampled participants may not be statistically representative of the population, they are qualitatively representative of a diverse range of cases that are relevant to the research objective. As information needs and sources can vary across different users, this sample considered both male and female captive public transport users from all modes present in Cape Town and sought to include both high-tech and low-tech users of each gender. High-tech users are defined as people who have physical, financial and cognitive means to access and use digital transport information and low-tech users are those that do not.

The questionnaire was designed to understand which information captive users might most value in understanding how to navigate the hybrid system, with the emphasis on non-routine trips, by targeting respondents' information needs in three scenarios: weekday work, weekend leisure, and evening leisure (see Appendix A for the ethics clearance and Appendix B for the survey instruments). Questions were designed to present hypothetical situations to respondents, each with new origin-destination pairs (see Figure 3.1 for an overview of areas used in interviews). Destinations were selected based upon proximity to respondents' homes so that the trip would demand transfers and would be unlikely to be one they are familiar with. The questions were intended to be simple and omit discipline-specific words like "mode", "routine", etc. to avoid unnecessary confusion and ensure responses were aimed at the intended question. While questions were specifically worded for each category of intended responses (e.g., information needs under hypothetical, non-routine travel scenarios such as at night or during the day to a new destination), additional questions were asked to expand on respondent replies where needed to clarify the response or to expand on additional points raised about information needs and access. Where a respondent mentioned that they would not need information for a specified scenario, they were prompted to explain why this was the case and the explanations were noted on the response recording sheet and included in the results and discussions section (3.4). Information needs were extracted from responses and organised into the pre-determined information needs categories around which the questionnaire was orientated (i.e., work-related trips both using a non-routine mode and to a non-routine destination, non-routine leisure trips, and non-routine evening trip). Similar information sources were extracted and grouped into ICT and non-ICT sources from the responses.

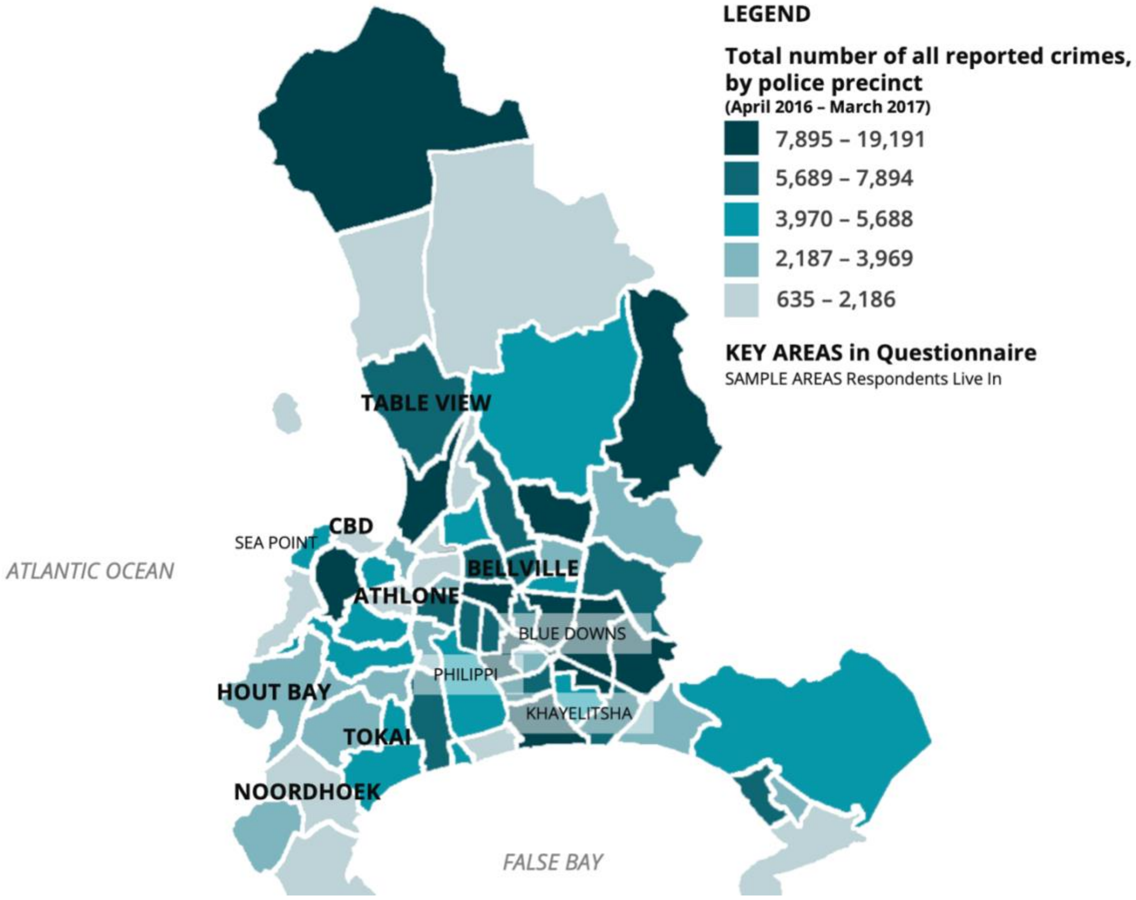

Figure 3.1. Map of Cape Town areas referred to in questionnaire overlaid on crime areas to demonstrate how locations referenced may affect responses.
(Crime map adapted from CoCT (2018c); Note that not all crimes are reported.)

The interviews were preceded with a pilot study to test the survey wording, particularly around transport-specific terminology, and relevance of responses elicited. In the pilot, respondents defaulted to replying that they would use e-hailing services in scenarios with unfamiliar trips, so the questionnaire was adapted to tell people that Uber, Bolt, etc. were all striking to force the respondent to consider how they would use public transport in new situations. Respondents also tended to respond to scenarios with trips that relied on only one mode, although all scenarios were designed to require at least one transfer. Thus, a question was added specifically around what information would be needed to complete a trip using both a MBT and a MyCiTi bus.

3.4 RESULTS AND DISCUSSION

Following the pilot, 22 people were interviewed in November 2018, until no new information around information needs and sources of information cited were revealed. This was confirmed by plotting interviewees in addition to three pilot surveys that followed the final survey design against the number of new information needs and then again against new information sources mentioned, to identify if and when new information types revealed with additional interviews was plateauing at zero (example in Figure 3.2).

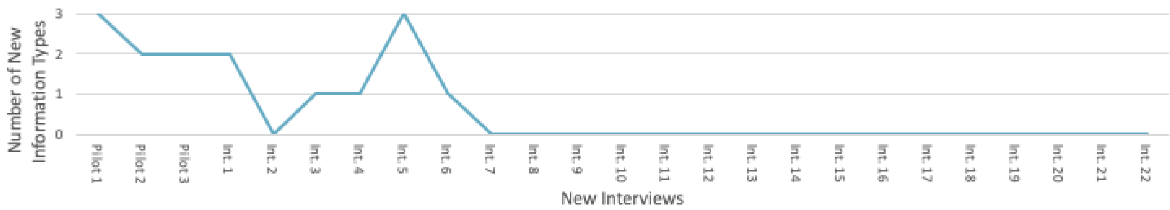

Figure 3.2. Example of Saturation of Revealed New Information Types: Late Evening Trips.

Respondents surveyed came from different areas in Cape Town with varying levels of average household income and crime levels (see Figure 3.1). For example, these areas included the CBD where the average annual household income is almost four times that of the provincial average and ranged to Makhaza in Khayelitsha where the average annual household income is the provincial average of R29,400 (Stats SA, 2011).[1] Respondents ranged in occupation (e.g., students, skilled professionals, and cleaning and security staff) and expressed reliance on different modes covering the four major modes present in Cape Town. While these socio-demographic factors likely influenced the responses of these participants, ensuring respondents came from a breadth of locations was essential to gathering a diverse understanding of information needs. Respondents could mention using multiple modes, and so MBT was listed as a mode used 19 times, Metrorail nine times, GABS five times, and MyCiTi three times. In total 12 female and 13 male respondents were interviewed. Respondents reported a wide range of public transport usage frequency, ranging from less than five times a week (10 respondents) to at least six days a week (three respondents), with the majority (12 respondents) using public transport five days a week. The majority of respondents reported using MBT, but Metrorail, GABS, and the MyCiTi were all cited modes of transport. Frequency of public transport use and the type of transport that respondents were most familiar with using may have impacted users' perceptions of information

[1] Census data is collected every ten years in South Africa making 2011 the most recent year data was collected.

needs around alternative modes as well as their routine mode. For example, respondents coming from areas that are not served or sparsely served by the MyCiTi (and vice versa) were less familiar with MyCiTi use and therefore had different information needs (largely around payment) to those who were familiar with the MyCiTi but not with how to use MBTs.

3.4.1 Information Needs

Information needs expressed by respondents were organised into information types to consolidate specific modal needs (e.g., which taxi do I use?) as a need across all modes (e.g., vehicle-route identifier). An overview of all the information types mentioned in each scenario group is in Table 3.3.

Overall, of the information that respondents expressed needing to plan trips, only information on basic route, fare, stop, and scheduling information was available on scheduled modes. But to even consider these modes viable options, respondents wanted to know about different aspects of safety, such as onboard, while waiting at the stop or station, and the general areas the routes pass through. Non-users of specific modes were confused about payment methods and how to use a particular mode, highlighting the inadequacy of currently available information in clearly explaining these processes to first-time users to bolster confidence. Furthermore, for MBT, respondents wanted to know information other than the usual information that data collection companies gather on MBT routes (e.g., routes and fares). Their information needs extended to where in the rank the right taxi is located and which routes depart from which ranks.

Some general findings that affected stated information needs were as follows. Firstly, respondents with different public transport experiences have different information needs. For example, those with past experience of crime on their public transport trips expressed interest in safety information. Those who are more familiar with how the MyCiTi worked needed more general information about MBTs, and vice versa. Secondly, it was found with probing about intended trips that respondents made many assumptions - from what the relative cost of different travel modes are to what modes may be available where and when - which influenced the information needs they believed they do and do not need. This will be further discussed in the following sections.

Table 3.3. Collective information types desired to plan a trip using public transport in Cape Town with at least one transfer, by scenario.

Information Types	Work Trips	Leisure Trips	Late Evening Trips	Dual Minibus Taxi & MyCiTi Trip
Fare cost	✓	✓	✓	✓
Payment Method	✓			✓
Travel time	✓	✓		✓
Waiting time	✓	✓		✓
Total walking time/distance	✓	✓	✓	✓
Operating times	✓	✓	✓	✓
Departure times	✓	✓	✓	✓
Arrival times	✓	✓		✓
Cancellations, delays	✓			
Route Options	✓	✓	✓	✓
Number of transfers	✓	✓	✓	✓
Transfer/Interchange locations	✓	✓	✓	✓
Stops/landmarks	✓	✓		✓
Safety onboard	✓	✓	✓	
Safety at stop/station	✓		✓	✓
Frequencies	✓	✓	✓	✓
Station/Rank Locations	✓	✓		✓
Which routes depart from which stations/ranks	✓	✓	✓	✓
Modes available	✓	✓	✓	
Vehicle-route identifier	✓			
Vehicle and platform number	✓	✓	✓	
Safety of environment that route runs through		✓	✓	
Safety on walk to/from vehicle			✓	
Seat availability/vehicle fullness	✓			

3.4.1.1 Work/Study Trips: Alternative Modes and New Destinations

Respondents were asked what information they needed to get to their usual place of work/study on alternative modes in the case of a strike and then again in the case of a new work/study location in Noordhoek, Bellville, or Table View.

Respondents tended not to express a need for much additional information on alternative modes to their usual place of work or study as opposed to new work or study destinations. Respondents reported that they were aware of the other options available to them in the event of a strike and that they would have sufficient notice of the strike to make alternative travel arrangements. While respondents did not desire information on spatial aspects of the trip to travel to their usual place of work or study (such as which stop to board a vehicle or transfer locations) as they knew of alternative trips, they did note that departure and arrival time information would be useful as they were less familiar with how the overall travel time of alternative modes impacted their ability to arrive on time. Many respondents living in the Cape Flats and travelling to the CBD mentioned compensating for unknown travel times by leaving two hours in advance to create buffer time.

For those respondents living in parts of the city where only the train, MBT and GABS are available, in the case of a MBT strike, respondents said that GABS would be prevented from operating in the area as well. In this case, respondents would have no choice but to use the train. Some stated that they would not consider the train a viable option due to onboard safety concerns. Others who would consider the train but relied on taxis to access the station, said that walking to the station would not be an option, as they fear for their personal safety walking in their neighbourhoods. Both of these respondent groups said they would likely not attend their study or work that day: "Sometimes you have to miss lessons, that's the reality of it."

In terms of trips to new work/study destinations, spatial and temporal information types were required such as modes available, where to transfer, and trip duration. One respondent specifically mentioned a need to understand her monthly travel costs before accepting a new job offer. She needs to be able to compare longer term travel costs with her salary. This highlights that there might be a larger need amongst users to know options for discounted monthly and/or weekly ticket fare options for regular trips as opposed to the single fares that are largely provided by currently available trip planning tools.

3.4.1.2 Leisure Trips: New Destinations

To assess information needs in leisure trips, respondents were asked to make a Saturday trip to Hout Bay (new destination) in the morning, followed by a trip to Tokai in the afternoon (new origin - new destination pair). Overall, respondents mentioned the same set of information needs as for weekday trips, but arrival time was stressed less and more concern was placed on operating hours because of reduced services on weekends.

Respondents tended to mention that they would need attribute information, like fare cost, but did not recognise that they needed spatially-related information such as which modes serviced Hout Bay or Tokai. Routing information (e.g., which mode to take, where to transfer, etc.) was often not mentioned as required because respondents assumed they knew the best route to take. However, it was clear that routing information would be necessary when the respondents were prompted to describe how they would get to Hout Bay. Some respondents mentioned they would use a train to go to Hout Bay, unaware that there is no train service to this part of the city. Many said they would first go to the main interchange in the city centre, even though there were more direct routes from their homes that would not require going into the city centre at all. One respondent from Grassy Park had been to Hout Bay before and was aware of the more direct route that connected in Wynberg, rather than the CBD. While the routes in and out of the main station in the CBD are well understood, it was clear that the links between smaller hubs in the city are less known to those without first-hand experience of the hub.

3.4.1.3 Late Evening Trips

To assess off-peak evening travel information needs, respondents were asked to imagine a scenario in which they needed to travel home from a mall in a new origin (Tokai) on a Saturday evening at 10pm. Respondents overwhelmingly said that they would call an Uber to get home. When then asked to imagine that all e-hailing systems were striking that evening, respondents mostly gave one of two revised answers: that they would seek information on how to get home from the mall staff or spend the night in the area. In several cases, respondents said that they would not even venture out to the mall if they expected that they would only be returning home after dark. The information needs that primarily arose across both males and females were safety onboard and while waiting for the vehicle to arrive, operating hours to plan ahead the trip back home, and what modes would be available in the evening. Cost was not an issue because respondents believed that they had no alternative choice. In terms of onboard safety information, respondents wanted to know if there were other passengers onboard, particularly women, as a group of men onboard still raises safety concerns. Females on board were noted as a sign that the vehicle was safe to travel on after dark.

Especially for those living in high-crime areas, travelling after dark makes them feel vulnerable to personal attacks and they will avoid situations that would have them travel during those times. One female respondent from Philippi said that travelling by public transport after dark is such a safety risk for her, that she cannot attend evening work functions and therefore feels excluded from such social activities. Her early exits prior to the social events (often beginning around 6pm) are misinterpreted by other employees as a sign of her not wanting to join in and engage with others. While for some public transport users e-hailing is an option to get home, for others this option is unaffordable, thereby restricting what activities they can partake in.

3.4.1.4 Dual Minibus Taxi and MyCiTi Trip

In previous scenarios, respondents tended to assume that they would use only one mode to travel, though all the scenarios demanded at minimum one transfer. This scenario asked respondents to consider their information needs to plan a trip using both MBT and MyCiTi to travel from Athlone to Table View on a Saturday morning.

In this scenario in particular, responses were divided based on respondents' past experiences, especially in MyCiTi bus use. Frequent users of MyCiTi buses tended to need information on transfer locations between the MBT and MyCiTi. One respondent (who is not a regular MBT user) specifically said he would like to know how to minimise travel distance using the MBT to transfer as quickly as possible to the MyCiTi where he felt more comfortable. Respondents who had never used the MyCiTi expressed the most interest in fare related information, particularly how the card and fare system work. One respondent was confused about onboard ticketing which requires users to tap in and out to calculate their distance-based fare, but where the failure to do so results in penalties: "I haven't gone on myself, but I heard you must tap when you get in and tap again when you go out. If you didn't tap when getting out, the ticket is very expensive." Another respondent elaborated that she found the point system confusing. She said she is unclear what these points are, but understands that they are somehow earned: "I heard you can earn points for MyCiTi? Is it like Pick n Pay points? I've seen these stations in town, but I don't know how it works."[2]

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[2] Pick n Pay is a supermarket chain offering a reward-based system where cardholders earn points proportionally to their total purchase and can use points towards future purchases. The MyCiTi point system, in contrast, allows users to load "Mover points" via bulk packages onto their card. These packages offer 30% discounts on trips as opposed to a standard single trip fare, and do not accrue points for ticket purchases.

3.4.2 Information Sources Currently Drawn On

Information sources varied across scenarios, gender and respondents' preferred mode of transport. Respondents tended to rely on the same sources in different scenarios. Collectively, the information sources mentioned included both technical, paper-based, and word-of-mouth sources (see table 3.4). And yet regardless of access to technical sources or not, trip planning was mostly piecemeal relying on unimodal information sources, done from station to station. One respondent summed it up as "if you want to plan for all the facts, you might never end up going anywhere" because of the lack of information accessible from home. While recorded information may be available for the scheduled modes in Cape Town, it is not always up-to-date and reliable, and certainly not for MBT. This makes it difficult to plan multimodal trips without reassessing or gathering new information on the go.

Table 3.4. Consolidated information sources accessed in Cape Town across all scenarios.

ICT sources	non-ICT sources
Toll-free number	Interchange/rank personnel
Friends (phone)	Word of mouth
WhatsApp (friends)	Other passengers
WhatsApp group (transport-specific group)	Bus or minibus-taxi driver
Social Media: Facebook	Staff (non-transport workers)
Social Media: Twitter	Security/police
Website	Kiosks at station
Mobile app	Notice board at rank/station
	Map at station/stop

Where piecemeal planning was necessary due to multimodal information limitations, respondents would rely on a mix of ICT and non-ICT sources. Particularly in scenarios where respondents felt that they would need to use GABS or MBT to complete the journey (such as late in the evening after the train and MyCiTi services stopped running or in certain areas of the city), most respondents would rely on non-ICT sources. They overwhelmingly mentioned asking the bus or minibus taxi driver directly to source information on MBT and GABS, including those respondents who would use technology to source information on the other modes. Not everyone felt comfortable with asking though, saying that asking around too much in foreign places could attract the wrong kind of attention. However, nearly everyone said they would ask mall staff for advice on how to get back home in the late-night scenario – again because reliable recorded information is limited. In terms of apps, Google Maps was the predominant mentioned mobile app, but mainly by regular MyCiTi users to lookup information on MyCiTi buses. Only two females (both over 40) mentioned relying on toll-free call centres to get advice on GABS and Metrorail trips.

Though piecemeal planning was often cited, that is not to say, however, that there was no appetite expressed for multimodal trip planning, but rather that MTI and IMTI sources are limited in the journey planning advice they can offer. Respondents younger than 40 overwhelmingly mentioned Google Search as a tool for finding information, whether it be to find the websites of official operators or to search for specific questions to see if anyone has previously shared tips online. One respondent summed up the reliance on Google as, "Google is my friend. You can ask Google anything." Respondents said that they would draw on their personal networks as a major source of information for journey planning, primarily tapping into these using mobile devices. While many use WhatsApp as a way to reach out to friends for advice, other social media channels were less cited. Only one respondent mentioned Facebook as a useful channel. For him, sharing a question on his Facebook status with his social network about how to get from A to B is one of the quickest ways to get information on public transport.

Social media has become not only a source for finding basic journey planning advice, but also to get real-time notices on otherwise unreliable information. An example of how public transport users have collectively adapted to unreliable information using a social network is a private WhatsApp group – “Game of Trains” – made up of both Metrorail drivers and frequent passengers. One group participant says she actively relies on the group’s updates to inform her daily trip. There are many messages coming through on the group during peak times, so she looks at them while on her taxi on the way to the station before she waits at the platform. If she sees that her train will be quite delayed, she can still make the decision to use a bus. For example, one message on the group that morning of the interview was "219 Wynberg" (with a timestamp) which means that there is currently a train at Wynberg station and it is heading away from town. (Odd numbers mean away from town and even numbers mean going to town.) That kind of message is enough for her to estimate how long it might take the train to reach her station and further estimate when she can expect to arrive at her final destination. However, while the group has provided her access to valuable information, the information comes at a cost. Though the group has a policy that participants cannot send photos or videos, she says that even so the messages still take up a lot of data. This data cost issue was raised by several respondents as a barrier to accessing information via mobile-based journey planning tools.

A final point is language as a barrier to information access – an issue that arose through the process of conducting the interviews in English and a review of recorded information sources where it was found that almost all are in English. In many parts of Cape Town where car ownership is low and there is likely to be higher reliance on public transport, English is not the predominant language spoken at home - Xhosa and Afrikaans are. Information sources in multiple languages may be useful for non-native English speakers. This was highlighted when one Xhosa-speaking respondent pointed out that there is a toll-free number she calls into to ask for information on GABS and that, importantly, it is in multiple languages including Xhosa.

3.5 NEXT STEPS

Information needs for planning multimodal hybrid trips are extensive and range beyond information currently publicly offered. Safety was continuously raised as a concern across all scenarios, often posing as a barrier to travel by public transport entirely when the respondent's modes of choice were not available. This is not surprising given the prevalence of concerns in other surveys. The most recent National Household Travel Survey from 2020 reveals security concerns are present across all modes, with less than half of Metrorail users satisfied with security while walking to the station, while waiting at the station and onboard the train, as an example (Stats SA, 2021). Such surveys support the interview findings that in the face of lack of information to the contrary, safety concerns are potentially a barrier to public transport use. Given its prevalence, further research is needed to disentangle safety and security concerns to understand how information can aid users in accessing the hybrid network.

Planning a hybrid trip that involves at least one transfer in Cape Town reliably is generally difficult given the current information and sources available. Not one respondent said that they would look at multiple sources to consider whether a combination of modes would result in a favourable trip for them to a new destination as opposed to a unimodal trip. However, there does seem to be an appetite for multimodal trip planning, as several respondents mentioned using multiple modes to complete a trip and asking for advice within their social networks or extended networks for trips requiring a transfer. To more simply communicate the information that people need to make a multimodal trip, integrated information could be a way forward. However, given that limited IMTI sources do exist in Cape Town and have not gained in popularity, further research needs to be done into what means of communicating recorded IMTI are most appropriate given captive users' capabilities to access these means. A dual understanding of information needs and appropriate sources to gather information will provide a step towards better delivering accessible public transport information on the hybrid system.

While the purpose of the interviews was to gather a comprehensive list of information needs, the findings are not necessarily representative of each individual users' information needs. That is, not all users will find the list of information needs in its totality important to their decision-making in the hybrid network. Equally, such a long list would be unrealistic to gather the necessary data on to provide each point of information, especially if only a small proportion of the captive public transport user population finds certain types useful. A more statistically representative understanding of information needs is required to narrow down and focus the set of information needs to better understand what information captive public transport users need to make multimodal travel decisions that meet their individual needs using any of the modal alternatives in Cape Town and how best to deliver that via technologies such that the information is accessible. The following chapter builds on this chapter's objective in that a representative understanding of the most useful information needs for planning a hybrid public transport journey is sought.

4. OBJECTIVE 1B: INFORMATION CAPITAL – BEST-WORST SCALING

4.1 INTRODUCTION

This chapter builds on the comprehensive information needs found through the semi-structured interviews in Chapter 3 to lend a statistically representative understanding of the relative importance of the identified information needs amongst captive public transport users. Compiling a short-list of information needs is essential for Chapter 6's choice model. This chapter opens with a literature review of best-worst scaling as a method to obtain a deeper understanding of the relative importance of information needs (section 4.2). The following section (4.3) outlines the survey design and discusses the decision to separate information needs into spatiotemporal and organising types for the purposes of further investigating informational capital. The subsequent modifications to the survey design based on the pilot studies to reduce cognitive burden in understanding the phrasing used to describe information needs are detailed (section 4.4). The most and least useful information needs found through the surveys are presented (section 4.5) and the decision to take forward a subset of these for further analysis is discussed (section 4.6).

4.2 LITERATURE REVIEW

For the purposes of prioritising information needs gathered from the interviews prior to conducting the choice models in objective 3 (Chapter 6), a best-worst scaling (BWS) survey was used to gain statistically representative insights into weighted information needs amongst captive public transport users. As opposed to presenting a list of several items to rank in order of least to most important where respondents may struggle to distinguish preference between items that they have a more neutral opinion towards, BWS reduces cognitive burden and asks respondents to make choices based on extremes (Teffo et al., 2019; Potoglou et al., 2011). This survey technique was proposed by Jordan Louviere as a method requiring respondents to select the most and least important attributes from a set of choices (Teffo et al., 2019). The idea behind this is that given repeated choice tasks, respondents' choice frequencies will give an indication of how much those choices are valued. There are three different study designs that a BWS survey can take (for more information on these designs see Louviere et al., 2015). The one used for the purpose of this research is case 1 analysis, or the object case, and uses a list of objects. Briefly, case 2 analysis, or the profile case, creates profiles from attributes (e.g., 'Vehicle Type: Bus', 'Operator: GABS', 'Fare: $1') whereas case 3 analysis, or the multi-profile case, is similar to a choice experiment in that it uses at least three profiles, from which respondents select best and worst profiles (e.g., 'Vehicle Type: Bus *OR* Train *OR* Taxi', 'Operator: GABS *OR* PRASA *OR* UBER', 'Fare: $1 *OR* $0.15 *OR* $5').

In transport studies, the best-worst scaling approach has been used in understanding areas such as public transport needs (e.g., Teffo et al., 2019, Sañudo et al., 2019), barriers to mobility (e.g., Irlam and Zuidgeest, 2018; Larranaga et al., 2018), and attitudes towards public transport (e.g., Beck and Rose, 2016; Echaniz et al., 2019). While transport information has not been addressed directly per se, studies have applied best-worst scaling to information preferences in other disciplines, such as to identify consumer preferences for food information (e.g., Lui et al., 2018; Price et al., 2016).

4.3 SURVEY DESIGN

A balanced incomplete block design is used to construct the survey. Each item is shown a minimum of three times per block (or choice set), presented the same number of times across all the blocks, balanced orthogonally such that each item appears equally frequently with the other items, and balanced positionally to avoid order bias (Louviere, 2015). To calculate the number of choice sets, the following equation (1) can be used (from Teffo et al., 2019):

(1)

$$(c \times s)/I = r, \qquad r \geq 3$$

Here r represents the number of times that an item is shown in a single survey, c is the total number of choice sets needed, s is the number of times an item appears in a single choice set, and $items$ is the number of items to be tested in the survey.

The items used in this survey were derived from the information types identified in the previous qualitative interviews. From the original 24 information types, eight were excluded (delays and cancellations were later separated into two distinct information types) as they were considered basic spatiotemporal information that determine whether or not specific modes are available to use between an origin-destination pair. The basic information types identified include (1) operating times, (2) route options, (3) transfer/interchange locations, (4) stops/landmarks, (5) station/rank locations, (6) which routes depart from which stations/ranks, (7) modes available, and (8) cancellations. Spatiotemporal specific information is something that users must have to plan a trip to a new destination. From the qualitative interviews conducted for objective 1, it was observed that respondents overwhelmingly assumed they knew the spatiotemporal attributes of different modes in Cape Town and therefore did not acknowledge a need for these attributes, even though based on their answers of how they would get to a new destination it was clear they had limited understandings of the modes actually available. Instead, the focus in this survey is on the attributes that organise spatiotemporal information and help respondents match trip options with their individual needs and preferences, e.g., fares (cheapest trip), travel time (shortest trip), and safety while waiting.

Thus, in the final survey administered for the purposes of this research, a total of 17 items are included, each item is shown at least three times, each choice set includes four items, and 13 choice sets are given to each respondent. Due to safety issues concerning tablet-based surveys, paper and pencil surveys were used and a survey pack with eight variations was generated using Sawtooth Software's MaxDiff software, with differing combinations of choice sets. Each item appeared at least three times in each survey, and due to an uneven number of items, each of the eight survey variations had one item that appeared four times. Questions were also included to assess respondents' public transport use, age, sex, suburb of residence, and technology ownership (see Appendix C for the ethics clearance and Appendix D for the survey instruments).

For the best-worst scaling scenario question, unlike the previous qualitative interviews that broke down information needs by scenario to gather a comprehensive list of information needs, a single general question was posed with an unspecified new destination but with the condition of completing the trip using a minibus taxi and at least one other mode. This was used because in practicality information will likely not be communicated via ICTs on specific scenarios (e.g., separate information sources for weekend evening trips vs. daytime commutes).

4.3.1 Analysing BWS results

To determine which items were selected as more useful relatively to other items, an average best-worst score was calculated which uses the equation (2) below (adapted from Teffo et al., 2019):

(2)

$$\emptyset_i = B_i - W_i \qquad \forall_i \in I$$

$$\widetilde{\emptyset}_{avg.i} = \frac{\emptyset_i}{\sum_{i=1}^{n} S_n \times s_n} \ \forall_i \in I$$

For each information type i, $\emptyset_i$ is the raw score calculated by the total number of times the information type was selected as most useful (B_i) minus the total number of times the information type was selected as least useful (W_i). This is calculated for the full set of items I. To obtain the average-best worst scores, $\widetilde{\emptyset}_{avg.i}$, these individual scores are each divided by the respective times that they appeared in total across all surveys, where n is the number of survey variations (in the case of this research there were eight), S is the total surveys given of each variation and s is the number of times each item occurred in each survey variation.

4.4 SURVEY DESIGN THROUGH PILOT STUDIES

Three versions of the survey were piloted using three different ways of posing information needs to see which version was phrased most clearly (see Table 4.1). Survey Version A and B were piloted first and then, based on feedback, Version C was devised. For Survey Version A and B, 24 respondents in low-income areas in Cape Town were surveyed in the mornings of the 15th and 22nd of February 2020 at public transport interchanges in Dunoon, Mitchells Plain, and Khayelitsha. As only 16 information types were initially included, these surveys each had 12 choice sets. Survey Version A used information phrased as types (e.g., fare cost) and Survey Version B used information phrased as questions (e.g., How much will the trip cost me?). The consensus from the surveyors was that using the survey with information needs structured as questions is easier for participants to understand. However, discrepancies between the results of the two surveys were observed particularly in regard to information needs around payment method, walking distance, travel time and vehicle-route identifiers. Furthermore, information types such as fare cost and travel time had lower results than expected. A few things might have happened: (1) there may be non-negotiable information needs like safety that may play a hard *no* into whether a person considers using a specific vehicle or not; or (2) respondents may have assumed that they know information such as fares and travel time and therefore did not report needing information on such information types.

Table 4.1. Piloted Versions A, B and C wording variations.

Version A	Version B	Version C
Fare cost	How much will the trip cost me?	What is the cheapest travel option?
Payment method	How do I pay for the trip?	What are the different fare payment options?
Waiting time	How much time will I spend waiting?	Which option has the shortest waiting time?
Walking distance	How far do I need to walk?	Which option has the least walking?
Travel time	How long will it take me to get there?	Which option has the shortest travel time?
Vehicle departure time	What time does the vehicle leave?	Which option departs closest to the time I want to leave from home?
Vehicle arrival time	What time does the vehicle arrive?	Which option arrives closest to the time I want to arrive at my destination?
Number of transfers	How many times do I transfer?	Which option has the least transfers?
Vehicle fullness	How full is the vehicle?	Which option's vehicles are the least full?
Safety onboard	How safe am I onboard the vehicle?	For which option am I the safest onboard the vehicle?
Safety at a stop/station	How safe am I waiting at the stop or station?	For which option am I the safest waiting at the stop or station?
Frequency – how often the vehicle departs	How often does the vehicle come?	Which option's services run most frequently?
Where in the station/rank does the vehicle depart	Where in the station or rank does my vehicle depart?	Where in the station or rank does my vehicle depart?
Which vehicle to take	Which vehicle should I take?	Which is the right vehicle for me to get on for my destination?
Safety on the route that the vehicle goes through	How safe is the area that the vehicle goes through?	How safe is the area that the vehicle goes through?
Safety walking to and from vehicle	How safe am I walking to and from the vehicle?	For which option am I safest walking to and from the vehicle?
-	-	Are there delays on the route?

Survey Version C was designed (see Figure 4.2) to rephrase the items respondents choose from as a question around options (e.g., What is the cheapest travel option?). While the scenario question was designed to inform respondents that they have multiple choices, respondents may have continued to assume they know certain attributes about their trip like fare cost, travel time, etc. These assumptions were mitigated through reiterating in the choice items themselves that there are multiple travel options with different associated attributes. Additionally, "Which vehicle should I take?" was reworded to make it clearer that this is about vehicle-route identifiers (e.g., the 113 MyCiTi towards Adderley). 'Delays' was added as an additional information type as this does not strictly affect spatio-temporal information the way cancellations do and affects other attributes along the route such as waiting time and travel time.

Most Useful	Question	Least Useful
	Which option has the least transfers?	
	Which option arrives closest to the time I want to arrive at my destination?	
	Which option has the least walking?	
	What are the different fare payment options?	

Figure 4.2. Example of a BWS question in Survey C.

Survey Version C's pilot was delayed to the weekend of 23-24 May 2020, over three months after the initial pilots due to regulations regarding COVID-19 that made it impossible to conduct in-person surveys. The survey had to be rephrased to accommodate disruptions in travel and travel information needs, namely by asking respondents to consider their responses to the questions given pre-COVID-19 travel and work conditions. While 'imagining normal conditions' may present some difficulties for respondents, posing the scenario as a hypothetical is not unheard of in the methods that are regularly used, such as stated preference questionnaires, to pose hypothetical scenarios in the South African context (e.g., Plano et al., 2020). Some anticipated biases due to heightened health concerns and changes in public transport operations due to lockdown, that were thought to possibly nonetheless come through the responses, were increased desire for vehicle crowdedness information, increased need for reduced number of transfers to reduce interpersonal contact, and information related to disrupted operations such as frequencies and routes. Conversely, other information types may have been deprioritised, such as information specific to trains like delays, because trains were not running under Level 5 and 4 lockdown conditions.[3] As lockdown regulations prevented non-essential workers from travelling, an additional question asking respondents to state their occupation was added to the survey to ensure that a variety of people and travel habits were captured similar to who would have participated prior to lockdown.

From a third pilot involving 72 participants (equal male/female split) conducted at the public transport interchanges in Dunoon, Mitchells Plain, and Khayelitsha, the resulting positive average-

[3] Under Level 5 conditions of 26 March to 30 April 2020, only essential workers could travel to work by public transport. All others could not leave their homes and use public transport except to buy essential goods or access essential services. No travel was permitted between the Cape Town metropolitan area and outlying areas. Public transport vehicles could only operate during limited hours (05:00 to 09:00 and 16:00 to 20:00) and with only 50% of their carrying capacity. The only public transport that could operate were GABS, MyCiTi, and MBTs. Under Level 4 of 1 May to 31 May 2020, only essential workers could travel to work. Public transport vehicles operated between 05:00 and 19:00, and MBTs could only carry 70% of their capacity. Buses could only carry 50% of their capacity.

best worst scores were similar to the previous pilots in that safety related information needs came out as most useful (see Table 4.3). There was variation in least useful information across the three surveys. From the pilot, none of the anticipated biases due to lockdown came through with the exception of delays which was found to be one of the least useful information types. However, this might also be due to the overall decline in train passenger numbers seen prior to COVID-19 and less interest in considering the train for travel overall, as opposed to current restrictions on train travel. From around 2009 to 2020, passenger volumes have been dropping 15% annually (Onderwater, 2021). The final version used for the full-scale study was Survey Version C as respondents had an easier time understanding the item wording format compared to the formats in versions A and B. An additional choice set had to be added to accommodate the increase in items, but according to feedback from the surveyors, version C's length did not negatively impact the time it took to conduct the survey.

Table 4.3. Average best-worst scores for the three pilot results.

Information Type	Avg. B-W Scores, $\widetilde{\emptyset}_{avg.i}$		
	Version A	Version B	Version C
Sample Size	*24*	*24*	*72*
Fare cost	-0.264	0.000	-0.009
Payment method	-0.569	0.000	-0.394
Waiting time	-0.083	0.000	-0.120
Walking distance	0.042	-0.194	-0.302
Travel time	-0.181	0.111	-0.022
Vehicle departure time	-0.069	0.083	0.107
Vehicle arrival time	0.125	-0.028	0.250
Number of transfers	-0.417	-0.361	-0.138
Vehicle fullness	0.014	-0.111	-0.213
Safety onboard	0.625	0.542	0.204
Safety at a stop/station	0.528	0.681	0.329
Frequency – how often the vehicle departs	-0.375	-0.097	0.133
Where in the station/rank does the vehicle depart	-0.250	-0.181	-0.171
Which vehicle to take	-0.111	-0.431	0.111
Safety on the route that the vehicle goes through	0.542	0.444	0.111
Safety walking to and from vehicle	0.444	0.514	0.301
Delays	-	-	-0.176

4.5 FINAL SURVEY RESULTS

The final, in-person survey based on Version C's phrasings was conducted between the 17th and 25th of June 2020 at the major public transport interchanges in Bellville, Cape Town, Khayelitsha, Mitchells Plain, and Wynberg and the Khayelitsha Mall (see Figure 4.4 for overview of survey locations). Due to on-going protests at the MyCiTi stations, Dunoon was removed from the survey areas for the safety of the surveyors and to avoid bias in respondents sampled, as fewer MyCiTi users would be expected.[4] Following a review of previous sample sizes used, the target sample size was a minimum of 400 respondents, split evenly by sex. Sample sizes used in prior best-worst scaling research ranged in the hundreds, where Teffo et al. (2019) sampled 290 people with a 50-50 split by sex and split by six locations to identify public transport needs, Larranaga et al. (2018) sampled 390 people in 14 areas in a Brazilian city to identify barriers to walkability, Hinz et al. (2015) sampled 251 people in an electric vehicle adoption survey, and Beck et al. (2017) sampled 204 people in an electric vehicle choice study. Cheung et al. (2016) surveyed applications of BWS in healthcare research and found that the median number of people sampled for Case 1 analysis was 150.5, with a minimum of 25 and maximum of 603 participants.

Of the resulting 416 surveys conducted, three were discarded as they were from respondents outside of the 18 to 55-year age range. In all, 212 females and 201 males participated, with an average age of 30 for participants, skewed right towards younger participants, which does reflect the age distribution in the Western Cape which is skewed towards the younger age groups (Stats SA, 2019c). Of the respondents, 50% were between 18 and 29 years of age, 37% between 30 and 39, and 13% between 40 and 55. Seventy-nine people (19%) were surveyed in Bellville, 88 (21%) at the main Cape Town station, an additional 24 (6%) at both the Adderley Street and Civic Centre MyCiTi stops, 66 (16%) in Khayelitsha, 64 (15%) in Mitchells Plain and 68 (16%) in Wynberg. The MyCiTi stops in Cape Town CBD were included to capture more MyCiTi users to increase the share of these users who were underrepresented at the other survey locations. In terms of current mode use, 81% of respondents reported using MBT, 37% use GABS, 11% use MyCiTi, and 6% use Metrorail (compared to 27% who reported past Metrorail use). Respondents reported living in a diverse range of suburbs across Cape Town, with the majority (roughly 82% depending on how the area is defined) living in the Cape Flats. Respondents answered questions pertaining to current

[4] Dunoon is a township in the north-western part of Cape Town. Following the demolition of shacks, protests for housing at Dunoon affected MyCiTi operations as buses and a station were set alight in June 2020. Several MyCiTi stations and routes were affected and had to be rerouted.

and past modal use, basic demographics, and ICT ownership in addition to the 13 best-worst survey questions.

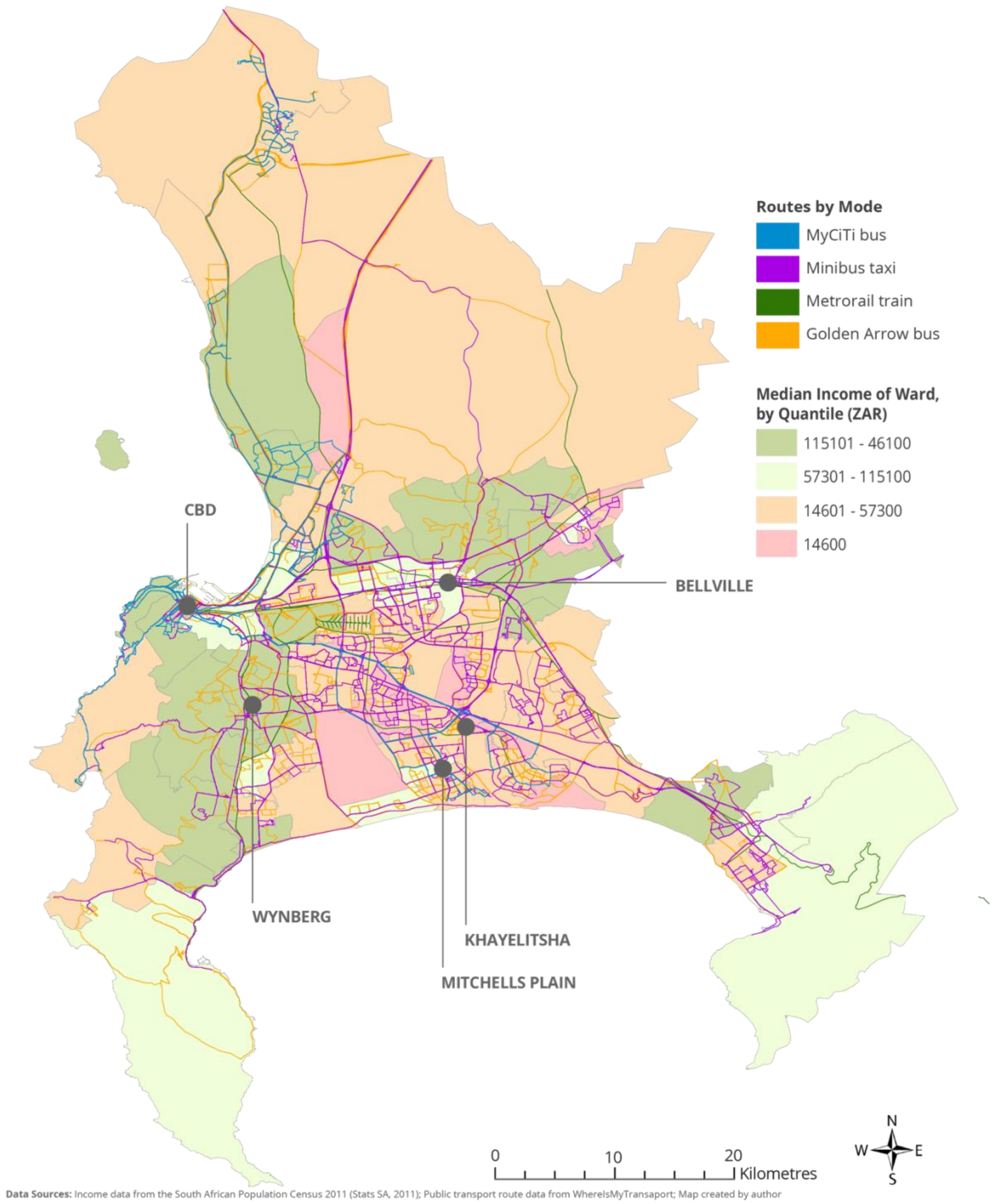


Figure 4.4. Public Transport Interchange survey locations overlayed on map of public transport routes and median income distribution by ward in Cape Town.

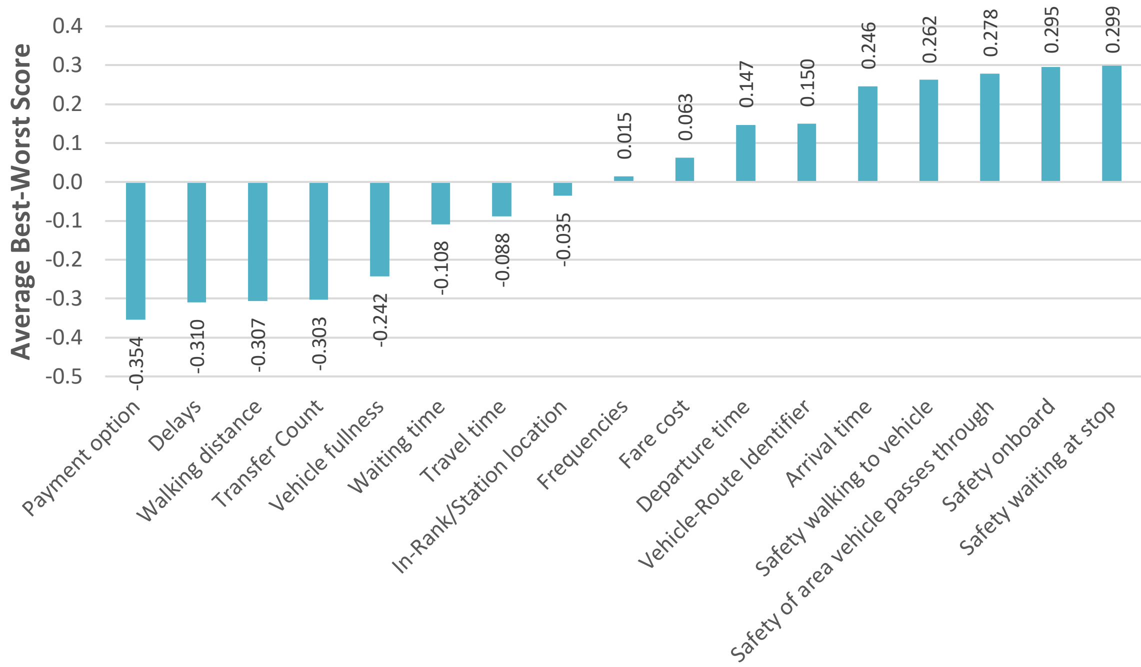


Figure 4.5. Overall average best-worst ($\widetilde{\emptyset}_{avg.i}$) scores across all respondents for information types $\boldsymbol{i}$.

As seen in Figure 4.5, all safety-related information types had the highest positive average B-W scores, followed by arrival time, vehicle-route identifier, departure time, fare cost, and frequencies. These types with positive scores were then the attributes included in the subsequent choice model study in objective 3. In order of smallest to largest negative average B-W score were payment option, delays, walking distance, transfer count, vehicle fullness, waiting time, travel time, and in-rank/station location of vehicle departure. Information on delays, waiting times, and travel time were perhaps not as important when given the option to receive departure, frequency, and arrival times, as these information types, if in real-time and not the scheduled times, would capture delay information. Worth noting is that all information types related to safety and arrival time were clustered towards the most useful information types. When segmented by sex, these five types had little variation in their B-W scores. One thought on this - preconceived notions of what people know and do not know may have affected how they perceived the value of certain information. For example, fares or frequencies might be something that people feel confident they are familiar with, despite the non-routine scenario posed, or perhaps are less sensitive to. Users may be more sensitive to safety and arrival information, which also may be perceived as less certain attributes of a journey. Given the qualitative interviews, where safety concerns were such an issue that respondents stated that without safety information they would not take a journey, the high scores for the safety related information are logical.

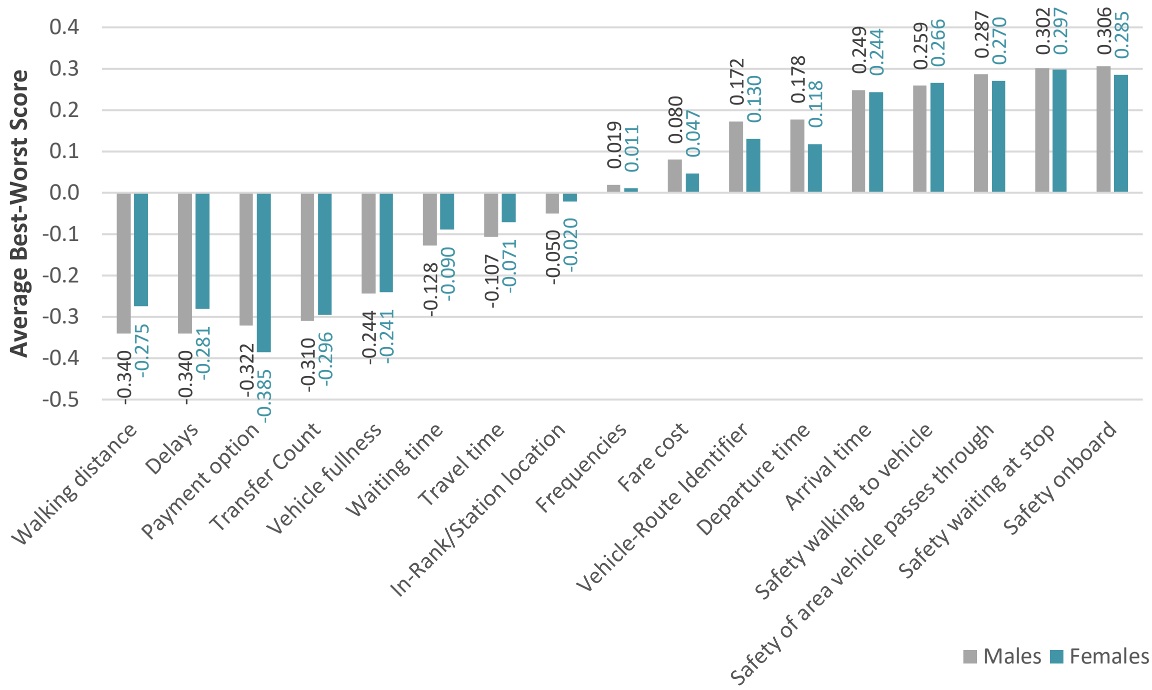


Figure 4.6. Average best-worst ($\widetilde{\emptyset}_{avg.i}$) scores by male and female respondents per information type $\boldsymbol{i}$.

Finally, a two-sample T-test was used to test whether there is a difference in the means of the information types between male and female respondents (shown in Figure 4.6). Given the results found in Table 4.7, at a 95% confidence interval (t=1.968), none of the means for the information types between male and female respondents significantly differ. Perhaps most significant, due to not showing any statistical significance, is that the null hypothesis could not be rejected for variation in average best-worst scores between men and women regarding safety-related information. While public transport safety is often framed in popular discourse around gendered dimensions (e.g., Sonke Gender Justice, 2018; Vanderschuren et al., 2019), the results of this study suggest that safety-related information is sought regardless of gender.

Table 4.7. T-test describing variance of means between men and women for each information type, α = 0.05, df = 411.

Information Type	Two-sample T-test			
	Difference	t (observed value)	|t| (Critical value)	p-value
Departure time	-0.401	-1.661	1.968	0.098
Vehicle-Route Identifier	-0.356	-1.04	1.968	0.299
Payment option	-0.296	-0.835	1.968	0.404
Fare cost	-0.238	-0.396	1.968	0.693
Safety waiting at stop	-0.132	-0.362	1.968	0.718
Safety onboard	-0.113	-0.242	1.968	0.809
Safety of area vehicle passes through	-0.1	-0.234	1.968	0.815
Arrival time	-0.064	-0.237	1.968	0.813
Safety walking to vehicle	0.068	0.174	1.968	0.862
Frequencies	0.089	0.201	1.968	0.84
Transfer Count	0.142	0.733	1.968	0.464
Vehicle fullness	0.159	0.839	1.968	0.402
In-Rank/Station location	0.178	0.821	1.968	0.412
Walking distance	0.179	1.018	1.968	0.309
Delays	0.261	0.858	1.968	0.392
Travel time	0.299	1.16	1.968	0.247
Waiting time	0.324	1.571	1.968	0.117

4.6 NEXT STEPS

For the purposes of forming recommendations for improving the informational capabilities of captive public transport users in Chapter 7, a subset of the information types included in the BWS surveys are taken forward in the research. For the choice model in Chapter 6, literature recommends keeping the number of attributes (in this case information types) to a minimum (Arentze et al., 2003). To reduce cognitive burden, only a subset of the information types is used as attributes which will be discussed further in Chapter 6, section 6.4.3. As the results for the BWS data showed no difference between information needs across males and females, a subset of the information types with the highest B-W scores across all respondents are those considered in the choice model's attribute selection.

A potentially contentious point is that just because respondents have stated that they believe specific information types are the most useful to them, might not necessarily imply that the information types that received low or negative B-W scores were useless. Whether or not a person desires and seeks information, depends on how informed they believe they are versus how informed they would like to be (Lyons et al., 2019). BWS survey respondents may have presumed to have knowledge about certain information types and therefore were biased in believing that those information types were less helpful to them then information they believed they knew less about. However, they may be equally ill-informed on the information types they found to be least useful as for those they found to be most useful. For example, fare information had a very low score close to zero, however in qualitative interviews it was clear that people had biases around fares across different modes and also could not possibly know the fares of an entire public transport system which works largely on a pay-per-distance basis. While this means that we might not be testing the complete set of information types that people may actually want to know *if they were aware their perceived notions might be incorrect*, we will, on the other hand, be testing information that people have demanded and therefore might seek to actually access.

5. OBJECTIVE 2: ICT CAPABILITIES

5.1 INTRODUCTION

The purpose of this part of the research is to investigate objective 2:

> To determine users' ICT capabilities within the context of hybrid network-related travel information.

This chapter therefore focusses on investigating the level of access and skills users have to use different ICT infrastructures as related to travel information and, where possible, trends in access levels overtime. This entails a two-part approach involving secondary data analysis and primary data collection to fill outstanding knowledge gaps.

The chapter opens with a literature review of the trends in the digital divide as a question of material access and individual barriers to use, before focusing on how capabilities have been investigated within the context of transport information (section 5.2). This leads to a discussion of the digital poverty framework which is applied to the secondary data analysis and to ICTs for transport information in the primary data analysis (section 5.3). The findings in trends around ICT ownership, internet access, and ICT capabilities based on secondary data analysis are presented (section 5.4) followed by the primary data analysis of ICT capabilities specific to captive public transport users (section 5.5). The chapter closes with a synthesis of both the primary and secondary data findings and where these findings inform the subsequent chapters surrounding informational capabilities (section 5.6).

5.2 LITERATURE REVIEW

Inequalities and inequities in access to ICTs and skills to use these technologies have been largely studied through the concept of digital exclusion, or the digital divide (van Dijk, 2006). Research into the digital divide can be broken into three levels of study: physical access, social constraints and opportunities, and capabilities to use ICTs (Ragnedda, 2017).

Initially, research mainly focussed on the digital divide as a material access problem where there are those with physical access to the infrastructure needed to be digitally connected and those without (e.g., Castells, 2001). In South Africa, physical access to ICTs has been evaluated in the context of socio-economic development (Lewis, 2013) particularly with a view towards access to improved education (e.g., Oyediran-Tidings, 2021; Asongu and Odhiambo, 2019). Data around access to material resources such as ICT ownership, internet penetration, data affordability, etc. tended to be used in the analysis of this type of research. While information was taken as an essential good everyone needs material access to (van Dijk and Hacker, 2003), early research tended to overlook the role of social and cultural capital in selecting, processing, and situating information within an individual's own context (Bornman, 2016).

Studies have turned to understanding the digital divide within the context of social inequalities (e.g., gender, age, income, education), looking at why, despite theoretically having access to technologies, individuals may not use them (e.g., Hargittai and Hinnant, 2008; Bornman, 2016). Using the South African questionnaire surveys conducted by Afrobarometer in 2008 and 2011, Bornman (2016) investigated the general impact of demographic, socio-economic and cultural factors as barriers to ICT access, despite widespread mobile phone ownership in South Africa. This research found that there is a large discrepancy in internet and mobile phone access, with gaps particularly apparent between population groups, gender, and education levels. Males tended to use computers slightly more than females, and White people used computers more than Black people. Those with tertiary qualifications indicated a much higher percentage of daily computer use than those with some or no schooling. Similar trends were noted in internet usage. However, widespread access to mobile phones was observed, though this trend did not extend to mobile access to the internet. May (2012) similarly sought to understand how ICT access may be a predictor or inform other measures of deprivation through research involving secondary data analysis of multidimensional measures of poverty in East African countries. May found that financial (e.g., per capita monthly expenditure) and human capital (e.g., formal education) largely determine inequities in ICT access. Access to ICTs has also been studied from the perspective of access as a predictor of ability to use ICTs. From their study of determinants of ICT fluency using data from 1237 university students in East Africa, Niyigena et al. (2020) found factors like computer ownership and whether the person comes from a rural or urban area were major predictors of individual ability to use a computer. However, these various studies did not go into depth to unpack 'ability to use' to understand to what extent individuals benefit from access to and use of ICTs.

Most recently, the discussion around the digital divide turned to capabilities, or the potential benefits technology use can provide and the uneven capacities of individuals to tap into these benefits. Access to ICTs is not enough to result in advantageous outcomes. ICTs need to be considered within their global and local context to ensure that intended beneficiaries are able to access and use them advantageously (Volkow 1995). This extends beyond infrastructure to a consideration of the capabilities of individuals to ensure that they can access, assess, and apply information to expand their opportunities (Alampay, 2006; Heeks, 2000). This focus on capabilities shifts the narrative away from the inputs (e.g., material access and individual barriers to ICT skills) mitigating the digital divide, to a focus on the benefits achieved through digital inclusion. This shift in focus to capabilities emphasises the consequences of a continuing digital divide – of those who are capable of expanding their opportunities through digital access and those who are not.

Analysis around the benefits of technology moves away from focussing strictly on values like internet penetration rates and socio-demographics (e.g., gender) to focus on observable outcomes directly or indirectly obtained through use of ICTs (e.g., employment, access to healthcare) (Ragnedda and Gladkova, 2020). Gender, income, education level, age, and available infrastructure are often included and studied as predictors ICT capabilities (World Bank, 1998; UNDP, 2001).

In South Africa, this discussion of digital inclusion as an assessment of capabilities has primarily come from the health sector to understand how digital health information has translated into enhanced capabilities (e.g., Hampshire et al., 2015; Cilliers et al., 2018; Ruxwana et al., 2010). Hampshire et al. (2015) conducted in-depth interviews to understand the impact of education, livelihoods, healthcare, political and religious life, etc. on phone use to access forms of healthcare together with descriptions of general phone use over the prior two days. This was followed by a questionnaire survey to understand patterns of phone use and potential differentiators of use like gender, age, and rural-urban residence. Cilliers et al. (2018) sought to understand the demand for information, or hypothetically expanding ICT capabilities. They studied this from the perspective of behavioural intention to adopt ICTs to fulfil a desired outcome (e.g., access health information) using a cross-sectional survey to gauge perceived usefulness, perceived effort, social influence, attitudes towards technology, and mobile phone experience amongst a sample of 202 university students. Ruxwana et al. (2010) similarly studied variables approximating acceptance and ease of use of ICTs to gauge potential uptake of new ICT-based solutions using questionnaire items and interviews around perceptions and perceived barriers to ICT use.

Methodologically, several studies in South Africa have investigated ICT capabilities either through observation and interviews (e.g., Jiyane and Mostert, 2010) or questionnaire surveys (e.g., Fasasi and Heukelman, 2017 employed a self-assessment of ICT skills level on a Likert scale). Both Jiyane and Mostert (2010) and Fasasi and Heukelman (2017) relied on subjective self-assessment of one's own ICT skills, though Jiyane and Mostert (2010) also used observation to validate some of the responses. Fasasi and Heukelman (2017) compiled a list of items to describe e-skill capabilities and used Item Response Theory to assess whether questions around capabilities on the questionnaire were answered honestly (for more on this theory see Hays et al., 2000).

However, starkly missing from the research into ICT capabilities is a deeper understanding of individuals' ability to use transport-related information. Studies conducted in the Global North have indirectly linked ability to use ICTs to access travel-related information and the influence of this information on travel choices. Hong et al. (2020), through a study in the United Kingdom, found that increased mathematical literacy has the potential to improve access to the Internet and positively increase a person's travel behaviour. Line, Jain and Lyons (2011) indirectly explored people's ability to understand travel-related information via ICTs through a study in United Kingdom on the influence of ICTs on the everyday life of young participants. Their finding that technologies enable participants to better accommodate fluctuating events and uncertainties in activity and travel scheduling while still engaging in activities, reveals the capacity to productively use travel-related information. Likewise, Ben-Elia's and Avineri's (2015b) review of studies surrounding information and travel behaviour finds that people are able to make use of travel information to cope with uncertainty in transport systems thereby indirectly illustrating individuals' capabilities to use ICTs to influence their travel choices. Though perhaps in contrast to regions where information in different formats is widely available and familiarity with interpreting travel information is high, the widespread ability to understand public transport information cannot be assumed for regions where certain populations have little to no access to recorded public transport information and therefore experience in interpreting various formats. Surveys conducted internationally or in Cape Town have not yet assessed people's ability to meaningfully use ICTs nor surveyed people's use of ICTs to access travel information. Furthermore, research into individuals' ability to understand travel information more generally is lacking.

Certain forms of communicating travel information like route maps, require specific skills to use. To illustrate the skill complexity required, take the example of route maps. Both MyCiTi and Metrorail utilise visual maps to communicate their routes. In several existing ICTs (e.g., Google Maps, GoMetro Move), maps are an essential feature in delivering information. Map-reading through these apps requires a cognitive process referred to as survey mapping. This is where an individual uses a cartographic map to inform their cognitive map (Lobben, 2004). In contrast, without a map, individuals rely on environmental mapping, whereby the individual gains route knowledge through experience moving through an environment without a map (ibid.). Using a map to navigate requires two processes: visualisation and self-location (ibid.). Visualisation is the ability to mentally transform a 2-dimensional map into 3-dimensional form to transpose the map onto reality. Self-location is the ability to locate a real-world location on a map using clues on that map that represent real-world components. Little research has focused on the ability to read and use public transport maps in South Africa, and instead looks at map literacy more generally. While map skills (e.g., spatial orientation and map reading) are a required part of the South African school geography learning curriculum, teaching and learning around mapwork skills has been poor (Ahiaku, Mncube, and Olaniran, 2019; Larangeira and van Der Merwe, 2016). Though ICTs may be used to provide transport information, not only may ICT capabilities be a barrier to the use of digitally communicated transport information, but also the skills that transport information itself demands may pose barriers to use.

To understand the complexity of ICT capabilities as they relate to individuals' ability to benefit from transport information, the concept of digital poverty is applied. Digital poverty, a term popularised by Barrantes (2007), conceptualises these three levels of the digital divide as inequities in capabilities along a digital access and skills spectrum. According to Barrantes (ibid.: 30), digital poverty refers to "the lack of goods and services based on ICTs." Four primary determinants influence an individual's digital poverty level: education, age, ICT supply, and use of ICTs. Those with more education are thought to be less likely to be digitally poor, whereas the older an individual is, the less technologically savvy they might be. Those with older equipment will also be considered to be less digitally wealthy than a person with access to newer ICTs. Barrantes separates out ICT skills by the functionality an individual achieves, i.e., whether an individual uses ICT passively or actively. An individual who uses ICTs to passively receive information or stream content (e.g., watch videos or play games) is considered to be less digitally wealthy than an individual who actively uses ICTs to interact with and create digital content.

In her master's thesis, Allen (2018) applied Barrantes' concept of the Digital Poverty Framework (DPF) to her analysis of the potential contribution of ICTs to the urban poor's wellbeing in South Africa using the *RIA ICT Access Survey 2017-18* household dataset. Based on access to ICTs and use of ICTs, Allen (ibid.) created a method of quantitatively applying the framework to five categories of digital poverty. These categories were:

- **Extremely digitally poor:** neither own a mobile phone nor have used the internet before
- **Digitally poor:** own a basic phone, but never used the internet
- **Passively connected:** own internet-enabled phone, and use the phone in a passive way (e.g., daily use of information-receiving based apps)
- **Mildly active:** own internet-enabled phone, and use the phone for active use of internet, but only weekly or occasionally
- **Digitally wealthy:** own internet-enabled phone, and use the internet daily

Using this structure, Allen was able to categorise South African urban respondents into groups by digital wealth, finding that 16.2% could be said to be extremely digitally poor, 18.7% are digitally poor, 1.4% are passive, 51% are mildly active, and 12.8% are digitally wealthy. This implies that while individuals can access internet-capable phones, this access does not necessarily equate to capabilities. Limitations in access to the internet prevents individuals from realising the full potential of ICTs. This level of analysis that Allen was able to achieve through her methodology is relevant to the research objective at hand as it concerns itself with an individual's ability to use ICTs to tap into information as opposed to rudimentary infrastructural-oriented questions like ICT ownership and internet penetration. An adaptation of this type of analysis is used in subsequent secondary and primary data analysis in this chapter.

5.3 METHODOLOGY

5.3.1 Digital Poverty Framework to Assess ICT Capabilities

Both primary and secondary data were used in this research to investigate ICT capabilities with further analysis of secondary data to investigate how these ICT capabilities may trend over time. The DPF methodology was applied to limited secondary data where enough variables exist to draw a general picture of the greater population's ICT capabilities, and to the primary data collected through surveys to understand specifically ICT capabilities in relation to transport information within a captive public transport user group.

These DPF levels were informed by Allen's (2018) levels but modified to allow for variation across datasets in response fields and survey methodology. For example, while the *RIA ICT Access Survey 2017-18* household dataset has information on respondent's use of different mobile app types, the *2011-12* dataset does not. Instead, the *2011-12* dataset has data on use of the internet for different use cases (e.g., sending or receiving an email). Furthermore, though all respondents replied to the questions concerning mobile phone ownership, not all responded to the internet and app-use related questions.

Table 5.1. DPF categories for secondary data analysis.

DPF Category	Mobile Phone Ownership	Mobile Phone Type	Mobile App Usage: Passive Use	Mobile App Usage: Active Use	Restricted Internet Use
Extremely digitally poor	No	-	-	-	-
Digitally poor	Yes	Basic	-	-	-
Passively connected	Yes	Feature/Smartphone	Yes	No	-
Actively connected	Yes	Feature/Smartphone	-	Yes	Yes
Digitally wealthy	Yes	Feature/Smartphone	-	Yes	No

The DPF categories were defined based on the variables as shown in Table 5.1. These categories were used in both the secondary and primary data analysis (though lightly modified in the latter as explained in the primary data results section).

Passive and active use of digital technologies were defined as the difference between information-receiving and consumption uses of ICTs versus generating content and engaging with ICTs. The use cases are shown in Table 5.2 for calculating the DPF categories of the general urban South African population using the *RIA ICT Access Survey* household datasets for 2011-12 and 2017-18.

Table 5.2. Passive vs. active use of ICTs for secondary data analysis.

Use type	Application	Use Cases
Passive Use		
	Informational	News, weather, search tools
	Entertainment	Games, entertainment
	Text-based communications	Voice, messaging
Active use		
	Economic	Business, trading, transport
	Social	Social networking, dating
	Self-education	Educational, health

To calculate the passive and active use cases of technology as related directly to transport information, a different categorisation of passive and active use cases to that used for the general secondary data analysis was needed. The following Table 5.3 takes the categorisation approach of Table 5.2 whereby passive use encompasses informational-search and consumption use cases, and active use comprises use cases of direct engagement with information.

Table 5.3. Passive vs. active use of ICTs + transport information for primary data analysis.

Use type	Application
Passive Use *(reading + searching for information)*	Searching for information online
	Sending a message using WhatsApp, Messenger or similar messaging service
	Making a phone call
	Uploading a photo or file to an email, message or other application on a phone or computer
	Communicating with others via social media
	Installing mobile applications on your phone
	Understanding a route map, like MyCiTi's or Metrorail's
	Understanding a timetable for departures and arrivals
Active use	
	Using an e-hailing application like Uber or Bolt
	Transferring money on a mobile banking app like Capitec or Absa
	Making an online payment
	Following verbal navigation directions
	Following written navigation directions
	Using Google Maps or a similar navigation tool to get directions
	Locating your current location on a paper map
	Locating your destination on a paper map

5.3.2 Data Sources

Data used in the analysis were drawn from both primary and secondary sources. While secondary sources provide an overview of general population ICT capability characteristics, there was not enough existing data to make a claim about captive public transport users' ICT capabilities regarding transport information. Therefore, further data collection was necessary to specifically investigate transport-related use cases of ICTs.

5.3.2.1 Secondary Data

Secondary data was used to construct an understanding of ICT and internet capabilities and access trends over time, particularly for public transport users. Given that ICT ownership rates and device types are changing yearly and could affect how information could be packaged in dynamic formats, gaining an understanding of ICT access trends helps to better anticipate how packaging needs may change in the next few years. Secondary data was drawn from the following sources. In Cape Town, several surveys were conducted that assessed access to ICTs and some even crossed over to ask travel-related questions. Research ICT Africa (RIA), a non-profit research entity focused on ICT access and use in African regions, collected extensive data for the *RIA Household and Small Business Access and Usage Survey* on ICT use and demand across households and businesses across thirteen countries, including South Africa, in 2017-18 and 2011-12. While these RIA datasets offer a far more detailed insight into ICT capabilities (e.g., model of phone, mobile data affordability), the data is not disaggregated beyond a country-wide and urban level. The South African Audience Research Foundation's *All Media and Product Survey* (AMPS) offers data collected at a metropolitan level, with detailed data on cell phone and internet access, though the most recent dataset dates to 2015. The *General Household Survey* (GHS) has consistently collected data at a provincial level up to as recently as 2020 and spanning back to 2002, with questions around access to ICTs and internet included in the surveys since 2009 and refined in the following years' surveys.

5.3.2.2 Primary Data

To understand barriers and facilitators to the use of public transport information-related ICTs, a survey was used to gather feedback on self-reported abilities (see Appendix E for the ethics clearance and Appendix F for the survey instruments). Respondents were asked to state their ICT ownership, access to mobile data and internet, and ability to use ICTs to access and understand different types of transport information packaging (e.g., interactive map versus chat group). Questions entailed real examples of travel information formats in Cape Town and were measured on a Likert scale with an option to state total unfamiliarity with the example format. These questions were informed by previous surveys including the *2017 South Africa General Household Survey* and the *2011-12 Research ICT Africa ICT Access Survey*. As this research objective seeks to understand what public transport information formats different user types can understand, the outcomes of this objective's research were not needed for the development of the third method (the investigation of informational capabilities). Therefore, these additional questions were included in the choice model surveys in the third methodology, where a large representative sample of captive public transport users was sought. Demographic variables included in the survey to assess potential inequities to ICT capabilities were age, gender, race, and language.

These questions were piloted in the last week of November 2020 with 144 respondents, sampled from the main public transport interchanges in Cape Town CBD, Bellville, Mitchells Plain, Wynberg and Khayelitsha. The final surveys were conducted from May through August 2021 at four public transport interchanges: Khayelitsha Site C, Cape Town Station, Bellville, and Mitchells Plain. Respondents were intercepted at these locations and pre-screened to ensure they were between 18 and 55 years of age and captive public transport users. The sample size was determined in part by the number of respondents needed for to obtain statistical representation for the choice model component of the survey and to obtain statistical significance at the 95% confidence interval and ±5% margin of error. Using Cochran's sample size formula (see Cochran (1953) for more information), a sample size of roughly 400 respondents is suggested. To account for surveys that potentially would need to be disqualified, a total 576 respondents were surveyed. Of these total surveys, 40 were removed from the analysis because they contained blanks to ICT-related questions, leaving 536 for the final analysis, of which 265 respondents were male and 271 were female.

5.4 SECONDARY DATA RESULTS AND DISCUSSION

5.4.1 Digital Poverty Levels

The digital poverty levels from Tables 5.1 and 5.2 were applied to the secondary datasets, *RIA ICT Access surveys 2011-12* and *2017-18* (see Table 5.4 for results). RIA's *Household and Small Business Access and Usage Surveys* include data on mobile phone and internet use on households and individuals, aged 16 and older, across multiple African countries including South Africa. The data was filtered to only include respondents living in urban areas in South Africa. This meant 1086 respondents for the 2011-12 data and 1050 respondents for the 2017-18 data were included in the digital poverty analysis. Since in both datasets some respondents did not respond to the internet or mobile app-based questions, the percentages for the passively connected, digitally connected, and digitally wealthy categories were normalised so that all respondent numbers were assessed proportionately on the same scale. Household attributes related to gender, age and race were not included in the public 2011-12 dataset and only partially included in the 2017-18 version, and thus segmented analysis was omitted.

There is a discrepancy between the 2011-12 and 2017-18 datasets for the categories 'actively connected' and 'digitally wealthy.' This is likely due to the changes in the way the questions assessed internet restrictions. Not only did the 2017-18 survey have a far more extensive list of possible limitations to internet use respondents could agree or disagree with, the 2017-18 survey also explicitly asked whether respondents had no limitations to internet use at all. For the 2011-12 data, no restrictions to internet use had to be inferred by the lack of a respondent agreeing that one of the pre-defined limitations was applicable to them.

Table 5.4. Digital poverty across the general urban South African household population for 2011-12 and 2017-18. (Based on data from *RIA 2011-12* and *2017-18*)

DPF Category	2011-12	2017-18
Extremely digitally poor	13%	12%
Digitally poor	36%	28%
Passively connected	1%	3%
Actively connected	29%	47%
Digitally wealthy	21%	9%

Regardless of this discrepancy, between the two timeframes, there was growth in the combined actively connected and digitally wealthy categories and a decline in the proportion of those considered to be digitally poor. The proliferation of more affordable smartphone options has likely enabled a steady growth in the number of individuals who have access to technology to get online.

5.4.2 Digital Access Trends

The following secondary data analysis provides an understanding of trends in access to different ICTs and the potential barriers to ICT use. The following results and analysis drew on three data sources detailed in the following section. The trends are organised by category and were analysed using the combined results of these various datasets to get a deeper understanding of the trends than one dataset might allow.

5.4.2.1 About the Datasets

The *General Household Survey* datasets from 2013 to 2020 included households across all provinces in South Africa and includes information on household characteristics and individuals' characteristics. A subset of this dataset was used to focus analysis on the smallest unit possible, the Cape Town metropolitan region in the Western Cape province, and to include only respondents who indicated that they had used public transport in the last week. It should be noted that the data was collected via in-person interviews with the exception of the 2020 dataset which due to the COVID-19 pandemic entailed telephone interviews.

RIA's *Household and Small Business Access and Usage Surveys* from 2017-18 on households and individuals living in urban South African locations was used. The most recent survey, 2017-18, asked the most extensive questions regarding mobile phone access. The 2017-18 data included 615 South African respondents in urban areas without household access to a working car or motorcycle. Since no public transport usage data was available, non-car ownership was used as a proxy for public transport use. Though this may have skewed the data to include non-motorised transport captive users (e.g., pedestrians) who may be of a lower-income profile than captive public transport users.

The *All Media and Products Survey (AMPS)* for 2015 collected demographic data on households and ownership and usage of products and services across the four major South African metropolitan areas (SAARF, 2019). For the purposes of this analysis, only responses from the Cape Town metropolitan region and non-motorised vehicle owners were included, which for 2015 came out to a total of 492 respondents.

5.4.2.2 Access to ICT Ownership

Data on access to ICTs reveals that mobile phones account for the largest ownership share as opposed to landline telephones or computers which only a small percentage of households reported having access to (see to Figure 5.5). Of all the households surveyed, 93% reported having access to at least one mobile phone, with about 1.6 mobile phones on average per household that does have a mobile phone (RIA, 2020). Only a small percentage of households have access to working computers, laptops and tablets, but a far larger portion has access to radios and TVs.

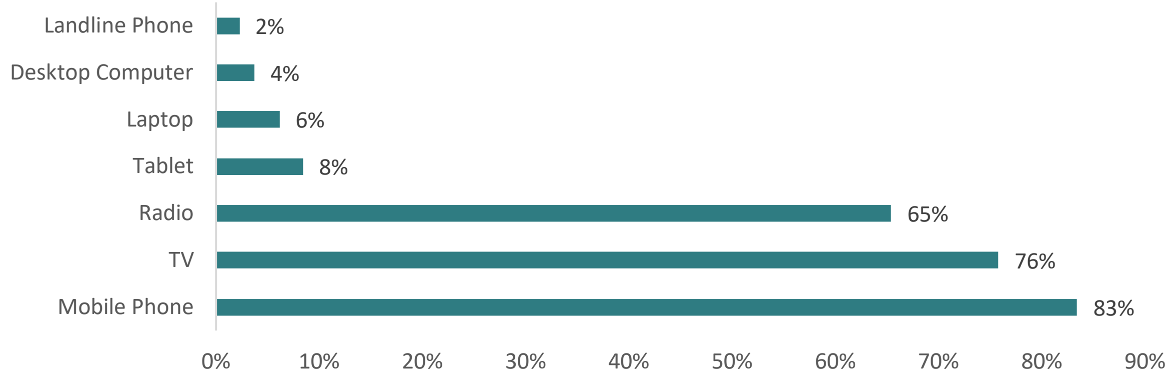


Figure 5.5. Access to technologies across urban South African households.
(Based on data from *RIA 2017-18*)

These are country-level statistics that are on par with the Western Cape statistics from the *General Household Survey*. According to GHS, almost all households who used public transport at least once have access to a cell phone.

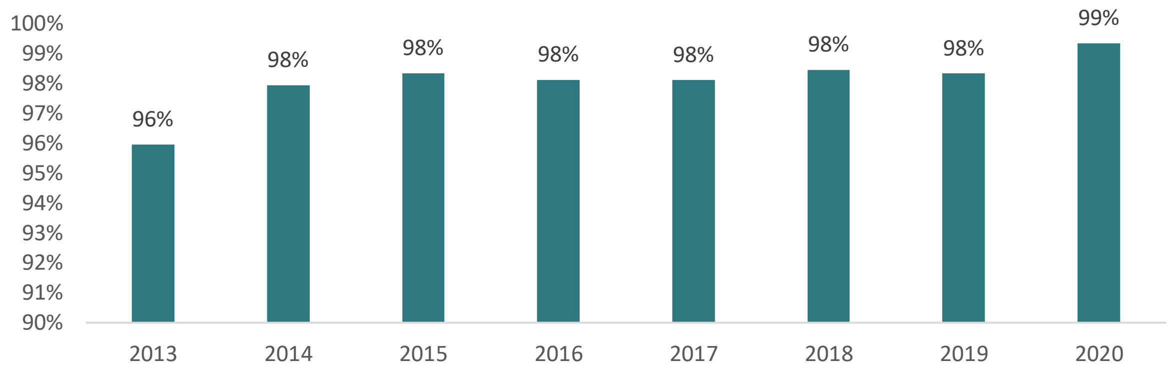


Figure 5.6. Percentage of households that used public transport at least once and have access to a cell phone.
(Based on data from *GHS 2013* through *2020*)

Given that these percentages across the two survey datasets are similar, we can assume that the breakdown of type of mobile phone ownership at a national level is likely to reflect a similar breakdown at the Cape Town metropolitan level. As seen in Figures 5.6 and 5.7, of households with mobile phone access, an approximately equal number of households have basic phones as have smartphones, and only 9% have feature phones (RIA, 2020). Households who wanted a smartphone, but chose not to obtain one, reported the main reason being expense (48%) followed by finding such phones too complex to use (15%), while 33% reported having no need for a smartphone (RIA, 2020). According to AMPS 2015, the majority of people who own a phone but do not own a car, have Samsung phones (37%), followed by Nokia (27%), Blackberry (27%), LG (6%), and Apple iPhones (2%) (SAARF, 2019). That means that the most popular operating system used by non-car owners is Android.

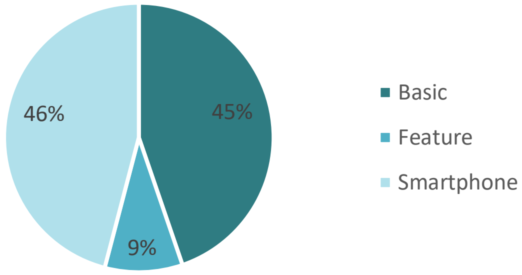


Figure 5.7. Type of mobile phone owned by urban South African households. (Based on data from *RIA 2017-18*).

5.4.2.3 Access to the Internet

Overall, across households in the Western Cape, there is a positive trend for access to mobile internet. As seen in Figure 5.8, there was essentially no change overall in access to internet via school or work. There was a decrease in change in access to home internet in 2019 and 2020, which may be due to a change in the public transport commuter type (GHS 2013-19). It is possible that as the quality of the Metrorail service decayed over recent years, those who could afford to use private means or alternative modes of transport did so (Heyns and Luke, 2018). The 2020 data was captured from September to December 2020 when there was a shift to working from home which would have also impacted the commuter type to represent more lower income users whose jobs demanded regular commutes to work and may not have access to expensive, and limited home internet. Hence, when the datasets are filtered for people who have used public transport recently as a proxy for public transport users, the datasets from recent years likely contained a higher proportion of captive users.

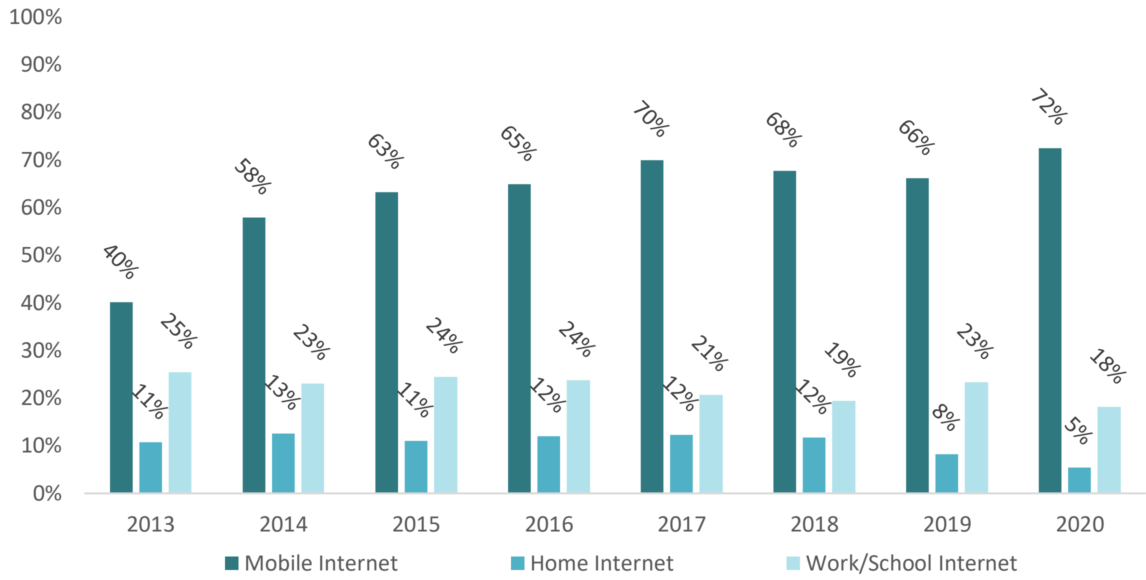


Figure 5.8. Percentage of Western Cape households that have used public transport at least once and have access to internet, via mobile phone, via home, and via school/work. (Based on data from *GHS 2013* through *2020*)

Similarly, this modal shift and change in commuter type might explain the recent upward trend (see Figure 5.9) following a downward trend in the proportion of public transport users who do not have access to internet via any of the major means (e.g., fixed at home, via mobile phone at any point, or at their place of work or education) (GHS, 2013-20). Once again, the data from 2020 stands out likely because of the dramatic shift in commuter type due to the impacts of the COVID-19 pandemic on public transport use and shift to work-from-home.

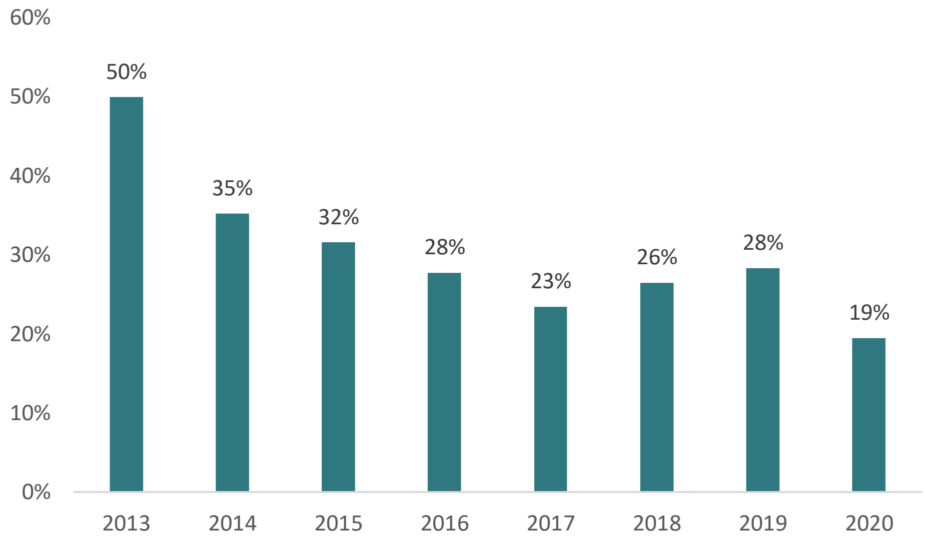


Figure 5.9. Western Cape households that have used public transport and do not have access to internet via home, work, school, or mobile phone. (Based on data from *GHS 2013* through *2020*)

In terms of internet usage amongst urban South Africa respondents, the main reported barriers to access to internet in a household were the unaffordable cost of the service, cost of the equipment, and lack of knowledge to use the internet (RIA, 2020). In terms of limitations to use of the internet, the most common limitation was expense followed by slow internet speeds (ibid.). Only 16% of respondents said they had no limitations to their internet use (ibid.).

5.4.2.4 Barriers to ICT Ownership and Use

Though access to mobile internet data may in theory be possible via a feature or smartphone, high mobile data costs can pose a barrier to mobile phone use. According to the RIA 2017-18 data, a third of urban South African households without access to motorised vehicles and who own a smartphone reported that the cost of data prevents them from using their phone more (ibid.). To save on mobile phone data charges (see Figure 5.10), 38% of these respondents indicated that they wait for internet use until they have access to a public Wi-Fi area. Cost of airtime to make calls prevented a further 29.2% of households from meeting their mobile phone needs. A larger share of households with access to basic phones found the cost of airtime to be problematic to their phone use, with 52.6% citing this as a barrier. Only 19.1% of basic phone and 16.5% of smartphone owning households did not report any barriers to their mobile phone use.

The high expense of access to mobile internet and airtime is magnified by the type of service provider plans these households have access to. Of those who own a mobile phone, 98% rely on prepaid, pay-as-you-go, SIM cards (ibid.). These prepaid options tend to be more expensive than contract rates. Mobile data contract plans are restricted to those who can provide proof of a stable monthly income and bank statements, which makes such plans inaccessible especially to informal workers. Because of this, low-income mobile phone users in particular rely on expensive prepaid data plans or out-of-bundle data. Across the two largest mobile networks in South Africa, in 2019, prepaid prices were consistently more expensive than contract prices for data, with up to 1000% difference for 10GB through Vodacom as an example ("Massive difference", 2019). Out-of-bundle rates are even higher than prepaid data bundles, where rates per megabyte are five times greater than in-bundle rates (Vodacom, 2020). In South African cities, readily available fibre and broadband tend to be restricted to higher income areas, leaving internet connectivity options in low-income areas limited to mobile data. The lack of widely available public Wi-Fi exacerbates the dependency on mobile data in urban townships (Phokeer et al., 2016).

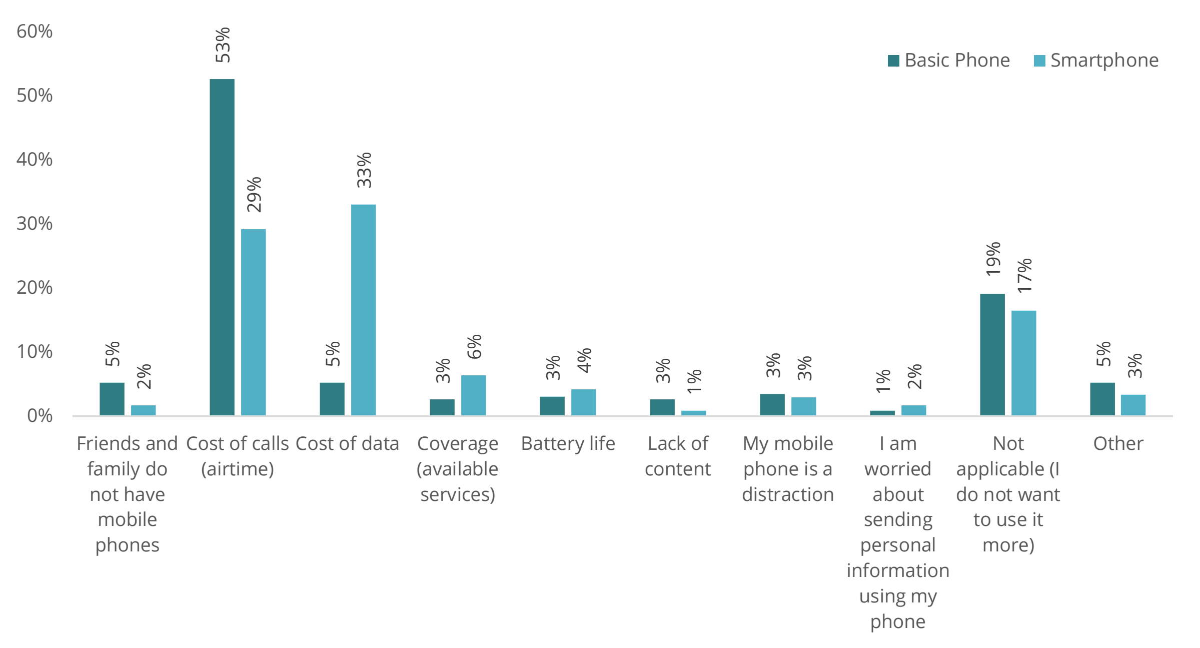


Figure 5.10. Limitations to smartphone/basic phone use. (Based on data from *RIA 2017-18*)

5.4.2.5 City of Cape Town Household Travel Survey 2020

While a subset of ICT-related questions that were in the primary data surveys was also included in the City of Cape Town's *2020 Household Travel Survey*, the travel survey was not completed due to COVID-19 disruptions. The two ICT questions that were included were household ICT ownership and access to the internet at various locations. Data collected was limited to 1975 households, 1,582 of which were in macrozones with enough completed surveys to lend to statistically representative findings of those specific areas (Umtha Strategy and Planning, 2020). These macrozones are Langa, Ottery-Parkwood, Browns Farm, Khayelitsha Village 3 North, Lotus River, Fish Hoek-Noordhoek, and the Deep South (see Figure 5.11).

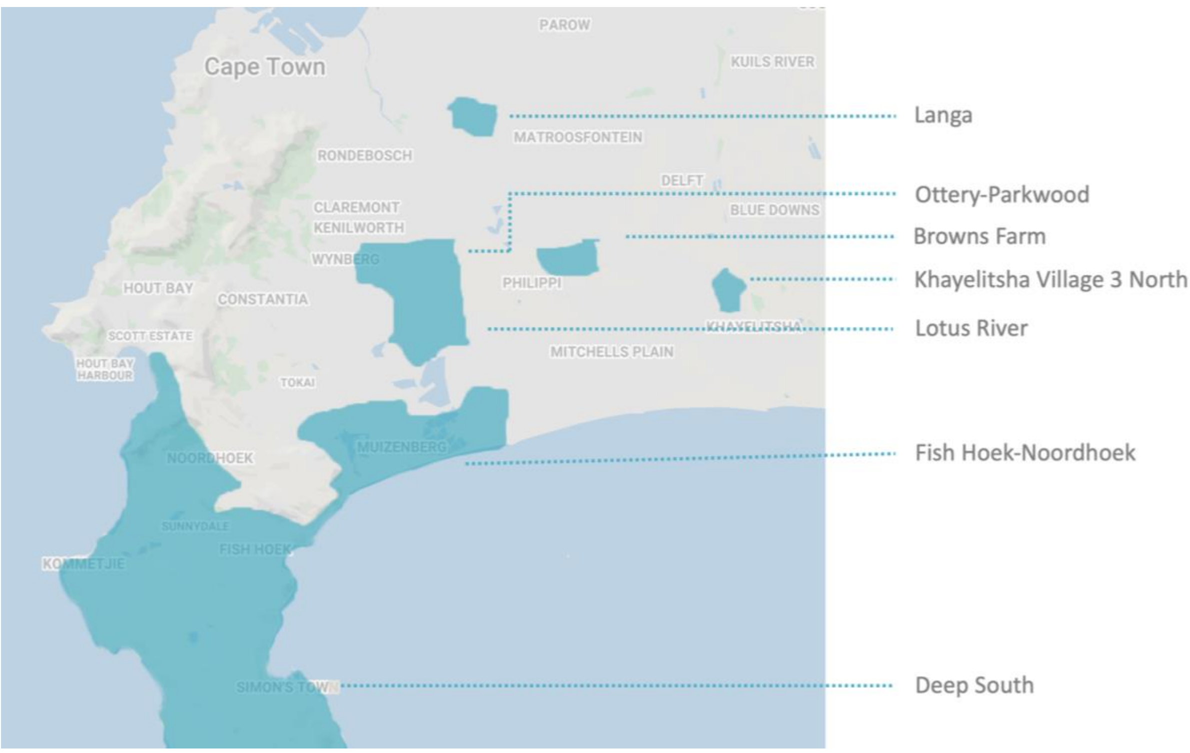


Figure 5.11. Spread of Cape Town macrozones included in the CoCT's Household Travel Survey 2020.

Of these surveys, 1003 households reported having no access to a privatised means of motorised transport, but based on public transport expenditure there were likely 846 captive public transport households surveyed. From those likely to be captive public transport households, access to ICTs was high with 90.7% households who reported access to a mobile phone and 16.5% to a computer or laptop. Access to the internet was limited, with only 17.9% reporting access to internet at home, 23.5% via mobile phones, 10.2% via their place of work, and 30.9% with no access to the internet at all. Given the distribution of these macrozones, the results cannot be taken to be representative of Cape Town as a whole. The figures do however, for the most part, support and follow the trend of the GHS surveys. Access to the internet is proportionally higher via mobile phones as compared to access at home or at their place of work. However, for these respondents, access to internet at the place of work was proportionally lower than access to internet at home as compared to the GHS trends. While this survey analysis included only responses from people with no access to private motorised vehicles, there was no comparable data on vehicle access in the GHS surveys to filter out choice public transport users which would have skewed the results to include more higher-income earners. The percentage of those with no access to the internet at all found in this 2020 survey data is similar to the percentages found in the GHS datasets, though since 2019 those with access to internet at some place has improved.

5.5 PRIMARY DATA RESULTS AND DISCUSSION

The purpose of the primary data collection was to understand captive public transport users' ability to use ICT, with a focus on transport information use cases, as the secondary data insufficiently addressed this. Of the 576 respondents surveyed, 536 responses were included in the ICT analysis. Respondents outside of the 18-to-55-year age range were removed along with surveys with non-responses to the ICT-related questions, and where a surveyor allowed multiple (conflicting) answers to a question (i.e., mobile data limitations) where multiple answers were not allowed. In total, 40 surveys had to be removed. For the purposes of the analysis where the data is segmented by race, only Black African and Coloured respondents are included as there were too few respondents for the other categories to warrant a representative sample size.

5.5.1 Digital Poverty Framework Applied to Transport Information

The digital poverty levels were adjusted for their application to transport information and the specific data collected in the surveys (see Table 5.12). All respondents, with one exception, who had access to a computer/laptop also had access to a mobile phone. All respondents with access to a mobile phone without internet capabilities had no access to a computer/laptop. Therefore, access to a mobile phone was used as a proxy for ICT access in the calculations. A respondent was classified as 'extremely digitally poor' if they had neither access to a mobile phone nor desktop computer/laptop. Passive and active use were defined based on the self-reported difficulty levels of using various aspects of ICT and transport information. A category, 'digitally poor with phone' was added between 'digitally poor' and 'passively connected' to accommodate those with access to an internet-capable phone but with poor skills for the passive use cases. A respondent was categorised as 'digitally poor with phone' if they responded to more than half of the passive use cases with 'some difficulty', 'a lot of difficulty', 'unable to do' or have neither seen nor done one of the items asked. In contrast, 'passively connected' respondents reported 'no difficulty' to more than half of the passive use cases and reported 'no difficulty' for a maximum of half of the active use cases. 'Actively connected' respondents differentiated from passively connected respondents in that for more than half of the active use cases they reported 'no difficulty' but diverge from 'digitally wealthy' respondents in that they have limited access to mobile data.

Table 5.12. Digital poverty categories for primary data analysis.

Category	Mobile Phone/ Computer Ownership	Mobile Phone Type	*Transport Information Usage* Passive Use	Active Use	Restricted Mobile Data Use
Extremely digitally poor	No	-	-	-	-
Digitally poor	Yes	Basic	-	-	-
Digitally poor with phone	Yes	Feature/Smartphone	<50%	-	-
Passively connected	Yes	Feature/Smartphone	>50%	<50%	-
Actively connected	Yes	Feature/Smartphone	>50%	>50%	Yes
Digitally wealthy	Yes	Feature/Smartphone	>50%	>50%	No

By applying this DPF for transport information to the survey data, the following breakdown is found, as shown in Table 5.13. Based on respondents' self-reported abilities to use transport-related information, 64% of respondents are capable of using active forms of transport information (e.g., using Google Maps or a similar navigation tool to get directions). However, limitations to mobile data use constrained 58% of these respondents, which reduced the number of people who would be considered digitally wealthy. Passively connected respondents made up only 24% of the total, with about a third of these reporting no restrictions to their mobile data use. Respondents considered to be digitally poor made up only 3%, but a further 10% of respondents lacked ICT skills at the passive use level and therefore could be considered digitally poor as well despite their access to a feature phone or smartphone.

Table 5.13. DPF for transport information applied to survey responses, as percentages.

DPF Category	Total
Extremely digitally poor	0%
Digitally poor	3%
Digitally poor with phone	10%
Passively connected	24%
Passively connected (w/ limited internet access)	*68%*
Passively connected (w/ unlimited internet access)	*32%*
Actively connected	37%
Digitally wealthy	27%

However, the proportion of captive public transport users who have active use skills might actually be lower than what was captured due to the limitations of analysis based on self-reported abilities. Self-reported abilities are fallible to biases such as where respondents inaccurately assess their skills, interpret the question differently than intended, or conform their answer to perceived notions around what is socially acceptable (e.g., Johnson and Fendrick, 2005; Palczyńska and Rynkno, 2021). For example, Balcombe and Vance (1996) found that more people claim to understand timetables than in reality actually are able to understand and use timetables. In a study of self-reported versus observed ICT skills, Palczyńska and Rynkno (2021) found that those with ICT skills tend to overestimate their skills, but that the tendency to overestimate decreases with age and fluctuates with gender with males overestimating abilities more than females.

Overall, compared to the RIA ICT Access survey's data for the urban South African population for 2011-12 and 2017-18, the primary data results are more heavily skewed towards the *actively connected* and *digitally wealthy*, with only 13% of respondents considered *digitally poor* and none considered *extremely digitally poor*. In comparison, in the secondary data 40% of the urban population was either *extremely digitally poor* or *digitally poor* and 56% were either *actively connected* or *digitally wealthy*. The discrepancy may in part be explained by the specific population surveyed for the primary data. All respondents were captive public transport users, whom by their nature can to some extent afford to use public transport. Whereas in the RIA ICT Access surveys the dataset also included those who are non-motorised transport captive users and cannot afford to use public transport. Therefore, the respondents captured in the primary data as opposed to the secondary data are likely of a higher income level and therefore have greater access to mobile phones and mobile data.

Table 5.14. Percentage of respondents per DPF category, by demographic variable.

	Sex		***Race***		***Age***		
	Female	**Male**	**Black African**	**Coloured**	**18-29**	**30-39**	**40-55**
Digitally poor	1%	4%	4%	1%	2%	4%	2%
Digitally poor with phone	10%	10%	10%	10%	11%	9%	10%
Passively connected	25%	22%	24%	24%	22%	24%	26%
Actively connected	35%	39%	37%	39%	36%	41%	31%
Digitally wealthy	28%	25%	25%	25%	29%	22%	31%

When segmented by sex, race and age, the results in Table 5.14 are found. The race category only includes Black African and Coloured respondents as there were too few respondents surveyed of the other groups. The DPF category *extremely digitally poor* was excluded, since there were no respondents that fit this category. A chi-square test was applied to each of the segmented data sets to test whether there is a relationship between the two categorical variables: the DPF categories and the demographic category. A chi-square test reveals that digital wealth is independent of sex, given the p-value of 0.3860 is greater than 0.05. Nor is digital wealth found to be dependent on race (p-value is 0.6681) or sex (p-value is 0.6491) within the context of the captive public transport users surveyed in Cape Town.

5.5.2 Specific Capabilities

The capabilities of the sampled captive public transport users were further broken down by common transport information ICT use cases. These included: transport-specific websites, journey planning, chatroom/messaging services, and crowdsourcing. An overview of the percentage of respondents' capabilities per individual transport information-related functionality can be found in Figure 5.15.

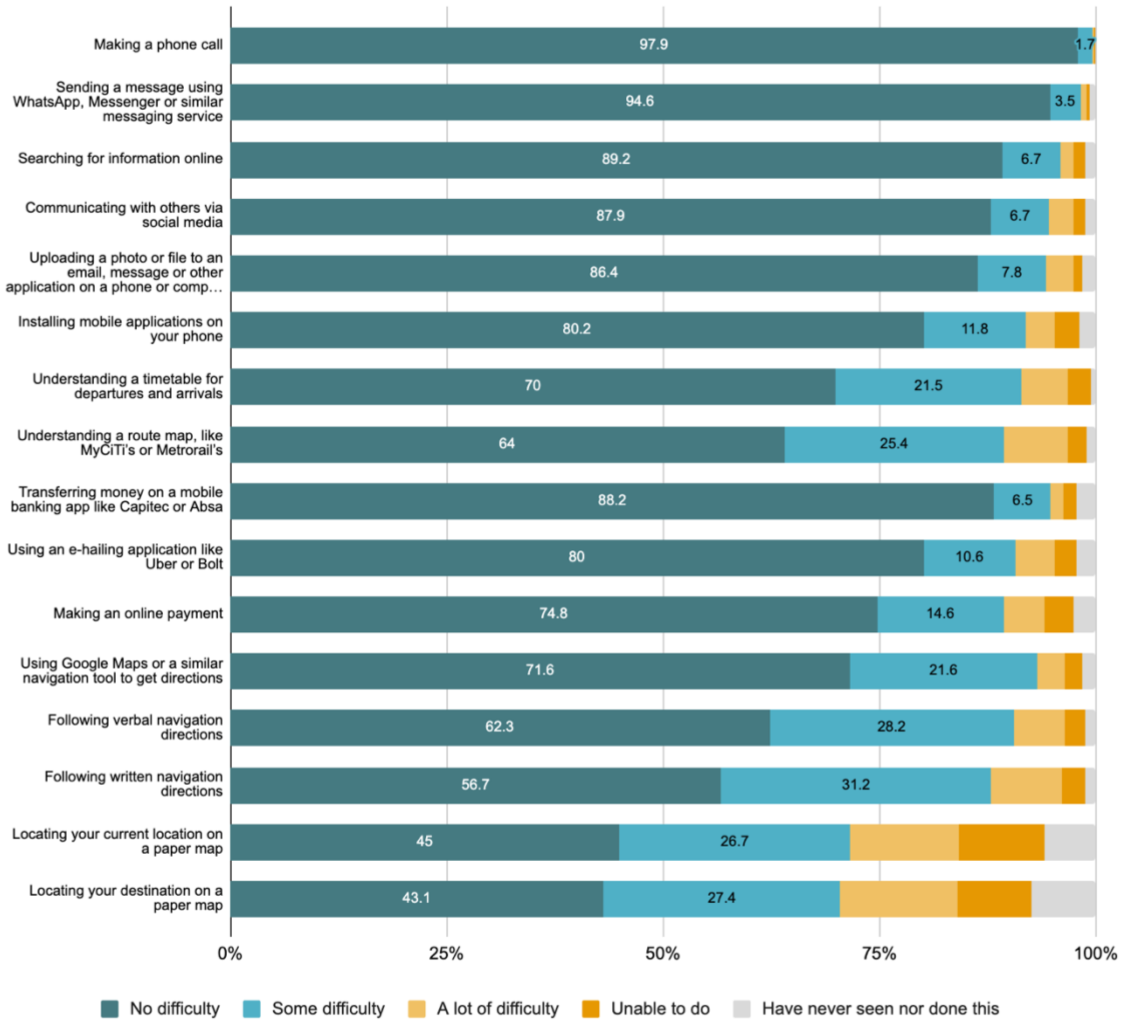


Figure 5.15. Percentage of respondents per individual transport information skill based on self-reported capabilities, ordered by passive/active use skills and descending order of no difficulty.

5.5.2.1 Websites for Public Transport Information

Websites are commonly used as a method of communicating vital operational information on public transport services in Cape Town with GABS, Metrorail and MyCiTi all hosting their own websites. Respondents' ability to utilise public transport specific information via a website was assessed using the three criteria: (1) searching for information online, (2) understanding a route map, like MyCiTi's or Metrorail's, and (3) understanding a timetable for departures and arrivals. These three skills were used as they represent the most basic levels of interacting with public transport information – maps and timetables are the most traditional and common elements of Cape Town's operators' official websites. Though a ubiquitous source of information, and in some cases the only official source of recorded online information for some of Cape Town's public transport services (e.g., GABS), websites with traditional forms of public transport information may not reach a widespread group of captive public transport users as only 56% of all respondents reported no difficulty with capabilities related to website-based public transport information. These results (Table 5.16) vary only lightly when segmented by sex, age, and race (for the purposes of this analysis only Black African and Coloured were included as there were too few respondents for the other race categories).

Table 5.16. Public transport information website capabilities across respondents.

Public Transport Information Websites	All	Sex		Age			Race	
		Female	Male	18-29	30-39	40-55	Black African	Coloured
Total Respondents	536	*271*	*265*	278	197	61	312	214
No difficulty with anything	302	159	143	163	107	32	179	114
Percentage with web capabilities	56%	59%	54%	59%	54%	52%	57%	53%

5.5.2.2 Journey Planning

Respondents' ability to journey plan using map-based ICTs was assessed using a combination of responses to three questions: (1) 'locating your current location on a paper map', (2) 'locating your destination on a paper map, and either (3a) 'using Google Maps or a similar navigation tool to get directions' or (3b) 'using an e-hailing application like Uber or Bolt'. If a respondent answered with 'no difficulty' to the first two questions and 'no difficulty to either 3a or 3b, they were said to have the skills for journey planning. A person's ability to use an e-hailing application was included as current popular applications (e.g., Uber and Bolt) have functionalities similar to journey planning apps in that they require the input of an origin and destination and the use of a map. Though many journey planning apps can automatically find a user's location and allow users to type in an address, respondent's location finding abilities on a map were still considered an essential part of journey planning capabilities. This is because, especially in Cape Town, not all locations have street addresses and hence would require manually locating the origin or destination. The calculation also assumes that people do not have complete knowledge of all addresses of points-of-interest and there might be multiple addresses associated with a point-of-interest (e.g., "KFC" has 9 locations near the CBD) which would require a user to know which specific location they want to go to.

Table 5.17. Journey planning capabilities across respondents.

Journey Planning Capabilities	All	*Sex*		*Age*			*Race*	
		Female	Male	18-29	30-39	40-55	Black African	Coloured
Total Respondents with mobile phone	536	271	265	278	197	61	312	214
No difficulty with anything	216	*103*	*113*	110	81	25	116	92
Percentage with journey planning capabilities	40%	*38%*	*43%*	40%	41%	41%	37%	43%
Unlimited access to mobile data	99	*53*	*46*	56	31	12	49	42
Limited access to mobile data	117	50	67	54	50	13	67	50
Percentage with limited access to mobile data	54%	49%	59%	49%	62%	52%	58%	54%

Using these three items as requirements for calculating journey planning capabilities, it was found that 40% of all respondents could be considered to have journey planning capabilities. When segmented by sex, age, and race (i.e., Black African and Coloured), the distribution of respondents with journey planning capabilities did not significantly vary by demographic category (see Table 5.17). When a chi-square test was applied to test whether the ability to journey plan is independent between the Black African and Coloured demographic groups, a p-value of 0.1806 was found which is not significant at the 99% confidence level. Similarly, this test was applied to age categories and mobile data limitations and also to sex and mobile data limitations finding that the categories were independent, given p-values of 0.2171 and 0.1133, respectively. However, when access to mobile data is factored in, just more than half of those with journey planning capabilities also have unlimited access to mobile data. The implication of this finding is that to attract and retain users, journey planning apps likely need to be data conscious and highly useful to be worth the cost of the data needed to access journey information.

5.5.2.3 Chatrooms/Instant Messaging Services

Respondents were assessed on their potential capability to use chat rooms or instant messaging services to send and receive public transport information. Three criteria were included: (1) "communicating with others via social media", (2) "sending a message using WhatsApp, Messenger or similar messaging service", and (3) "installing mobile applications on your phone." Those who responded with "no difficulty" to all three criteria were said to be skilled. Unlike the criteria for journey planning capabilities, instant messaging services include the criteria for installing applications on a mobile phone. While journey planning can be done on a website via an existing browser preinstalled on the phone, instant messaging or chatroom services would likely require the installation of an application (apart from Samsung phones which often have apps such as WhatsApp preinstalled). Across all respondents with access to a mobile phone, 78% have the potential for chatroom/instant messaging capabilities – almost double that of those with journey planning capabilities (see Table 5.18). When segmented by sex, age, and race categories, the results from a chi-square test to test whether messaging capabilities are independent do not differ significantly at the 99% confidence interval.

Table 5.18. Chatroom/instant messaging capabilities across respondents.

Chatrooms/Instant Messaging	**All**	***Sex***		***Age***			***Race***	
		Female	**Male**	**18-29**	**30-39**	**40-55**	**Black African**	**Coloured**
Total Respondents with mobile phone	536	*271*	*265*	278	197	61	312	214
No difficulty with anything	418	211	207	217	153	48	231	178
Percentage with messaging capabilities	78%	78%	78%	78%	78%	79%	74%	83%
Unlimited access to mobile data	169	87	82	91	57	21	92	68
Limited access to mobile data	249	124	125	126	96	27	139	110
Percentage with limited access to mobile data	60%	59%	60%	58%	63%	56%	60%	62%
Respondents with messaging capabilities and able to follow written directions	272	147	125	150	92	30	155	109
Percentage with messaging capabilities and able to follow written directions	51%	54%	47%	54%	47%	49%	50%	51%

When mobile data limitations are taken into consideration, roughly 60% of those with messaging capabilities are constrained in their data use. This means that public transport information messaging services need to minimise the data users need to access the services, for example by restricting photo and file uploads. If the messaging services were used to relay written navigation directions, the percentage of those capable of using such a service would drop to half. To maximise the benefits of information access through messaging services, information regarding non-directional information (e.g., service and safety updates) may better be communicated. Though, of the two – a journey planning app vs a messaging app – a messaging app would have a wider reach for communicating directions using the hybrid public transport network.

5.5.2.4 Crowdsourcing

Table 5.19. Crowdsourcing capabilities across respondents.

Crowdsourcing	All	*Sex*		*Age*			*Race*	
		Female	Male	18-29	30-39	40-55	Black African	Coloured
Total Respondents	536	*271*	*265*	278	197	61	312	214
No difficulty with anything	418	211	207	218	154	46	231	178
Percentage with crowdsourcing capabilities	78%	78%	78%	78%	78%	75%	74%	83%
Unlimited access to mobile data	169	87	82	91	57	21	92	68
Limited access	249	124	125	127	97	25	139	110
Percentage with limited access	60%	59%	60%	58%	63%	54%	60%	62%
Respondents with locational crowdsourced capabilities	229	109	120	120	84	25	125	97
Percentage of respondents with locational crowdsourced capabilities	55%	52%	58%	55%	55%	54%	54%	54%

Respondents were assessed on their potential capability to crowdsource data using three criteria: (1) "uploading a photo or file to an email, message or other application on a phone or computer", (2) "sending a message using WhatsApp, Messenger or similar messaging service", and (3) "installing mobile applications on your phone." These three criteria served as proxies for general crowdsourcing capabilities, as user reports/feedback, photographic evidence and the installation of the app are common requirements to use transport information crowdsourcing apps (e.g., Safetipin, Swiftly, OpenStreetMap). The proportion of people with crowdsourcing capabilities and access to mobile data is very similar to the proportion of people with messaging capabilities (see Table 5.19). An additional criterion was added to estimate the percentage of the captive public transport population that in addition to general crowdsourcing abilities can also find their location on a map – a potential requirement for manually geotagging information. As only little more than half of those with general crowdsourcing capabilities can also find their location on a map with no difficulty, crowdsourcing apps should automatically geotag shared files and reports with the users' permission to reduce error in the geographical location of the data point.

5.5.3 Method of Communication

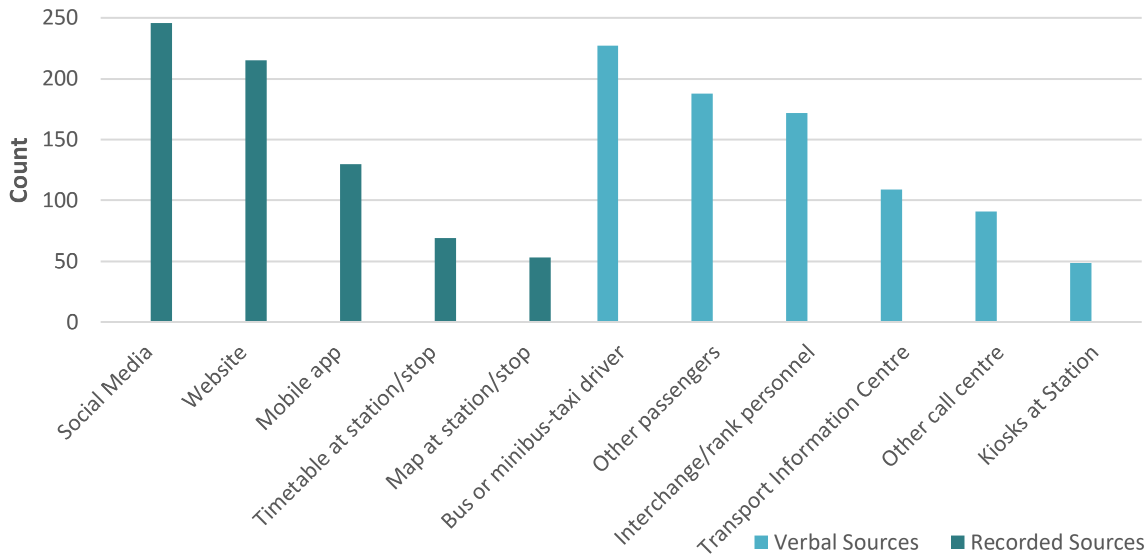


Figure 5.20. Frequency of citied sources of public transport information.

The survey asked respondents to state where they currently get their journey planning information from and offered a selection of multiple sources from a list of 11 sources, where six were verbal sources and five were recorded. Respondents had the option to offer another source not listed, but none were mentioned. Social media followed by the bus or minibus-taxi driver and websites were the top three most frequently cited sources of information. Kiosks, maps at station/stops, and timetables at stations/stops were the least cited sources (see Figure 5.20). Low frequency counts may have been due to the relative uneven availability of these sources across all stops/stations. Kiosks tend to only be available at the major interchanges, and maps and timetables are disproportionately available to MyCiTi services which have demarcated stops as opposed to the other three modes. The MBT has no such information on its services, and the infrastructure for intermediate stops along GABS and Metrorail routes has been vandalised or not been maintained so maps and timetables have vanished over time, if they had even been in place. Overall, 31% of respondents used only verbal sources, 23% used only recorded sources, and 46% used both verbal and recorded sources of information. Given the diverse sources people use to plan public transport trips, continuing to offer a mix of verbal and recorded sources would maximise the reach of public transport information. Even though ICTs traditionally are associated with non-verbal communication endpoints like apps or screens, verbal endpoints can use ICTs to source their multimodal information and relay this onwards.

5.5.4 Language

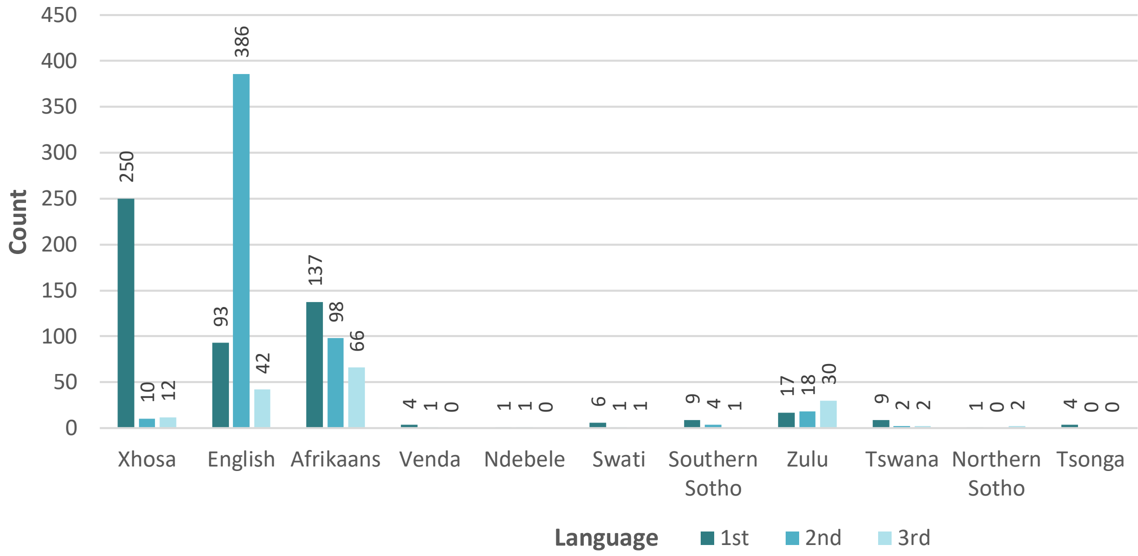


Figure 5.21. Frequency of first, second, and third languages.

South Africa has 11 official languages, of which Xhosa, Afrikaans, and English are the languages most used in Cape Town. This is reflected in the responses where 47% of respondents spoke Xhosa as their first language, 26% spoke Afrikaans as their primary language, and just 17% said that English was their first language (see Figure 5.21 for full frequency counts). This finding would imply that communications should be made in Xhosa and Afrikaans to reach the most potential beneficiaries who are captive public transport users in Cape Town. However, to reach the maximum potential users through a single language is with English as 89% reported English as either their first or second language. As the survey did not have a follow-up question to gauge respondents' comfort and confidence with their second reported language, it is not clear how easy they find it to navigate through mobility information using, for example, English. That said, ICTs should aim to offer information in at least Xhosa, Afrikaans, and English to maximise accessibility.

5.6 NEXT STEPS

The primary and secondary data reveal an overall positive trend in ICT capabilities, with primary data showing a trend in increased physical access to ICTs and internet services. Given mobile phones are the most accessible form of ICT devices, it is not surprising that the internet is most accessible via mobile phones compared to internet in the home. Overall, access to mobile phones is increasing, with almost all captive public transport users having access to a mobile phone. While the majority of those with access to a mobile phone have access to internet-capable feature or smartphones, access to mobile data affordability continues to be the greatest barrier to using phones to access internet-based services.

The proportion of those with both access to a phone and the skills needed to use their phones for general capabilities is increasing, though continued research would be needed to establish if this trend extends to the skills needed for transport information-specific capabilities. Compared to the primary survey captive public transport respondents, the *RIA 2011-12* and *2017-18* surveys included respondents who have access to vehicles and who cannot afford to use public transport and thereby represented a wider income range. Nevertheless, the overall upward trend in high levels of ICT skills in the DPF analysis from the secondary data likely extends to the captive public transport population.

Compared to the secondary data results wherein ICT skills were generalised use cases, when respondents' digital poverty levels were assessed based on ICT skills particular to travel information, a larger proportion of respondents were considered to have low ICT skills. Transport information is quite specific in the skills that it requires and, given the limited exposure people have across the hybrid system in Cape Town to transport-specific information (e.g., maps or timetables), training and education would be needed to teach people how to interpret information formats that they are unfamiliar with, if these formats are to continue to be used.

Despite the large proportion of captive public transport users with limited transport information skills, there is a lot of potential for the use of ICTs to communicate transport-related information, particularly if not communicated in transport-specific formats. Chatrooms and messaging services have the potential to reach a higher proportion of users compared to transport information websites and journey planners that would only reach half or less than half of the population, because such services could avoid relaying information using transport-specific formats. The uptake appetite for messaging-based services is also evident in the way that many respondents reported accessing travel information currently – via oral sources, like workers in the transport industry, and via informal non-transport-specific sources, like social media. If access to mobile data were not a constraining factor, three-quarters of captive public transport users have the ICT skills to lend to crowdsourcing efforts - an application of ICT that can be vital to creating information in a data-scarce city like Cape Town.

A limitation of these findings is that the surveys relied on self-reported abilities to utilise ICTs and transport information and may reflect an inflated view of ICT skills. Further research is needed to specifically investigate ICT skills through observations or controlled tests to lend a more accurate picture of digital poverty levels. Captive public transport users' abilities to use transport-specific information, in particular, would benefit from additional research as the ability to understand information such as maps and timetables requires certain cognitive skills that have largely gone under-researched. In a context like Cape Town where recorded information is sparse compared to oral information, further investigation could reveal how suited transport-specific information formats really are to the hybrid system context where the majority rely on unrecorded public transport services.

Because respondents responded within the same survey to both questions regarding the ICT capabilities and the information needs choice model (discussed in depth in Chapter 6), the categorisation of the primary survey respondents into DPF levels is applied later to the analysis of the information needs in the choice model to understand the intersection of ICT capabilities and information access as it plays out in the current information landscape and how ICT capabilities may pose as a potential barrier to accessing desired information. This together with the understanding of the opportunities and limitations captive users' ICT capabilities present are used to inform the recommendations put forward to enhance informational capabilities (Chapter 7).

6. OBJECTIVE 3: INFORMATIONAL CAPABILITIES

6.1 INTRODUCTION

The purpose of this part of the research is to investigate objective 3:

> To investigate which informational capital and level of quality would most enhance public transport users' ability to expand their mobility opportunities through travel decisions that meet their needs and preferences within the hybrid network for non-routine trips.

Specifically, this entails investigating what is the minimum information required to meaningfully make use of the hybrid network to access/expand mobility opportunities through the use of a stated preference choice model. An emphasis is on understanding what quality (certainty) of information is demanded. Certainty of information is chosen as the dimension of information quality that is tested because it best relates to the specific data that feeds the information - static or real time - and encompasses the possibility that perhaps no information on a given information type is needed at all to plan a journey. Various studies have centred on reliability as their focal point particularly in scenarios of travel uncertainty (e.g., Bifulco, Pace, and Viti, 2014; Wijayaratna and Dixit, 2016), but reliability relates more to the accuracy of the information provision services. Reliability in terms of public transport information can be thought of as "the certainty travellers have regarding the level of service they will experience when travelling" (Soza-Parra, Raveau, and Muñoz, 2022: 1) and the likelihood that what "users actually experience on the network to be consistent with the supplied information" (Bifulco, Pace, and Viti, 2014: 62). The study was focused on understanding information needs in terms of what the CoCT could collect in terms of data, rather than focusing at this time on accurately/reliably capturing that data. Cost and effort of accessing the information (or willingness-to-pay) is out of the scope of this research because that begins to look at an individual's capacity to pay for information services, whereas this research is concerned with whether the information itself expands the capabilities of the user to access mobility options.

In this chapter, an overview of applications of choice modelling in transport is given with a focus on transport information and how uncertainty has been incorporated (section 6.2). This is followed by the choice model methodology in theory (section 6.3) and then as it is applied to the investigation of this research objective. A detailed review of the different design options considered is provided (section 6.4) before introducing the final choice model design itself (section 6.5), the subsequent pilot studies used to refine the model design, and the full study results (section 6.6). The chapter ends on a note how the choice model findings relate back to the larger research objective and presents the prioritised information needs as the informational capital needed to enhance informational capabilities (section 6.7).

6.2 CHOICE MODELS IN TRANSPORT AND INFORMATION STUDIES

Discrete choice modelling has been applied widely to transport and passenger information studies. Multiple studies investigated the effects of travel attributes and attributes levels on route choice through a quantitative representation of attribute levels (e.g., Eluru et al., 2012; Bovy and Hoogendoorn-Lanser, 2005; Van Der Waard, 1988). Eluru et al. (2012) looked at both the factors that deter people from using public transport and the factors that influence public transport route decisions using a choice model. They used a mixed multinomial logit model to measure respondents' preferences towards each individual public transport alternative in a choice set with combinations of three modes. Bovy and Hoogendoorn-Lanser (2005) looked at multimodal choice behaviour given travel alternatives available and associated penalties like transfers to assess preferences for different feeder modes, and station and service types. Van Der Waard (1988) investigated the impact of route attributes, such as walking time and number of transfers, with different quantitative attribute levels on route choice. These studies are similar in that the focus was on the influence of quantitatively-defined attribute levels on mode or route preference, as opposed to understanding what attributes and levels specifically are needed to make that modal or route choice.

Stated choice model studies have investigated the effects of information itself on choices, though have mainly limited their investigations to the influence of information availability and reliability on travel choice (e.g., Meng et al., 2017; Wijayaratna and Dixit, 2016; Ben-Elia et al., 2008; Chorus et al., 2007). Meng et al. (2017) looked at car users' mode choice behaviour given multimodal travel information using revealed and stated preference surveys. Through their revealed preference survey, the researchers collected data on respondents' actual choices to inform the reference trips for the stated preference surveys. Their stated preference survey component was used to investigate both mode choice preference given congestion and information on available travel options, and mode choice when incentives specifically for public transport are given such as increased parking costs on private cars. Wijayaratna and Dixit (2016) employed a choice model to measure the risk attitudes of users to travel delay scenarios with and without information present. To explore risk-taking behaviour given real-time information, Ben-Elia et al. (2008) studied travellers' decisions given their experience and descriptive real-time information in an experiment involving two route options by car and different travel times and associated potential delays. Travel times were expressed as a value with a range (e.g., Option 1: 25 min, ±5; Option 2: 30 min, ±15). The study found that, given respondents' choices after repeated choice tasks, information via automatic terminal information services is most beneficial when drivers do not have long-term experience to base their decisions on. Similarly, through a stated preference choice model, Bifulco, Pace, and Viti (2014) studied car users' behaviour given travel time reliability using a travel simulator, finding that the less reliable information is, the less likely a user will follow its advice. Chorus et al. (2007) used a travel simulator to conduct a choice experiment to investigate the impact of multiple travel information types in situations with known and unknown information alternatives to gauge the quality, or consistency, of multimodal travel choices. An objective measurement of choice quality was derived from comparing the modal choice with unknown alternatives and information, with the choice with complete known alternatives and information. Where these modal choices remained the same within the same origin-destination pair, the first choice was said to be of high quality. They found that choice quality increases with completeness of knowledge and decreases with uncertainty of attributes attached to alternatives.

Additionally, limited studies have investigated the role of uncertainty (or quality) as attribute levels in decision-making. Where uncertainty has been incorporated into a choice model, it has been applied to individual attributes rather than the full attribute set and levels, such as the impact of travel time uncertainty on journey choices (e.g., Zhongwei et al., 2012; Li et al., 2016; Wijayaratna and Dixit, 2016). In the case of travel time uncertainty, Zhongwei et al. (2012) assessed risk attitudes given conditions of uncertainty by asking respondents to make travel choices while undergoing a hypothetical journey in which respondents could also choose to acquire new information and modify their trip. On the journey, the respondent is provided with a hypothetical information service with two types of information on delays: fully reliable and 80% reliable. Li et al. (2016) similarly looked at departure time choice given travel time uncertainty where travel time was defined as a range (10, 20, and 30-minute intervals), and expected arrival times were given based on the average travel times. In Wijayaratna's and Dixit's (2016) research on risk attitudes and delay information, they expressed delay uncertainty in terms of probability of die rolling given numbers. However, investigating the value of certainty itself, in particular regarding information quality, to understand for which attributes precise information is desired and for which a level of uncertainty is acceptable, has not been studied in the choice context of passenger information needs.

6.3 CHOICE MODEL METHODOLOGY

For the purposes of identifying which information types are most influential in enhancing users' ability to make travel decisions, a stated preference discrete choice model provides a means of quantifying the influence of information types in making a journey choice. Stated preference discrete choice models are useful where it is not possible to elicit preferences via revealed preference surveys, meaning in contexts where the goods or services do not yet exist and therefore a choice cannot be observed, but where we would like to understand the demand for a potential good or service (Mangham et al., 2009; Louviere et al., 2000). This is valuable particularly where it would be expensive or time-consuming to create actual interventions to study people's choice behaviour (Bifulco, Pace, and Viti, 2014). This is also true for contexts where there is little variation in the goods or services provided such that the overlap in product attributes makes it difficult to distinguish how each attribute individually contributes to the overall utility of a product (Mangham et al., 2009). A discrete choice model asks respondents to make a choice between distinct alternatives (such as to use a bus or a train), whereas continuous variables have infinite values between any two given values (such as length of a journey).

The following description, unless otherwise indicated, including equations of utilities and choice probabilities comes from Train (2003) and Hensher et al. (2015). In the survey, respondents, n, are given multiple alternatives, J, and asked to state a choice for one alternative, j. In a discrete choice model, the dependent variable is the respondent's choice of the alternative and the independent variables are the attributes (Mangham et al., 2009). Discrete choice models are grounded in random utility theory and assume that the respondent makes economically rational and utility maximising choices – that is, the respondent is assumed to make the choice which best maximises their individual benefit (Hall et al., 2004). The theory maintains that people will base their choice, more often than not, on their preferences, and in the case that they make a choice contrary to this, this event can be explained by random factors. The theory assumes that if a person chose X over Y, that then they preferred X over Y, however Sen (1973) maintains that all we know if a person chose X is that the person sees X at least as good as Y. Following from the idea that the respondent seeks to maximise utility, the respondent would choose an alternative, i, if it has the most or at least equivalent utility of all the available alternatives, or:

(1)

$$U_{ni} \geq U_{nj} \ \forall j \neq i$$

Here U_{ni} represents the total measure of utility for each alternative which is made up of both observable and unobservable factors.

A choice set contains at least two alternatives, with four being recommended as optimal, with defined attributes (Caussade et al., 2005). Through a study of stated choice experiment complexity and choice quality in contexts with less literate individuals, Arentze et al. (2003) found to reduce task complexity and the impact of respondent burden on choice quality, attributes and alternatives should be kept to a minimum. Attributes are defined and assigned two or more levels to help describe the hypothetical scenarios presented to the respondent. Mangham et al. (2009) maintain that it is important to understand your target population's perspective and therefore do research into defining these attributes - for example, this might mean looking at policy papers or other grey literature. Importantly, it can also include qualitative research to scope out what attributes the target population may consider key in making decisions between alternatives as was done through the interviews in Chapter 3. To avoid response fatigue, in practice, many discrete choice experiments limit attributes to ten, though in theory there is no restriction in number (DeShazo and Fermo, 2002). With too many attributes, there is the risk that the respondent becomes overwhelmed and bases their decision on only one attribute instead of taking all attributes into collective consideration. To assign attribute levels, levels should reflect what respondents would realistically experience. For example, if the attribute is 'bus fare cost' then the levels should reflect actual costs of travelling by bus. Knowledge of these realistic levels can come from qualitative interviews.

We are able to observe the attributes contained within the alternatives represented as $x_{nj} \ \forall j$ and some of the individual characteristics of the respondent captured through the surveys, s_n. These characteristics can help point to insights about groups of people with similar characteristics and tendencies to choose certain alternatives. The representative utility is the observable parts of the total utility and is represented by the function $V_{nj} = V(x_{nj}, s_n)\ \forall\ j$. The unobserved utility, or the utility that also influences an individual's choice beyond the given attributes and levels that we do capture, is referred to as ε_{nj} which together with the representative utility, V_{nj}, composes the total utility:

(2)

$$U_{nj} = V_{nj} + \varepsilon_{nj}$$

As we cannot observe ε_{nj} and thereby cannot measure this error term, it is treated as random. Based on the choices respondents make, estimated weights called parameter values, β, can be assigned to the attributes, x_{nj}. The purpose of the choice experiment is to determine how significant these attributes are in influencing individual choice of an alternative, and the relative importance of one attribute over another (Mangham et al., 2009). If utility is linear in β then the utility equation becomes:

(3)

$$U_{nj} = V_{nj} + \varepsilon_{nj} = \beta' x_{nj} + \varepsilon_{nj}$$

To put this equation into practical terms, let us say we applied this to car hire rental. A website contains multiple car hire choices with information on four attributes: price (budget, economy or luxury), car size (small, medium, large), car model (Toyota or Ford), and kilometrage included (limited or unlimited). As the experiment designers, we know what the values (x_{nj}) are for the different options (levels) for the four attributes that are given for each alternative, but we do not know how important (β) each attribute is for the individual making a decision. For example, for one person, the car model may be inconsequential, but price is important. For another, car size is most important. We can capture this through the model, but there are externalities that we may not capture (ε_{nj}) that influences choice, like in the case of the first person who is on a solo backpacker holiday and the second person who has a lot of luggage they need to fit in the car. We can capture some of this information by asking additional questions in the survey like demographic questions.

Because the choice model is probabilistic as we can only predict the likelihood that an individual may choose a given option, the probability equation becomes:

(4)

$$P_{ni} = \text{Prob}(U_{ni} \geq U_{nj} \ \forall j \neq i)$$
$$P_{ni} = \text{Prob}(V_{ni} + \varepsilon_{ni} \geq V_{nj} + \varepsilon_{nj} \ \forall j \neq i)$$
$$P_{ni} = \text{Prob}(\varepsilon_{nj} - \varepsilon_{ni} \leq V_{ni} - V_{nj} \ \forall j \neq i)$$

This says that when given two alternatives *A* and *B*, a person will choose *A* if the unobserved utility difference of *A* minus *B* is greater than or equal to the observed utility of *B* minus *A*. Different choice probabilities, or discrete choice models, come from different assumptions around how the proportion of unobserved utility is distributed. That is, while the observed portion of utility might be the same for a population group, the unobserved utility might differ across the population group. In the case of the multinomial logit (MNL) model, the assumption is that these unobserved effects, ε_{nj}, are independent across alternatives and have the same variances for all alternatives j, or a Gumbel type I extreme value (see Hensher et al., 2015 for a complete explanation). This proportion, or density, of each unobserved utility component is represented by the density distribution:

(5)

$$f(\varepsilon_{nj}) = e^{-\varepsilon_{nj}} e^{-e^{-\varepsilon_{nj}}},$$

where the cumulative distribution is

(6)

$$F(\varepsilon_{nj}) = e^{-e^{-\varepsilon_{nj}}}.$$

This assumption that ε_{nj} is evenly distributed does come at the risk that unobserved effects may in reality not necessarily be independent across alternatives and that the same factors may affect an individual's assessment of multiple alternatives. However, if representative utility, V_{nj}, is sufficiently captured by the attributes and defined then ε_{nj} and its distribution effectively become white noise as one alternative's error term provides no information about the error for another alternative (Train, 2003). The logit probability for the multinomial equation where representative utility is linear in parameters then becomes (see full derivation in Train, 2003):

(7)

$$P_{ni} = \frac{e^{\beta' x_{ni}}}{\sum_j e^{\beta' x_{nj}}}$$

While the MNL model in equation 7 captures systematic, observable taste variation, it cannot represent random taste variation. For example, women may be more sensitive than men to the quality of safety information in public areas at night. However, demographic or other observable factors may not capture all variation in preferences. Mixed multinomial logit (MMNL) models, on the other hand, allow for random taste variation as well as allow unobserved factors to follow any distribution (Train, 2003). Unlike the MNL model which assumes independence within the unobserved portion of utility, the MMNL model assumes that the unobserved portion is not random but rather partly dependent and explainable by heterogeneity across sampled respondents' taste preferences and similarity issues across alternatives where choices are correlated across space or time (Chen et al., 2013). By integrating the parameters of the MNL model, the probability equation for the MMNL model can be obtained (see Train, 2003 for full derivations):

(8)

$$P_{ni} = \int \left(\frac{e^{\beta' x_{ni}}}{\sum_j e^{\beta' x_{nj}}} \right) f(\beta) d\beta$$

As respondents have different socio-economic backgrounds and previous experiences with public transport that may have affected their preference for information, despite all being captive public transport users, the MMNL model was used for the analysis of the final choice surveys used in this research.

6.4 CHOICE MODEL DESIGN

The following sub-sections outline the decision process and options considered behind formulating the final choice model design. These include the scenario prefacing each choice set, how to incorporate modal combinations into the choice sets, how certainty is represented in the choices, and the final experimental design used to produce the choice sets used in the surveys.

6.4.1 Setting the Scenario

A mix of trip purposes and origin-destination (O-D) pairs was used to identify information needs for journey planning across a range of scenarios (see Table 6.1) and to inform a design-for-all approach in terms of targeting information needs across a diverse population (Lyons et al., 2019). While the trip purposes are realistic reasons for travel that a respondent can identify with, the O-D pairs were designed to be abstract routes that respondents would likely not have taken. For pre-trip planning purposes, research has shown that public transport users are less likely to require or access information on routine trips that they are familiar with as opposed to non-routine trips (Pronello et al., 2017; Chorus et al., 2007). To avoid respondent bias towards what they perceive their information needs to be, these non-routine routes were designed so that respondents will be less likely to believe they have complete knowledge of the full journey. The non-routine trip used O-D pairs selected based on their spatial relationship to one another – that is routes that are less likely to follow the traditional east-west journeys that radiate from Cape Town Station. However, the trade-off with this approach is that asking respondents to travel to unfamiliar areas may have created some bias towards non-mode-specific attributes. While experience can help inform prior expectations around mode-specific information types (e.g., Metrorail often runs late and MyCiTi tends to run to schedule), experience may be less useful for forming expectations around the need for non-mode-specific information types. For example, the need for information on walking safety will vary from area to area and may be heightened in non-routine circumstances.

Table 6.1. Origin-Destination pairs and trip purposes used in the choice sets.

Trip Purposes	Origin-Destination Pairs
Attend job interview Meet up with friends	Montague Gardens to Meadowridge Elsies River to Hangberg

To avoid bias around safety information needs, O-D pairs were also chosen based on different crime levels and average incomes. For trip purposes, activities with different time sensitivities were selected to avoid bias towards only time-related information types. A 'job interview' set time constraints on the journey and 'meet with friends' is a social excursion where time can be more flexible.

6.4.2 Approach to Mode Labelling

Three options were considered for contextualising the alternatives by modes – labelled and unlabelled, and a hybrid of the two. The following is an overview of the options considered.

6.4.2.1 Option 1 – Labelled Discrete Choice Model with Different Modes (mode dependent)

For this option, there are three alternatives per choice set and each alternative is assigned a *distinct* modal combination ('MBT + MyCiTi', 'MBT + Train', 'MBT + GABS'). Respondents would be asked to make a choice based on a scenario in which they need to complete a non-routine trip.

With modes defined as a dependent variable, this option gives the advantage of understanding how availability of accurate information relates to mode choice. However, a drawback is that respondents would likely have a bias towards a specific modal combination and would be inclined to choose that modal combination regardless of the information attributes related to it. That said, adding modes might allow us to see if increased access to accurate information can sway a person to choose a different modal combination from their preferred combination. In the case of CoCT who runs the MyCiTi, they might find a survey where mode choice is considered useful to their planning efforts to increase MyCiTi ridership.

6.4.2.2 Option 2 – Unlabelled Discrete Choice Model with Preferred Mode (mode independent)

This is the same as Option 1 above, except a choice set does not include three different modal combinations, but rather the respondent pre-selects a modal combination preference which is valid for all the alternatives in the set. The risk with unlabelled choice sets is that respondents may believe that the information packages (i.e., alternatives) all relate back to the same trip. That is, they would not be making a decision on which information set would most help them decide which journey option to take from a choice of journey possibilities. To ensure that respondents treat the alternatives as independent from one another, each option within a choice set would need to be marked as distinct, e.g., it would need to be clear within each choice set multiple journeys are possible.

The benefit of this would be that modal bias would not be a factor in decision-making. The disadvantage is that there would be no insight into what information types need to be made certain and accessible for people to consider unfamiliar modal combinations viable travel options. However, if previous research holds true that people will only look to access information that they are interested in acquiring, they will likely look for their preferred mode, and any information they would find on other modes would be coincidental. Given this, focussing on how information certainty leads to changes in choice within the same mode would support the research objective without the additional complexity and bias inherent in the previous option.

6.4.2.3 Option 3 – Hybrid Labelled and Unlabelled Discrete Choice Model

The third option is a hybrid of the previous two in that it would entail complete choice set scenarios to be divided between the three modal combinations (‘MBT + MyCiTi’, ‘MBT + Train’, ‘MBT + GABS’), while within a single choice set itself the alternatives would be unlabelled (see Figure 6.2). This modal combination follows from CoCT’s strategy of MBTs becoming a feeder to services with higher passenger capacities, and so the idea is to see what information users would need to plan a trip using both scheduled and unscheduled services. The MBT is a constant across the scenarios, whereas the paired scheduled mode is effectively an independent variable.

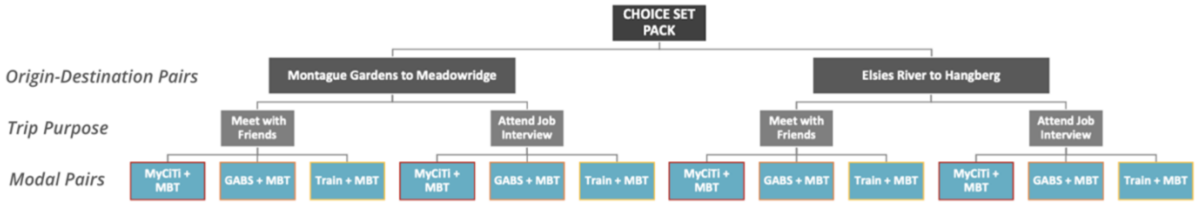


Figure 6.2. Hybrid labelled and unlabelled choice set.
Each of the three modal pairs is referred to individually in context of each trip purpose and origin-destination pair. This differs from Option 1 in that modal pairs are embedded in the overarching scenario in a distinct choice set as opposed to assigned individually to alternatives with multiple modal pairs per choice set, and Option 2 where modal choice is dictated by the respondent and remains the same throughout all choice sets.

The advantage of this option is that, unlike Option 2, we could see how the impact of information types on choice varies dependent on the mode without the risk that Option 1 carries where a respondent may display strict mode allegiance. For the purposes of obtaining results that will be used to provide recommendations, knowing for which modes particular information types are most important would help transport and ICT providers take a more targeted approach to providing access to these information needs. Given that the quality of services greatly varies dependent on the mode and operator, passengers may have different needs for information types. For example, during the interviews, onboard safety was explicitly raised as a concern for Metrorail use, whereas interviewees were less concerned about their safety onboard MyCiTi services. By introducing modal combinations, we would see whether respondents do have varying information needs dependent on the modes in question. This was the option used going forward for incorporating modes in the alternatives.

6.4.3 Attributes

Though there is no restriction from a modelling standpoint of how many attributes can be included in a choice model, limiting the number of attributes shown to respondents is recommended to help reduce cognitive burden, as choice consistency can be negatively affected by an increase in the number of attributes (Louviere et al., 2008). The number of attributes considered appropriate ranges, with some citing eight (e.g., Carson et al., 1993), others finding the cut-off to be closer to four (e.g., Green, 1974; Schwabe et al., 2003), and others finding that in applications in middle-income countries five to eight are fine with eight approaching the maximum (Ryan et al., 2012). Given the starting number of items included from the interviews in the BWS study was 17 (refer to

Chapter 4), this design set the cut-off to eight attributes to maximise the number of information types that could be tested in the choice model without exerting too much cognitive burden. Because a B-W scoring system cuts the number of included items in two, with one half with positive scores and the other half with negative scores, a list with 17 items meant that that the eight selected would have positive B-W scores. The selection of these information types was then additionally refined. Four types of safety information scored highly in the BWS surveys. However, *safety of area vehicle passes through* was not included in the list of attributes in the choice model for two reasons. Firstly, it shares similarities with *safety onboard* in that safety onboard encompasses the information and data needed to feed information on safety information on the area the vehicle passes through, as external stimuli can affect onboard safety. Secondly, in the literature around safety and security perceptions related to public transport use, passenger security can be tied to three different situations: at the station or stop, onboard, and walking between transport points (Kruger and Landman, 2007). Therefore, safety onboard is taken forward in the choice model. Thus, the eight information types included in this part of the research were:

1. frequency
2. fare cost
3. departure time
4. vehicle-route identifier
5. arrival time
6. safety walking to/from vehicle
7. safety onboard
8. safety while waiting at stop

The number of attributes included going forward is reduced to mitigate the risk of attribute nonattendance, or the idea that respondents ignore attributes because they are irrelevant to their situation and/or to simplify choices (Alemu et al., 2013).

6.4.4 Attribute Level Design Options

Two options were considered for the attribute labels: one where labels are descriptive representations of information certainty (Table 6.3) and another where labels are qualitative representations of certainty (Table 6.4).

To reiterate, the purpose of this part of the research is to understand what the minimal information is a user needs to make a hybrid public transport journey. This means the focus is on understanding for which attributes is precise information desired and for which is uncertainty acceptable, as opposed to testing the importance of defined values. Given this, the attribute labels are defined in terms of certainty. This is to ensure that respondents do not make a choice based on information as a value (e.g., ZAR 10), but on information as a degree of precision and certainty (e.g., exact fare).

To define these attribute labels, particularly in the design of the assigned attributes option, Prospect Theory is used to understand how to position the most certain level as the most attractive choice. To summarise, Prospect Theory is made up of three concepts: certainty, loss aversion and isolation effect (Kahneman and Tversky, 1979). The idea around *certainty* is that people prefer to pursue certain outcomes even if that means giving up the chance of getting an even more favourable outcome that is coupled with the probability of risking a less favourable outcome than the certain outcome. *Loss aversion* is the idea that people are more sensitive to certainty of losses than certainty of gains and likely to take a gamble to avoid loss. The *isolation effect*, or framing effect, refers to the phenomena that people tend to disregard similarities and focus on the differences in choice situations, even if the outcomes of two choice situations are statistically equivalent, but one is framed as a gain and the other as a loss.

Because of this, how the choice scenario and the attribute labels within it are framed is vital to influencing the perceived utility of the attribute level. The utility of the attribute labels needs to positively reflect the increasing certainty levels, so that the information with most certainty is the most attractive to the respondent while conversely the least certain level should be the most unfavourable choice. If the attribute level that is most certain could be a loss compared to the more unknown levels, the respondent might then display risk-seeking behaviour and prefer to gamble with a less certain choice in the hope that it has better rewards. Conversely, if the most certain attribute level is more likely to result in a better outcome than the less certain attribute levels, then the respondent would likely be risk averse (ibid.).

6.4.4.1. Attribute labels – Assigned - Option 1

In the case of defining the attribute labels wherein attributes are assigned descriptive values to resemble actual journey options, there is a risk in variable subjectivity across the respondents to whether the levels are perceived as a loss or gain. That is, when a person looks at the attribute levels of certainty, whether the most certain one is a loss or a gain will depend on their perspective. For example, a fare of ZAR 10 for a short-distance trip could be a loss for one respondent who might perceive this as an unaffordable cost and may risk choosing an option with a less certain fare to take a gamble to save money. Another respondent may perceive that same fare as acceptable and would rather have the certainty of choosing that option than taking the risk to pay more for the option with less precise fare information.

This dilemma supports the case for individually pivoting the values to fit the respondent's subjective view of what is considered an attractive value given a particular situation. Preceding the choice study, the respondent could fill out a questionnaire around which some of the attribute levels could pivot, such as fare cost. Time-related attributes are equally challenging to define given that time is subjective and fluctuates based on trip purpose and societal norms, where, for example, 'on-time' for one person can mean the time written on the invite whereas for another arriving an hour after the invite time is still acceptably on-time. Thus, in this case, avoiding precise times in defining the attribute levels and opting for loose terms that can be interpreted subjectively like 'you arrive on-time' is a favourable way of avoiding inadvertently reducing the utility of the most certain attribute levels for time.

With attribute levels defined in a way that represents the level of information certainty through realistic values (see Table 6.3), the choice model would ask respondents to make a choice based on journey options given the information available. The disadvantage of this option is that there is still a risk that respondents will make choices based on the value of the attribute label rather than on the precision of the level. In the case that respondents mistake each alternative as representative of a unique journey option, respondents may, in the absence of information ('no information given'), assign a value to the missing information rather than recognise that it is a level of certainty. Del Mistro and Arentze (2002) found that choice model results can be compromised when respondents mistaken hypothetical scenarios as real scenarios and factor in their own experiential values into the choices presented. The advantage, however, is that by framing attribute labels as realistic pieces of information, the respondent may have an easier time of understanding the choice task and make a choice of information needs that would more likely reflect reality as opposed to hypothetical information in the following section.

Table 6.3. Example of attribute levels as descriptive information.

Attribute	Levels	**Attribute levels** *Least, medium, and most certainty, where most certainty should be the most attractive, safest choice to the respondent*
Fare Cost	3	• No information • ZAR 0.8 x *f* to 3 x *f*, where 0.8 x *f* is the lowest possible fare for the shortest distance in off-peak and 3 x *f* is the highest possible fare for the longest distance in peak travel* • ZAR 0.9 x *f*, based on time of day and trip length* *where f is the amount set by the respondent as what they consider acceptable to pay for a trip*
Arrival time	3	• No information • Scheduled arrival time based on timetable • Estimated arrival time based on live locations
Departure Time	3	• No information • Scheduled departure times based on timetables • Estimated departure times based on live locations
Frequency	3	• No information • Every 0.4 x *t* – 0.8 x *t* minutes, based on scheduled frequencies* • Every 0.5 x *t* - 0.7 x *t* minutes, based on actual frequencies* *where t is the time set by the respondent as what they consider to be acceptable to wait for a vehicle*
Vehicle-route identifier	2	• No information • E.g., 108 MyCiTi towards Hangberg and the minibus taxi with "Sea Point" in the dashboard
Safety onboard	2	• No information • No issues in last 6 months
Safety walking to/from vehicle	2	• No information • No issues within 5km of the station/stop the last 6 months
Safety while waiting	2	• No information • No issues in last 6 months

* values such as '0.8', '3', and '0.9' are examples of how an acceptable value as defined by the user might be manipulated to either increase or decrease perceived utility

6.4.4.2 Attribute labels – Unassigned - Option 2

For the second option, attribute labels are unassigned values and are qualitative representations of certainty (Table 6.4). Time-related attributes would be split into three levels reflecting the certainty of information: no information given, scheduled times, and real-time information. These levels also reflect the data requirements for delivering this information such that results from the analysis translate into realistic interventions. Though the two terms are alike, the term *frequency* was used over *wait times* to mirror the language used by the respondents in the one-in-one interviews. Interviewees expressed concern with 'how often will the vehicle arrive' (frequency) as opposed to 'how long will I wait for the next vehicle' (wait time). Fare information is also divided into three levels to reflect how this information may translate into real information: no information given, estimate (e.g., fare range based on off-peak/peak pricing), and exact amount (e.g., fare specifically for a given trip). For the other attributes, information is either said to be given or not given. Further detail is purposely omitted since the form 'information given' can take when employed in ICTs can vary (e.g., what kind of safety information, the extent of the safety information, the time period the safety information is relevant over) and could otherwise introduce bias in respondents' interpretations of the relative worth of that information compared to other attributes.

Table 6.4. Attribute levels as qualities.

Attribute	Levels	Attribute levels *Least, medium, and most certainty, where most certainty should be the most attractive, safest choice to the respondent*
Fare Cost	3	• Exact amount • Estimated amount • Not available
Arrival time	3	• Live actual times • Estimated times • Not available
Departure Time	3	• Live actual times • Estimated times • Not available
Frequency	3	• Live actual times • Estimated times • Not available
Vehicle-route identifier	2	• Information given • No information
Safety onboard	2	• Information given • No information
Safety walking to/from vehicle	2	• Information given • No information
Safety while waiting	2	• Information given • No information

With attribute labels as qualitative representations of certainty, the choice model would ask respondents to make a choice based on which information package would most help them plan a journey. While this option averts the risk of respondents making decisions based on the value of the attribute label itself as in the first option, the disadvantage here is that respondents might be unable to conceptualise what these attribute levels equate to in reality and may interpret their meanings differently. However, this can be tested in the pilot and attribute labels can be subsequently reworded to clarify meaning if needed. Because of this advantage, the design going forward used unassigned attribute levels.

6.4.5 Experimental Design

The experimental design is the process of generating choice sets such that the effect of the independent attribute levels can be seen on the response variable, the choice itself (Hensher et al., 2015). It results in the setup of the choice sets and contains the matrix layout of the various attributes, their levels and the respective alternatives. It is effectively a blueprint for the actual choice sets that the respondent sees.

Treatment combinations, or the possible ways of arranging attribute levels in an alternative, can be selected for the experimental design multiple ways. A full factorial design uses all possible treatment combinations. For example, in the case of this research where there are four attributes with three levels and four attributes with two levels, the total number of factorial combinations required would be 3^4 x 2^4, or 1296 combinations. In a case such as this research where many attributes need to be tested, the disadvantage of a full factorial design is that this could result in a very large and expensive survey and may include choice sets that have dominant and unrealistic alternatives that do not lend to the analysis (Louviere et al., 2000; Hensher et al., 2015). Many stated choice experiments have tended to rely on orthogonality in the experimental design, in which attributes are statistically independent, as part of a fractional factorial design (Tang et al., 2014). While some effects would go unobserved in a fractional design, it has been found that main effects account for about 70 to 90 percent of the explained variance with two-way interactions accounting for 5 to 15 percent, and therefore designs with estimations that take into account these two effects should suffice (Louviere et al., 2000). However, orthogonality has been critiqued because, though it produces a comprehensive set of possible combinations for the attribute levels within choice sets, not all of these combinations are sensical (Hensher et al., 2015). For example, in this research, an alternative with all the most certain level for all attributes and another with no information given for all attributes is possible but would also be a fairly obvious choice for the respondent and therefore an undesirable choice set to test. Instead, an efficient design can be used which can reduce the number of choice sets needed, and thereby also the sample size, if some information about the parameters is available (e.g., knowing if the sign of the parameter is negative or positive) (Hensher et al., 2015). This information can come from literature reviews, pilot studies, and previous relevant research.

A D-efficient design using a multinomial logit model for the survey choice sets was created in NGene. Dummy coding, used for categorical variables, was used to assign numerical values to the attributes to detect non-linear effects. As all variables were dummy coded, the challenge was ensuring that the choice sets did not contain dominant alternatives, or an alternative where there was no trade-off because it was the obvious best choice. In the case of this particular survey, 'no information' as an attribute level is not equal to at least some information given. In other words, the design needed to avoid choice sets with disproportionate counts of 'no information' where, say as an extreme, two of the alternatives has five out of eight attributes labelled as 'no information' and the third alternative has all attribute levels labelled as at least some or complete information.

Two possibilities were considered for mitigating highly unequal counts of 'no information' across the alternatives in a single choice set: strong priors and requirements. A prior is another term for the parameter value, or the beta value in the utility equation in section 6.3, equation 3. In the case of strong priors, prior estimates were set to -1.0 for 'no information' for all eight attributes and 1.0 was set as the prior estimate for the most certain information attribute for the fare and three time-based attributes. While this had the desired effect of creating choice sets with mostly non-dominant alternatives, there was the risk that the estimated prior is off from the real prior value and would ultimately negatively impact the analysis. The other approach used more conservative prior estimates for 'no information' and the most certain information levels, -0.1 and 0.1 respectively, but instead added in a requirement that no alternative can have more than one more or one less 'no information' than the other alternatives. As this option had the advantage of the two in eliminating all dominant alternatives entirely without compromising the prior values, this was the version that was subsequently used in the first NGene pilot experimental design.

To select a suitable design from those generated, the D-error and the S-estimate were considered. In a choice experiment, a D-error gives an indication of how a particular experimental design compares to other possible designs where the prior and parameter values are the same. To maximise the statistical efficiency of the experimental design, or the suitability of the design given the sample size required to elicit a model, the key is to minimise the D-error, and select the design with a D-error smaller than that of comparable designs (Hensher et al., 2015). Similarly, designs are also selected to minimise the S-estimate, because this value indicates the sample size requirements of the design to obtain parameters of statistical significance at the 95% confidence level. These S-estimates assume that the parameter priors set in the experimental design equations are accurate, and thus are only an indication of the sample size rather than a definite value.

6.5 SURVEYS

Respondents were intercepted at the main transit interchanges in Cape Town CBD, Bellville, Mitchells Plain, and Khayelitsha. Respondents were screened to include only those between the ages of 18 and 55, and those who did not report having access to a private motorised means of transport (i.e., are 'captive'). The paper-based surveys were orally administered, and responses were manually recorded (see Appendix E for the ethics clearance and Appendix F for the survey instruments). Respondents received a prompt prior to the choice tasks explaining that they would need to make a choice on which information they would need to plan a hypothetical travel situation. It was explained how information can have different levels of accuracy and they were told to assume they already have information on stop locations, transfer points, and operating hours. The different information types represented in the choice tasks were individually explained using the same terminology as in the BWS surveys (e.g., "fares – what is the cheapest travel option?") to provide a basic level of understanding of the information for those unfamiliar with the concept. Frequencies were explicitly expressed in this explainer as most related to MBTs, because they were the only mode without timetables and scheduled arrival and departure times. A map of the various O-D pairs used in the choice tasks was presented to respondents for reference. Innovative Transport Solutions (ITS), a local surveying company that often runs travel studies for the City of Cape Town, conducted the in-field surveys following training and with simultaneous feedback and monitoring.

6.5.1 Pilot Studies

Two pilot studies were conducted to (1) test whether the wording of the attribute labels clearly reflects their certainty levels and (2) obtain prior estimates to refine the utility equations to produce a more effective D-efficient experimental design.

The final designs for the pilots had 24 choice sets with six blocks of four choice sets. To ensure that each choice set was equally balanced with the two O-D pairs and two trip scenarios, permutations of each block were generated, thus resulting in 144 unique surveys.

6.5.1.1 Pilot 1

The first pilot's experimental design had three alternatives per choice set and was piloted in the last week of November 2020. The design had a D-error of 0.266 and S-estimate of 174.782, with a constraint of no more than one more or less 'none' information in one alternative than the other alternatives. 144 respondents were surveyed, which was more than the recommended 10% of the S-estimate of 18 people per block (rounded up from 17.5) giving 108 respondents total for the pilot (Bliemer, 2020). A dummy task was added to the beginning of the choice tasks with an alternative that clearly had the highest utility to check that respondents understood the choice task and were paying attention. Surveys that did not have a logical response to this task (in this case, 'C') were to be discarded.

Analysis of the data revealed several problems that had to be solved before the survey could be used to obtain unbiased prior estimates. Firstly, there was a high tendency to pick alternative C out of a choice of A, B, and C for the subsequent choice tasks if the respondent picked "C" for the first dummy task. Conversely, for the 23% of respondents that did not pick "C" for the dummy task, the answers to the rest of the choice tasks were more varied. This revealed that choice tasks and prompts were problematic and ineffective. Of the three surveyors, it was noted that one did consistently record 'C' as the response, which could be because either they did not understand the survey and explained it improperly to respondents or because they consciously recorded the responses with 'C' despite the respondents' choices. The other two surveyors also had respondents with surveys that missed the logical answer to the dummy task. In both cases, it was clear that the choice tasks and prompt were problematic and ineffective.

From these learnings, a couple of changes were made. Firstly, the dummy task was placed at the end of the choice tasks, so as not to influence respondents into thinking that there are correct answers to all the choice tasks. Secondly, the prompt leading into the choice tasks was revised to break down sentences with multiple pieces of information into statements with only one piece of crucial information each. Specific examples to explain the information types were also added, any complex words, and statement structures (e.g., if-then) were removed.

Following feedback from the surveyors, two additional changes were made. The number of alternatives was reduced from three to two to reduce complexity and response burden. The vehicle-identifier information type was removed as it was argued that it is a necessary piece of information that a public transport user needs to have to travel the appropriate route. Unlike the omitted pieces of spatio-temporal information (e.g., operating hours) that constrain whether a journey is possible or not, vehicle-identifiers do not place constraints on the possibility of a journey. However, in a city like Cape Town where there is not much overlap in routes in a given mode, a vehicle-identifier is a given piece of information that is uniquely connected to a route. On the other hand, a vehicle-identifier could be seen as an optional piece of information in a case like New York City with overlap in a mode, where knowing whether the next subway or not is an express or local service – those who have unwittingly boarded the express service and watched as their stop flew by will understand the pain of having missed that crucial piece of information as they wait for a subway to carry them back in the opposite direction.

6.5.1.2 Pre-pilot 2

A mini-pilot was conducted with 12 participants around Cape Town station to confirm that the changes made following the analysis of the first pilot were effective in making it easier for respondents to understand the survey and make choices that fit the objective of the study. The results from this study showed greater variability in the alternatives chosen, and all participants chose the correct answer to the dummy task.

However, a noticeable trend was observed where respondents tended to choose the alternative with less attributes with the attribute level 'no information given'. For example, if one alternative had two 'no information given' versus another with three, respondents would choose the one with two. This is problematic, as the objective of the study is not to have participants making choices based on the quantity of information but rather the quality of information. While setting a constraint that required NGene to produce a design that allowed for variability of a single 'no information given' attribute level across the alternatives gave the software flexibility to produce an efficient experimental design, it still left room for respondent bias. Thus, the objective in producing the next experimental design was to ensure that each alternative within a choice did not have noticeably unbalanced 'no information' attribute levels.

6.5.1.3 Pilot 2

The three concerns arising from the early pilots that needed to be addressed were (1) complexity of the choice set given the respondents' abilities to understand them, (2) the impulse to fall back on the number of 'no information given' attribute levels and make a decision based on the alternative with the least 'no information given' (lending answers showing a preference for quantity of information as opposed to the quality), and (3) falling back on a single information attribute to make a choice. The third concern is more likely to arise out of a design that is too complex leading to the respondent feeling overly burdened, possibly wanting to quickly make a choice, and so chooses one attribute to focus on to reduce the cognitive complexity.

The obvious answer to these concerns would be to generate a 2-alternative design with a requirement wherein each alternative contains the same number of 'no information given' attribute levels as the other. However, such a strict design is impossible to generate in NGene. It is, however, possible for NGene to produce an efficient design where up to six attribute levels out of the seven can be exactly the same level of 'no information given', but then one condition needs to allow flexibility, e.g., if the first alternative contains only one 'no information' then the second can contain two. However, this still generates a design with a high D-error and would require a sample size beyond the budget of this research.

On the other hand, a 3-alternative design offers a lower D-error and requires a far smaller sample size. NGene is not able to calculate a design with strict constraints to balance a single attribute level across all alternatives, nor can it do so if these constraints are relaxed as was the case in a 2-alternative design. However, a compromise can be achieved in setting design constraints such that no alternative contains more than or less than one 'no information' level than the other two. At least two of the three alternatives will have the same level of 'no information given'. If a respondent is found to be chasing alternatives that have the least 'no information given' for all 12 choice sets, then their survey responses can be omitted from the analysis. While a 3-alternative design is more complex than a 2-alternative design, cognitive burden can be decreased by setting a requirement that each alternative has at least three 'no information given' levels, so the respondent must only consider the information quality of a maximum of four attributes per alternative. This decrease in complexity can help reduce the issue of the third concern (i.e., deciding based on a single information attribute). The second pilot study was created and used a 3-alternative design with a D-error of 0.299 and an S-estimate of 151.44 and run in March 2021.

The MNL model estimation results for analysis of the limited number of sampled surveys in the final pilot study (Appendix G) were calculated using Apollo, a freely available software, in R Studio to generate new parameter prior estimates for the final survey's experimental design (see Hess and Palma, 2021). The model included 91 respondents in total of the 145 surveyed, as 54 responses with illogical answers to the dummy task were omitted. Estimated information was set as the base in the case of the fare and time related attributes and exact information was set as the base for safety information.

6.5.2 Full Study Design

6.5.2.1 Design

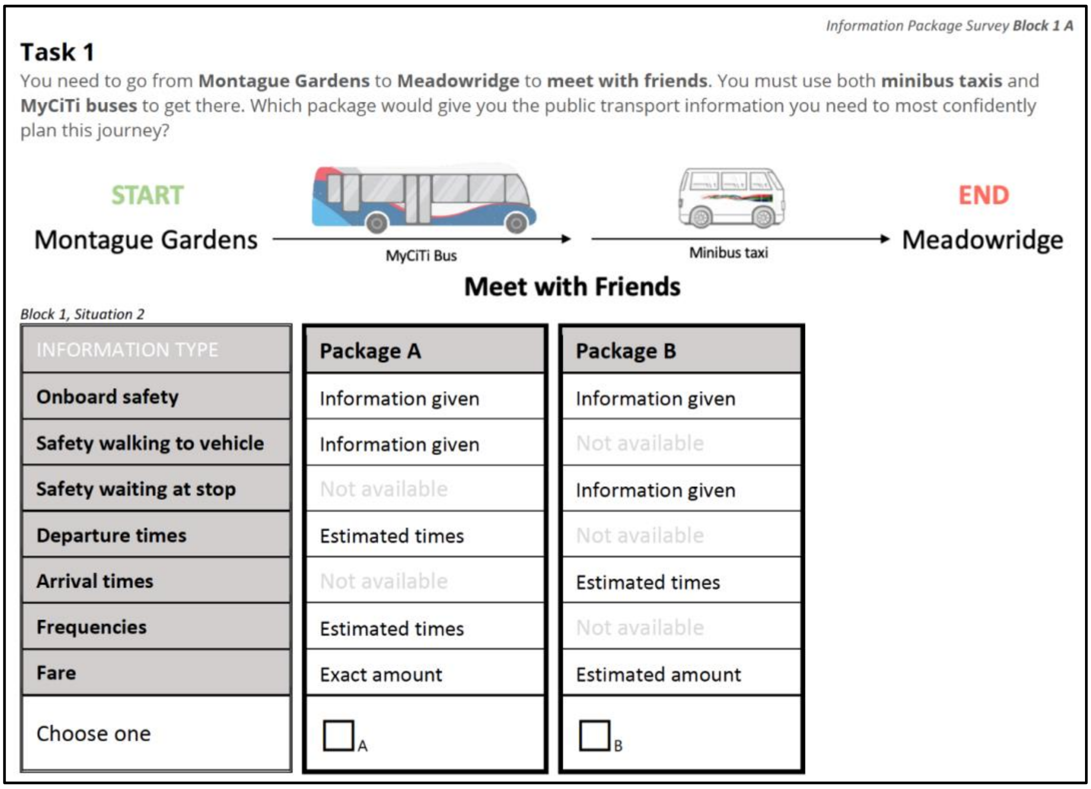
The final choice model design used coefficient estimates from the MNL model results of the second pilot study. The prior for exact fares needed to be tweaked because it was too close to zero, and so greatly affected the S-estimate, or sample size needed, to estimate this prior in the full study. The S-estimate was in the several thousands. This prior was brought back to the estimate value used in the pilot study (0.1).

From the estimation results, *estimated arrival times* (timetables) followed by *exact arrival times* are most important in terms of impact on utility. There may have been biases in terms of 'timetabled times' vs 'actual arrival times', where respondents viewed 'timetable' as a type of information rather than as a descriptive word for quality. Thus, 'timetabled' was changed to 'estimated' as it was for frequencies.

Furthermore, there was still a problem with the choice task comprehension in the second pilot study, as 37% of respondents failed to answer the dummy task logically. Most of these respondents were surveyed by the same surveyor, so there may still have been a surveyor training issue which could be addressed prior to the final study. However, this still left too many unusable surveys. From feedback from the surveying company, a two-alternative design was strongly encouraged over a three-alternative design to reduce complexity for respondents and mitigate response burden. While a two-alternative design introduces imbalances in the attribute levels with information given, it was thought respondents would more likely give thoughtful answers than quick answers.

The dummy task was altered to capture a deeper understanding of respondent's ability to comprehend the choice tasks. Both alternatives had information given for all attributes (i.e., there is 'no information' listed). The first alternative had partial information (estimates), while the second had full (exact) information. The logical choice, if a person understood that the survey task, was to choose the second alternative with the best quality information for their travel needs. This approach solved the concern that uneven information given in the dummy task might predispose respondents into making choices based on quantity rather than quality of information given. The dummy task was moved back to the front of the survey, as it might help ease respondents into the survey.

A question followed the dummy task asking the respondent to explain their choice, after which the surveyor then indicated whether the respondent understood the task given their rationale. While the dummy tasks traditionally are used to test whether a respondent is making logical choices across the choice tasks, this method is not fail-proof. The respondent may have simply guessed the right answer correctly or had a rational answer for choosing the choice with less utility. Asking this additional question provides complementary feedback on comprehension of the choice tasks.


Information Package Survey ***Block 1 A***

Task 1

You need to go from **Montague Gardens** to **Meadowridge** to **meet with friends**. You must use both **minibus taxis** and **MyCiTi buses** to get there. Which package would give you the public transport information you need to most confidently plan this journey?

Block 1, Situation 2

INFORMATION TYPE	Package A	Package B
Onboard safety	Information given	Information given
Safety walking to vehicle	Information given	Not available
Safety waiting at stop	Not available	Information given
Departure times	Estimated times	Not available
Arrival times	Not available	Estimated times
Frequencies	Estimated times	Not available
Fare	Exact amount	Estimated amount
Choose one	☐ A	☐ B

Figure 6.5. Example of a choice task given to respondents.

The final D-efficient design had a D-error of 0.342 and an S-estimate of 203. Constraints were set such that neither of the two alternatives had one more or one less 'no information' than the other, and the number of times 'no information' appeared per alternative was limited to either three or four times. An example of a choice card used is in Figure 6.5.

6.5.2.2 Sample Size

Sample size requirements for discrete choice models have been argued to be estimated various ways (e.g., Rose and Bliemer, 2013). NGene provides an S-estimate which is the minimum number of respondents required per block estimated to be needed for the model estimation. In this case, with an S-estimate of 203 and 6 blocks, 1218 respondents are needed to estimate the model. However, it is important to note that a small prior estimate can greatly skew the S-estimate towards large values. So, if the prior estimates determined in the pilots were off, these could negatively impact the S-estimate, and in fact a smaller sample size may be needed than estimated in NGene. Johnson et al. (2007) suggest that the minimum sample size, n, to study main effects can be estimated through the following equation where *NLEV* is the largest number of levels of any attribute, *NALT* is the number of alternatives per choice set, and *NREP* is the number of choice questions per respondent:

(9) $$n = 500 * \frac{NLEV}{NALT * NREP}$$

In this case with two alternatives per choice set, three levels at most per attribute, and four unique choice questions per respondent, 188 people are needed per block, or 1128 respondents.

Other guidelines for determining appropriate sample sizes would require far less respondents, as compared to NGene's S-estimate and Orme's rule of thumb applied to this research. Sample sizes over 100 surveys are generally enough to estimate models, according to Pearmain et al. (1991), while Lancsar and Louviere (2008) found that about 20 respondents per survey version would suffice to estimate models for main effects. That is, for this survey of six blocks, 120 total respondents would be needed.

The final survey used these conservative sample size guidelines as a benchmark. To balance sufficient sampling with resource efficiency, the final sample size was determined by conducting the survey in blocks of 144 surveys and applying an MNL estimation to see whether the estimates of the information types greatly changed ranking. The main effects were considered the most important points of analysis in the survey, so the objective was to reach the sample size needed to estimate these.

6.6 RESULTS AND DISCUSSION

A total of 501 surveys from 576 (87%) collected were included in the choice modelling results, as 53 surveys were not included because the surveyor indicated lack of understanding of the choice task, the respondent was outside of the acceptable age range (18 to 55), or the respondent did not seem engaged with the survey and chose the same alternative (e.g., leftmost alternative) for all 12 choice tasks. Of the included respondents, 256 (51%) were male and 244 (49%) were female, 265 (53%) were between 18-29 years of age, 184 (37%) between 30-39, and 52 (10%) between 40-55. The racial split was predominantly between Coloured (39%) and Black (59%) respondents with only a few of other categories (2%). Infrequent public transport use (less than once a month or 1-3 times a month) was limited, with most people 64% reporting using public transport 5-7 days a week, 31% reporting 5-7 days a week, and only 4% stating only once a week. They were surveyed at the four major interchanges: evenly split between Cape Town CBD, Bellville, Mitchells Plain, and Khayelitsha. Summary counts of respondent characteristics are provided in Table 6.6.

Table 6.6. Overview of survey and respondents' characteristics (counts).

Sex		**Race**		**Age Range**	
Male	256	Coloured	197	18-29	265
Female	244	Black	295	30-39	184
Unknown	1	Other	8	40-55	52
		Unknown	1		
Survey Location		**Frequency of Public Transport Use**			
Bellville	126	5-7 days a week	321		
Cape Town	125	2-4 days a week	156		
Mitchells Plain	125	Once a week	19		
Khayelitsha	125	1-3 times a month	4		
		Less than once a month	1		

An MMNL model was applied in the analysis where equation 3 (from section 6.3) can be adapted to factor in a respondent's repeated choices, such that utility varies over respondents but is consistent for the responses that a respondent makes across choice situations (t). The utility equation becomes (Train, 2003):

(10)

$$U_{njt} = \beta' x_{njt} + \varepsilon_{njt}$$

This is panel data, or data that represents repeated choices, which is what results if you show a respondent multiple choice sets. All MMNL models generated in this section used the same approach to simulating estimation. For these models, Halton sequences were not used for the draws because of the large number of parameters that needed to be estimated (Bhat, 2003). Instead, the models used Modified Latin Hypercube Sampling (MLHS) for the draws which was shown to be a promising approach given the model type and large number of parameters (Hess et al., 2006). For all MMNL models, 800 draws were used as this was found through testing to be where the estimates stabilised.

For each attribute in the models, the level 'no information' is set as the base in the modelling. The representative utility functions used in each model account for main effects only (see Appendix H for all utility equations used in Apollo for the final MNL and MMNL models presented). The MMNL models account for variation in information needs across respondents (i.e., using inter-individual draws), but not variation in a respondent's own information needs across multiple choice situations (i.e., using intra-individual draws). Variation within an individual's choices was not incorporated into the model because it would say little given that each scenario that an individual was given lent a slightly different context to the hybrid journey.

The performance of the models across all responses were generated using Apollo and compared. Several measures can be used to compare the strength of one model over another including the likelihood ratio test, the Akaike Information Criterion (AIC), and the Bayesian Information Criterion (BIC). The AIC and BIC measures both penalise models that have more parameters, though of the two, BIC penalises models with a larger number of parameters more (Hess, 2021). While all three measures were considered in the performance of the models, where the values for BIC and AIC were quite similar, the likelihood-ratio test was applied.

Using the likelihood-ratio test (also known as the Wilks test) the goodness of fit of the MMNL model was compared to the MNL model and the MMNL model without sociodemographic coefficients was compared to an MMNL model with sociodemographic coefficients. This test using the following equation can be used to compare the ratios of two models' log-likelihoods in instances where a simpler model (restricted) is nested within a more detailed version of the model (unrestricted):

(10) $$-2(LL_1 - LL_2) \sim \chi_d^2$$

Essentially the log-likelihood of the restricted model (LL_2) is subtracted from that of the unrestricted model (LL_1) and compared to the chi-square critical value based on the degrees of freedom calculated by the difference in the parameters used in the two models (Hensher et al., 2015). If there is no significant difference, then it means that the unrestricted model simplifies to the restricted model.

6.6.1 MNL and MMNL Models for All Respondents Across all Scenarios

An MNL and two MMNL models were estimated to compare the strength of the models and determine which to use as the basic model going forward. An MMNL model with a normal distribution was generated for all attribute levels as parameters and a second with the inclusion of ASCs (Alternative-Specific Constants). Hensher et al. (2015) maintain that including ASCs in unlabelled choice experiments, even though they do not represent a choice in and of themselves, the way they do in a labelled experiment (car vs train), may be a good idea for a few reasons. One, there is no real reason not to include ASCs. Two, because of behavioural biases, ASCs can help account for these, such as the tendency to bias towards the choice on the left compared to those on the right. Hence a model with ASCs was generated for comparison.

Given a loglikelihood test, of the basic MMNL without the ASCs and MNL models, the MMNL model preformed the best. However, when this MMNL model was compared to the MMNL model with ASCs included, the latter performed better.

Table 6.7 provides the estimates for each attribute level (α) and the standard deviations (γ) for the MMNL models. The parameter estimates for the mean (α) of all information types, regardless of whether the level was exact or estimate, were significant at a 99% (α=0.01) confidence interval for a one-tailed t-test (one-tailed because some information is always expected to be of equal or higher utility compared to no information). Given the objective of this section was to understand which information types and level of quality are needed for planning non-routine trips within the hybrid network, where an attribute has both 'exact' and 'estimate' levels it is important to understand which level of quality is needed.

Table 6.7. Comparison of three basic models for estimating parameters across all respondents and choice situations.

Model	MNL		MMNL - Normal		MMNL - Normal w/ ASC	
Final LL	-3916.749		-3529.531		-3522.729	
Parameters	11		22		23	
Rho-sq.	0.0601		0.153		0.1547	
AIC	7855.5		7103.06		7091.46	
BIC	7929.21		7250.5		7245.59	
	Estimate	**Rob.t-ratio**	**Estimate**	**Rob.t-ratio**	**Estimate**	**Rob.t-ratio**
ASC_1	-	-	-	-	-	-
ASC_2	-	-	-	-	-0.4528	-3.6042
Arrival estimate (α)	0.4745	6.3342	0.8652	7.3761	0.9338	7.6270
Arrival estimate (γ)	-	-	0.7350	-5.1200	0.6235	-3.8459
Arrival exact (α)	0.7859	10.2190	1.3344	10.7558	1.0610	7.5333
Arrival exact (γ)	-	-	0.3248	-1.3794	0.4340	-2.7834
Departure estimate (α)	0.6327	9.3716	1.0535	9.3946	0.7965	6.3083
Departure estimate (γ)	-	-	0.7774	-6.6213	0.8402	-7.1361
Departure exact (α)	0.7400	9.7491	1.2651	10.5388	0.8962	6.0159
Departure exact (γ)	-	-	0.8503	-7.0749	0.7908	5.6739
Fare estimate (α)	0.7651	12.1444	1.2388	12.0102	1.1046	10.8376
Fare estimate (γ)	-	-	0.7081	5.6166	0.7204	6.1926
Fare exact (α)	0.8789	11.1430	1.3549	10.3165	0.9758	6.3768
Fare exact (γ)	-	-	1.1518	10.3214	1.1541	10.3499
Frequency estimate (α)	0.7642	11.5329	1.2247	10.7798	1.2982	10.9539
Frequency estimate (γ)	-	-	0.8048	-5.0604	0.8495	-6.2482
Frequency exact (α)	0.7582	10.4226	1.2588	10.0452	1.0400	7.7547
Frequency exact (γ)	-	-	0.9547	7.0221	0.8120	5.7533
Safety onboard (α)	0.5531	10.0251	0.8957	9.4111	0.7303	6.8275
Safety onboard (γ)	-	-	0.4435	-3.1276	0.5494	-4.2113
Safety waiting (α)	0.6853	10.6258	1.1188	10.5432	0.8261	6.3433
Safety waiting (γ)	-	-	0.5864	4.5241	0.5012	-4.4003
Safety walking (α)	0.8366	12.8038	1.3858	12.0482	0.9268	5.9833
Safety walking (γ)	-	-	0.2562	1.2372	0.2306	1.2597

Where α is the mean parameter estimate, and γ is the standard deviation of the parameter estimate.

In this case, the MMNL model without ASCs shows that for each attribute level with such levels, 'exact' information has larger estimates for its parameter values in all cases. Ranked by estimates, the top three attribute levels are safety walking followed by exact fares and exact arrival times. Estimated arrival times followed by safety onboard and estimated departure times were ranked as the attributes that contribute the least utility gains. However, with the inclusion of the ASCs in the model, potential left-right bias is accounted for and the parameter estimates and respective rankings change somewhat. When filtering the model with ASCs by information quality, such that the first quality (level) of an information type is taken and the second quality is not considered in the ranking (because, for example, if estimated arrival times have a larger parameter estimate value than exact arrivals then it can be said that the provision of estimated arrival times suffices), then estimated frequencies, estimated fares and exact arrival times had the greatest contribution to information utility. Safety while walking, exact departure times, safety while waiting, and safety onboard followed in that order in the ranking. Given exact arrival time had a large contribution to the overall utility, it makes sense that estimated arrival was comparatively small if respondents rejected estimated times as useful compared to exact times, or even as useful given the context of the reliability of schedules on ground.

Both models' estimation results are entirely plausible – it would make sense that respondents selected the alternative with 'exact' attribute levels if these happened to be largely within the first alternative and hence the preference for all exact information in the first MMNL model. Likewise, it is possible that respondents did exhibit left-right bias and that they also found estimated frequencies and fares at least just as good as the exact information equivalents. However, a likelihood ratio test reveals that the MMNL model with ASCs included is significantly stronger than that without ASCs and both the AIC and BIC values are lower for the model with ASCs despite the additional parameter. Hence, the model with ASCs is a likely stronger model and thus used going forward.

Unlike the MNL model, the MMNL model also tested for heterogeneity across respondents. Given the corresponding p-values of the standard deviations of the coefficients less than 0.05 (the 95% confidence level) for all but one parameter estimate, the values of the standard deviations are highly significant, revealing that there is variation in these coefficients in the population. Safety while walking was the only parameter estimate where the standard deviation of the parameter estimate was not statistically significant at the 95% (or even 99%) confidence interval, meaning that there is no reason to accept the idea that there is variation across the population in demand for information on walking safety. While preferences differed across the population for information needs such as exact departure times (and in part this may be because of changes in the scenarios surrounding the choice sets), information on walking safety consistently was demanded across the population despite the changing circumstances of the choice sets.

6.6.2 MMNL Model for Interaction Effects with Sociodemographic Characteristics

Socio-demographics were analysed as covariates, to understand their individual effects on the parameter estimates (see Table 6.8). The socio-demographic variables sex (binary - female/male), age (categorical - 18 to 29, 30 to 39, 40 to 55), and race (binary - Black/other) were treated as interactions between each attribute within the utility equations for each alternative. Given the likelihood-ratio test (where -2 x (-3522.739 − -3515.087) = 15.304 is greater than χ^2_4 =9.488), this model was a significantly stronger fit than the original basic MMNL model where sociodemographic variables were not factored in. There was no significant difference in overall information needs based on race or age range. There, however, was a significant difference in overall information needs based on sex.

Table 6.8. MMNL model with normal distribution with sociodemographic coefficients.

Model	MMNL - Normal			Variable	Value	Estimate	Rob.t-rat.
Final LL	-3515.087	AIC	7084.17	Constant	ASC_2	-0.4516	-3.6685 ***
Parameters	27	BIC	7265.11	sex	female	-0.4511	-3.0701 ***
Rho-sq.	0.1565			race	Black	-0.1839	-1.2348
				age group	18 to 29	0.0991	0.4444
					30 to 39	0.1547	0.6600

Information Type	Value	Estimate	Rob.t-rat.	Value	Estimate	Rob.t-rat.
Arrival estimate	(α)	1.1299	4.3964 ***	(γ)	0.6991	-5.6652 ***
Arrival exact		1.2793	4.6564 ***		0.3697	-1.8741 **
Departure estimate		1.0086	3.7918 ***		0.7673	-6.5772 ***
Departure exact		1.1184	3.9663 ***		0.8458	-6.8276 ***
Fare estimate		1.3092	5.2068 ***		0.6930	4.9663 ***
Fare exact		1.1890	4.2410 ***		1.1362	9.9790 ***
Frequency estimate		1.5080	6.0102 ***		0.7858	5.6445 ***
Frequency exact		1.2789	4.7906 ***		0.8105	5.4389 ***
Safety onboard		0.9505	3.6979 ***		0.4647	-3.5688 ***
Safety waiting		1.0396	3.8076 ***		0.5942	5.2543 ***
Safety walking		1.1622	4.1538 ***		0.4341	3.8854 ***

*, **, *** indicates significance at the 10%, 5%, 1% level.
Where α is the mean parameter estimate, and γ is the standard deviation of the parameter estimate.

6.6.2.1 MMNL Model for Interaction Effect of Sex with Each Attribute Level

As sex emerged as the only sociodemographic where there was a difference in information needs, sex was investigated further as individual parameters with each attribute level. 'Male' was kept as the base, so 'female' was used as the variable in the estimations. Given the likelihood ratio test (where -2*(-3522.739- -3508.1) = 29.278 is greater than χ^2_{11} = 19.675), this model was a significantly stronger fit than the basic MMNL model where sex was not factored in. From Table 6.9, a significant difference at the 99% confidence interval is apparent for preference for the following information types: estimated fares, exact fares, safety onboard and safety while walking. While females prefer this information to no information at all, they are less sensitive to needing this information than male respondents. At the 95% confidence interval, there is a significant difference between preference for all information types between males and females with two exceptions: exact departure times and estimated frequencies. Males are more sensitive to needing fare and most time-based information compared to females. Most interestingly, males prioritise information regarding safety onboard, waiting safety, and walking safety significantly more to females. Travel patterns and past experiences may have influenced respondents' choices. Perhaps females travel in groups more as opposed to males because of the anticipated security risks (though there is no research to date to support this theory) and may collectively have less personal experience as victims of attack. Crime data suggests that males are more likely than females to be victims of crime, particularly young males (e.g., Schönteich and Louw, 2001). Opinions amongst female respondents might be quite varied which is why the parameter estimates for female interaction effects are all negative – the characteristics (e.g., occupation) of the females surveyed may have been more diverse.

Table 6.9. MMNL model where sex is an individual parameter for each attribute level.

					Value	Est.	Rob.t-rat.	
Model		MMNL - Normal						
Final LL	-3508.1	AIC	7084					
Parameters	34	BIC	7312		ASC_2	-0.4628	-3.6435	***
Rho-sq.	0.1582							

	Value	Est.	Rob.t-rat.		Value	Est.	Rob.t-rat.		Value	Est.	Rob.t-rat.	
Arrival est.		-0.5268	-2.2980	**		1.1370	6.8474	***		0.7448	-6.0903	***
Arrival exact		-0.4774	-2.0121	**		1.2479	6.8801	***		0.3937	1.7437	**
Departure est.		-0.4319	-2.0698	**		0.9677	5.8648	***		0.7319	-5.7867	***
Departure exact		-0.1449	-0.6337			0.9411	5.0511	***		0.7982	-6.4577	***
Fare est.		-0.6081	-3.1035	***		1.3836	10.1908	***		0.7048	6.0754	***
Fare exact	sex: female	-0.9351	-3.6367	***	(α)	1.3955	7.1424	***	(γ)	1.0944	9.3642	***
Frequency est.		-0.2043	-0.9805			1.3569	9.0688	***		0.8426	-4.8270	***
Frequency exact		-0.3853	-1.6789	**		1.1931	6.7824	***		0.8626	6.3618	***
Safety onboard		-0.5691	-3.1108	***		0.9890	7.3181	***		0.4983	-3.0299	***
Safety waiting		-0.4773	-2.3097	**		1.0153	6.2131	***		0.5527	3.9337	***
Safety walking		-0.7167	-3.3313	***		1.2651	6.6079	***		0.2676	0.9378	

*, **, *** indicates significance at the 10%, 5%, 1% level.
'Est.' is 'estimate'.
Where α is the mean parameter estimate, and γ is the standard deviation of the parameter estimate.

The dataset was split into two by respondents' sex and an MMNL model was run for both datasets to understand the individual rankings of attribute levels by estimates. Preference for information between males and females have some similarities (see Table 6.10). Both sexes prioritise exact arrival times to arrival estimates, as well as information on walking safety and waiting safety more than safety onboard. A stark difference is that males place the most importance on the usefulness of fare information in planning a journey compared to females who prioritise frequency information. Females are less sensitive to fare information and find estimated fares equivalent or preferable to exact fares. Overall, females prioritise time-based information (frequencies, exact departures and exact arrivals) to safety information, whereas men most prefer information on fares, exact arrival times and safety walking. Females ranked exact departure time over estimated departure time and far more highly than males for whom exact departure time was ranked absolute last. Heterogeneity in preference for the attribute levels varied significantly at the 95% confidence interval for every single parameter except for safety walking.

Though scenarios were given to frame the choice sets, it is possible that respondents still had the nature of their usual trips in mind when making choices. Differences in information preferences may stem from the types of trips males and females tend to make. According to Stats SA (2016b), South African females are more likely than males to make trips by MBT – respondents were informed at the start of the interview that frequencies relate to how often the taxis come, whereas departure and arrival time information is more relevant to scheduled modes. This could explain the strong preference for frequencies amongst females. Females may also tend to make more trips than males, particularly during off-peak times when services reduce their frequencies. Though national household travel survey data from 2013 suggests females make around the same number of trips as males (Vanderschuren et al., 2019), shorter trips may be underreported as international literature suggests that females in developing countries make more trips (Duchène, 2011). Differences in general trip patterns may explain some of the variation sensitivity to different information types.

Table 6.10. MMNL models for separate datasets for male and female respondents.

Model	**MMNL - Normal**	Final LL		-1733.97		Final LL	-1768.164	
Draws	800	Rho-sq.		0.1456		Rho-sq.	0.1696	
type	mlhs - inter	AIC		3513.94		AIC	3582.33	
Parameters	23	BIC		3651.53		BIC	3721.02	
	FEMALES			**Rank by α**		**MALES**		
Parameters	**Est.**	**Rob.t-rat.**		**Est.**		**Est.**	**Rob.t-rat.**	
ASC_2	-0.4733	-2.4531	***			-0.4791	-2.6794	***
Arrival estimate (α)	0.5885	3.4327	***	6	7	1.1064	6.5127	***
Arrival estimate (γ)	0.7584	3.3864	***			0.7266	-4.1365	***
Arrival exact (α)	0.7454	3.6133	***	5	4	1.1991	6.1028	***
Arrival exact (γ)	0.4319	2.0609	**			0.4827	-2.4056	***
Departure estimate (α)	0.5510	3.0956	***	7	8	0.9623	5.3019	***
Departure estimate (γ)	0.6876	3.4756	***			0.7616	4.8831	***
Departure exact (α)	0.7748	3.5333	***	3	11	0.9313	4.3831	***
Departure exact (γ)	0.7782	4.2822	***			0.7738	4.2130	***
Fare estimate (α)	0.7493	5.0534	***	4	1	1.3411	9.2058	***
Fare estimate (γ)	0.7338	3.6153	***			0.5626	1.7930	**
Fare exact (α)	0.4772	2.0177	**	10	2	1.3148	6.2845	***
Fare exact (γ)	1.0179	-7.1630	***			1.2352	7.4737	***
Frequency estimate (α)	1.1369	6.5723	***	1	3	1.2836	8.2674	***
Frequency estimate (γ)	0.8766	3.4220	***			0.6001	2.8801	***
Frequency exact (α)	0.7835	4.1244	***	2	6	1.1185	5.9718	***
Frequency exact (γ)	0.8725	-4.5108	***			0.9989	5.7453	***
Safety onboard (α)	0.4135	2.6321	***	11	10	0.9409	6.4956	***
Safety onboard (γ)	0.4813	-2.0430	**			0.4057	-1.4633	**
Safety waiting (α)	0.5166	2.6799	***	9	9	0.9527	5.1699	***
Safety waiting (γ)	0.6332	4.0940	***			0.5286	2.3088	**
Safety walking (α)	0.5482	2.4448	***	8	5	1.1667	5.2720	***
Safety walking (γ)	0.2804	-0.7379				0.2109	-0.4121	

*, **, *** indicates significance at the 10%, 5%, 1% level.
'Est.' is 'estimate'.
Where α is the mean parameter estimate, and γ is the standard deviation of the parameter estimate.
Ranking is determined based on the parameter estimate values and is in ascending order of largest to smallest.

6.6.3 MMNL Model for Interaction Effects of Scenarios

A MMNL model (Table 6.11) was run to see whether the trip scenarios surrounding the 12 choice sets shown to respondents had any effect on the information needs. The three modal combinations, journey purposes, and O-D pairs were included as coefficients across all the attribute levels. Given the likelihood-ratio test (where -2*(-3522.739- -3518.025) = 9.428 is not greater than χ^2_4 =9.488), this model was not a significantly stronger fit than the basic MMNL model where scenarios were not factored in. Though no significant difference was found at the 90% confidence interval in information needs depending on the modal combinations or O-D pairs, this model did suggest that trip purpose introduced a significant difference in information needs at the 90% confidence interval.

Table 6.11. MMNL model for interaction effects of each scenario.

Model	MMNL - Normal		
Final LL	-3518.025	AIC	7090.05
Parameters	27	BIC	7270.99
Rho-sq.	0.1558		

Variable	**Value**	**Estimate**	**Rob.t-rat.**	
Constant	ASC_2	-1.2177	-8.8126	***
Mode	MyCiTi	-0.0940	-1.0991	
	GABS	-0.0940	-1.1661	
Purpose	Meet with friends	0.1641	1.4449	*
O-D Pair	Montague - Meadowridge	0.0235	0.1526	

Information Type	**Value**	**Estimate**	**Rob.t-rat.**		**Value**	**Estimate**	**Rob.t-rat.**	
Arrival estimate		0.9216	5.4306	***		0.7075	-5.9203	***
Arrival exact		1.1175	5.4872	***		0.4574	3.2670	***
Departure estimate		0.7133	4.1468	***		0.6634	-4.4976	***
Departure exact		0.8811	4.3355	***		0.7720	-5.7661	***
Fare estimate		1.0115	7.1628	***		0.7332	6.0703	***
Fare exact	(α)	0.8925	4.5722	***	(γ)	1.0575	-9.0377	***
Frequency estimate		1.3529	8.0138	***		0.8093	-5.6741	***
Frequency exact		1.0855	5.6117	***		0.8212	6.0822	***
Safety onboard		0.6573	4.0872	***		0.5219	-4.3762	***
Safety waiting		1.3986	4.0357	***		1.3708	7.6429	***
Safety walking		0.7790	3.9952	***		0.1309	1.0472	

*, **, *** indicates significance at the 10%, 5%, 1% level.
Where α is the mean parameter estimate, and γ is the standard deviation of the parameter estimate.

6.6.3.1 Trip Purpose

To see how trip purpose may differentially affect information needs, a MMNL model was run whereby trip purpose was set as individual parameters as interaction effects with each attribute level (see Table 6.12) such that the preference for each attribute level given the trip purpose could be individually analysed. The social trip purpose “meet with friends” was used as the parameter while “job interview” was kept as the base. This newly generated MMNL model was significantly stronger at estimating the parameters than the basic MMNL model on all bases of comparison (e.g., log-likelihood ratio, AIC, BIC). In this case, significance was found at the 99% confidence interval for exact arrival times and exact frequencies, where meeting with friends was less likely to require these information types than planning a trip for job interview purposes. This makes sense given that a common rule to leaving a good impression at a job interview is to arrive on time. However, the need for information on walking safety for leisure trips versus appointment-based trips like job interviews was highly significant (α=0.01). At the 95% confidence level, exact fares, exact departure times, and estimated arrival times were less useful for the social trip purpose. Safety onboard, however, was significantly more useful for planning trips to meet with friends. This finding is in line with a study conducted by Nordfjærn et al. (2015) where safety and security perceptions were more sensitive for leisure trips than work trips. At the 90% confidence interval, estimated frequencies were less useful for social trip planning purposes. There was no significant difference in the need for information on waiting safety, fare estimates, and estimated departure times between trip purposes, meaning regardless of the trip purpose, this information was similarly valued. Overall, journeys for job interviews are more time-sensitive than for social purposes, while safety is a more important concern when making journey decisions to meet with friends.

Table 6.12. MMNL model for interaction effects of trip purpose as an individual parameter with each attribute level.

Model	**MMNL - Normal**						
Final LL	-3464.109	AIC	6996.22	**Value**	**Est.**	**Rob.t-rat.**	
Parameters	34	BIC	7224.07	ASC (asc_2)	-0.4261	-3.4128	***
Rho-sq.	0.1687						

	Value	**Est.**	**Rob.t-rat.**		**Value**	**Est.**	**Rob.t-rat.**		**Value**	**Est.**	**Rob.t-rat.**	
Arrival est.	trip purpose: Meet with friends	-0.5180	-2.0202	**	(α)	1.1498	6.6940	***	(γ)	0.397	-1.620	*
Arrival exact		-0.8293	-3.3596	***		1.4509	7.7310	***		0.407	-2.657	***
Departure est.		-0.0995	-0.4596			0.8526	5.0215	***		0.784	6.324	***
Departure exact		-0.3873	-1.6636	**		1.0957	5.8571	***		0.808	-7.340	***
Fare est.		0.1476	0.7318			0.9859	7.0914	***		0.606	-3.752	***
Fare exact		-0.4129	-1.6505	**		1.1554	5.7396	***		1.135	10.740	***
Frequency est.		-0.2911	-1.3441	*		1.3898	8.6935	***		0.895	-6.806	***
Frequency exact		-0.8953	-3.6690	***		1.4549	7.7458	***		0.822	5.986	***
Safety onboard		0.3488	1.9196	**		0.5434	3.9570	***		0.478	2.906	***
Safety waiting		0.1150	0.5868			0.7656	4.6905	***		0.508	-3.657	***
Safety walking		0.4970	2.4039	***		0.6649	3.5099	***		0.030	-0.065	

*, **, *** indicates significance at the 10%, 5%, 1% level.
'Est.' is 'estimate'.
Where α is the mean parameter estimate, and γ is the standard deviation of the parameter estimate.

To gain an understanding of ranked information needs, the dataset was split into two separate datasets based on trip purpose and a separate MMNL model was run on both datasets. The results and rankings for the parameter estimates (α) are presented in Table 6.13. Because of the time-sensitive nature of job interviews and associated importance of arriving on time, it is not surprising that time-based information, frequencies, and exact arrival times were most important. In fact, all time and fare-based attributes ranked higher than the safety information. Conversely, time-based information was relatively unimportant for leisure trip planning as compared to concerns such as safety and fare cost. Based on the value of the parameter estimates, all safety information ranked in the top half of the list for planning trips to meet with friends – hitherto, only walking safety had ranked highly in the other models. For both trip purposes estimated fares were seen to be better than or at least as useful as exact fares.

Table 6.13. MMNL model for two separate datasets for trip purposes.

Model	**MMNL - Normal**	Final LL	-1731.028			Final LL	-1717.204	
Parameters	23	Rho-sq.	0.1692			Rho-sq.	0.1758	
		AIC	3508.06			AIC	3480.41	
		BIC	3646.25			BIC	3618.6	
	MEET WITH FRIENDS					JOB INTERVIEW		
Parameters	**Est.**	**Rob.t-rat.**		**Rank**		**Est.**	**Rob.t-rat.**	
ASC_2	-0.2777	-1.6637	**			-0.7557	-4.0507	***
Arrival estimate (α)	0.5848	3.3782	***	11	4	1.1251	6.3895	***
Arrival estimate (γ)	0.5659	-1.9989	**			0.3556	-0.8276	
Arrival exact (α)	0.7103	3.6232	***	9	2	1.3465	6.2888	***
Arrival exact (γ)	0.0388	0.5051				0.9729	-5.0139	***
Departure estimate (α)	0.7962	4.6640	***	8	8	0.7259	3.8479	***
Departure estimate (γ)	0.4819	-1.0933				0.4708	1.8486	**
Departure exact (α)	0.8123	3.7957	***	7	7	0.8928	3.9878	***
Departure exact (γ)	0.7546	2.7545	***			0.8283	3.1035	***
Fare estimate (α)	1.1732	7.9079	***	2	5	0.9791	6.7440	***
Fare estimate (γ)	0.5694	1.8692	**			0.3384	1.0946	
Fare exact (α)	0.9541	4.3774	***	6	6	0.9526	4.1249	***
Fare exact (γ)	1.3500	6.0586	***			1.4000	-7.5576	***
Frequency estimate (α)	1.1051	7.0028	***	3	1	1.4342	8.9149	***
Frequency estimate (γ)	1.1250	6.4909	***			0.9958	4.3998	***
Frequency exact (α)	0.6575	3.5818	***	10	3	1.3387	6.6930	***
Frequency exact (γ)	0.4460	-1.5353	*			0.3255	-0.8555	
Safety onboard (α)	0.9826	6.7380	***	4	10	0.4012	2.6152	***
Safety onboard (γ)	0.1395	-0.5633				0.1453	0.6633	
Safety waiting (α)	0.9664	5.5647	***	5	9	0.5653	3.0303	***
Safety waiting (γ)	0.6031	2.7144	***			0.5634	-2.5039	***
Safety walking (α)	1.3139	6.1806	***	1	11	0.3508	1.5220	*
Safety walking (γ)	0.0175	0.0345				0.4667	-1.3001	*

*, **, *** indicates significance at the 10%, 5%, 1% level.
'Est.' is 'estimate'.
Where α is the mean parameter estimate, and γ is the standard deviation of the parameter estimate.
Ranking is determined based on the parameter estimate values and is in ascending order of largest to smallest.

In terms of the significance of the standard deviations and heterogeneity in taste for information given trip purposes, there was no significant variation in taste for several attribute levels. For meeting with friends, exact arrival and estimated departure times did not have significant standard deviations. Safety onboard and walking safety both ranked highly in terms of their parameter estimates but had no significant standard deviation in preference for these attributes

– meaning these are likely valued highly across the population for planning trips for social reasons. For job interviews, there was no significance found in the standard deviations for estimated arrivals, estimated fares, or exact frequencies – all attributes that had high rankings in terms of their parameter estimates. However, safety onboard, which was at the bottom of the rankings, also showed no significance in standard deviation in preference for the attribute.

6.6.4 MMNL Model for Digital Poverty Framework Levels

A MMNL model with a normal distribution was run to see whether there was any significant difference in information needs based on an individual's DPF level. Respondents were categorised in levels as they were in Chapter 5 except those considered digitally poor (with basic phone) and digitally poor with internet capable phones were grouped together to increase the group size for the purposes of the choice model and because the two are quite similar in their capabilities to access information via their phones. Thus, the four DPF levels included were digitally poor, passively connected, actively connected, and digitally wealthy (held as the base). To briefly recap, the categories are defined as: (1) digitally poor = no phone that can access the internet or have access to a phone with internet but possess limited passive ICT use skills, (2) passively connected = have access to an internet-capable phone but are limited in their passive and active skills, (3) actively connected = are proficient in passive and active ICT skills, but have limited access to mobile data, (4) digitally wealthy = have no barriers to ICT skills and have unlimited mobile data.

A first model was run which treated each level as a generic interaction effect with each of the attribute levels, which was then broken down to keep digitally poor as a generic coefficient and the passively connected and actively connected categories were divided into separate parameters to test interaction effects with each information parameter individually (Table 6.14). This was because the first model suggested that only these latter two DPF levels displayed significant differences in preference for information needs to the base and so a further model was run to understand which attribute levels specifically differed. Given the likelihood-ratio test (where -2*(-3522.739 - -3495.506) = 54.466 is greater than $\chi^2_{23} = 35.172$), this model was a significantly stronger fit than the basic MMNL model where DPF levels were not factored in.

Table 6.14. MMNL model with DPF levels as coefficients.

Model		MMNL - Normal		Value	Est.	Rob.t-rat.
Final LL	-3495.506	AIC	7083.01			
Parameters	46	BIC	7391.28	ASC	-0.4685	-3.8480***
Rho-sq.	0.1612			DPF: Digitally Poor	-0.1624	-0.6552

	Value	Est.	Rob.t-rat.		Value	Est.	Rob.t-rat.	
Arrival est.	DPF: Passively Connected	-0.5127	-1.8989	**	DPF: Actively Connected	-0.3110	-1.3117	*
Arrival exact		-0.3251	-0.9161			0.0523	0.1758	
Departure est.		-0.5015	-1.6714	**		-0.5684	-2.2460	**
Departure exact		0.0625	0.1924			0.0817	0.2974	
Fare est.		-0.7211	-2.4055	***		-0.0869	-0.3305	
Fare exact		0.1879	0.5731			-0.1763	-0.6380	
Frequency est.		-0.3351	-1.2071			-0.1917	-0.7992	
Frequency exact		-0.0653	-0.2031			-0.0731	-0.2792	
Safety onboard		0.0482	0.1826			0.1743	0.7996	
Safety waiting		-0.0466	-0.1662			0.0707	0.2976	
Safety walking		0.0011	0.0038			-0.1189	-0.4695	

	Value	Est.	Rob.t-rat.		Value	Est.	Rob.t-rat.	
Arrival est.	(α)	1.3769	7.7242	***	(γ)	0.6798	5.9245	***
Arrival exact		1.0544	4.5185	***		1.1842	11.0345	***
Departure est.		1.1439	5.3709	***		0.7542	-6.7600	***
Departure exact		0.8478	3.6367	***		0.8324	-7.4212	***
Fare est.		1.1274	5.7888	***		0.6756	-5.1335	***
Fare exact		1.1062	4.9332	***		0.2695	-1.4695	***
Frequency est.		1.4535	7.8229	***		0.7126	-4.0674	***
Frequency exact		1.1114	5.5198	***		0.8875	6.3265	***
Safety onboard		0.6617	4.0276	***		0.4744	-3.4904	***
Safety waiting		1.0045	4.8196	***		0.2968	1.8519	***
Safety walking		0.7999	4.1822	***		0.6006	4.7447	***

*, **, *** indicates significance at the 10%, 5%, 1% level.
'Est.' is 'estimate'.
Where α is the mean parameter estimate, and γ is the standard deviation of the parameter estimate.

Overall, there was no significant difference in preference for information based on a respondent's digital poverty level, except for five cases. For the passively connected group, estimated fares, estimated arrival times, and estimated departure times were all significantly less valued (at the 95% confidence interval) as useful information when compared to the preferences of the digitally wealthy. The actively connected group similarly displayed significantly less preference for estimated departure times than the digitally wealthy at a 95% confidence interval, and less preference for estimated arrival times at a 90% confidence interval. There are a few reasons that these differences may exist. People belonging to these DPF categories may have different job types than the digitally wealthy, perhaps with less flexibility and therefore are more time sensitive. They may also rely on inexpensive modes more, that are less reliable (such as the trains), and have more negative experiences with estimated times, either because these modes arrive infrequently or not to the scheduled times. In terms of the difference in preference for estimated fares between passively connected and digitally wealthy groups, the passively connected are likely more cost sensitive. There was no significant difference in preference for exact arrival and departure times nor for exact fares, meaning people of all digital poverty levels valued these types similarly. The lack of a significant difference in preference for estimated and exact frequencies follows the trend from the prior model estimations and likely is because the frequency of the MBT services is perceived as often enough to not elicit a strong preference for estimates over exact times and further diluted because MBT was combined with each other modal type. The lack of significance in preference for safety-related information between DPF groups highlights that safety concerns target all groups, and not one has an advantage to more existing information over the other due to their technological capabilities.

6.7 NEXT STEPS

Given that the attributes included were all vetted and selected as those with positive scores from a larger list of needs in a BWS exercise, it is unsurprising that all attribute levels regardless of quality had highly significant positive parameter estimates compared to the base which was no information at all. Had the information types from the least useful end of the BWS scores been included, more parameter estimates may have been expected to be less significantly useful compared to no information at all. Returning to the primary objective which is to understand which information needs and of which quality are most important to planning a hybrid public transport journey, the central aim of these models then is to understand which information needs to prioritise in practice.

Prioritisation requires a ranked understanding of which information needs most lend to overall utility gains of an information package. Across the models, when accounting for socio-demographic variables and journey planning scenarios, the significant contributors to variation in needs for non-routine trips are whether the person is male or female, whether they are planning a trip for social or appointment-based purposes, and which DPF category they belong to. For the other variables – i.e., modal combinations, origin-destinations, demographic characteristics of race and age – information needs do not significantly vary.

Sex

Offering separate sources of information to people based on their sex is not a pragmatic approach to handling differences in information needs. Rather, in practice, common information needs between the sexes should be prioritised or the information needs with the largest parameters for each individual sex should be catered for (e.g., top three parameter estimates). Another perspective to take is to consider all seven information types as key components for non-routine trip planning and prioritise the highest-ranking attribute level of an information type. This would mean that according to the basic MMNL model, estimated levels are acceptable for frequencies and fares, but for all other information exact levels are preferred. Then, factoring in information needs in a similar fashion from the models segmented by sex, a comparison of priorities reveals that the ranked levels align with the ranked levels of males and females, if combined.

Trip purpose

The variation in needs based on trip purpose perhaps most highlights the problematics of evaluating and basing information priorities on a subset of only the results of the basic MMNL model. For example, if looking only at the top three information needs from the basic model, then the overlap with these and that of the segmented trip purposes is limited to the fare estimates, frequency estimates, and exact arrivals. Frequency estimates, exact arrivals, and fare estimates were the top three most import information types for appointment-based trips while walking safety, fare estimates and frequencies estimates were the three most important information types for social trips. Thus, while the top information based on estimates overlaps in the overall model and that for time-based purposes, the most important information type would not be covered for social trips. Therefore, it is important to consider the most important information needs of both segmented trip types if the intent is to communicate information to benefit both non-routine trip purposes.

Alternatively, another option would be to cater to only one trip purpose type. If further research found for example that in the case of appointment-based trips and social trips, the larger proportion of people find that the lack of information is a greater barrier to undertaking social trips, then the related information needs should be prioritised accordingly to break down barriers to making these trips.

Digital poverty framework

If using the basic MMNL model's estimate rankings to inform implementing information needs in practice, this ranking would already account for the discrepancies in needs amongst the DPF groups. In the overall model, exact arrival and departure times ranked higher than the equivalent estimated times and so would account for the negative sensitivities to estimated arrival and departure times amongst the passively and actively connected groups. However, fare estimates ranked higher in the overall estimates than exact fares, but the passively connected group more negatively perceives the value of estimated fare information than the digitally wealthy. Hence, in the interest of this user group, providing exact fares would be the more equitable approach.

Prioritised needs considering differences in gender, trip purpose, and DPF levels

When considering the combined attribute level priorities across all information needs across all scenarios and sociodemographic characteristics by estimate ranking, then exact information is preferred in all situations to all other levels, except in the case of estimated frequencies which were found acceptable to exact fares in every model estimation. There is currently a massive gap between the information people need for planning non-routine journeys and that is publicly available (see Table 6.15). Currently, exact departure times are only available for the MyCiTi buses. Exact fares are available via recorded sources for the MyCiTi and Metrorail, while exact fare information for GABS requires getting in touch with a service representative. Ultimately, which of the information needs are made accessible to captive public transport users is dependent on resources available for capturing and communicating the necessary data.

Basing the translation of information needs into priorities in policy and practice on the model estimations for all respondents across all trip scenarios (i.e., the basic MMNL model) would be the most equal approach responding to the objective set out in this chapter. However, differentiating those needs based on scenarios and demographics of the intended user groups would be the most equitable approach. That is, returning to the capability approach, rather than provide information needs regardless of individual difference, to enhance capabilities, then information should be provided based on heterogeneous needs. In other words, to improve the informational capabilities of captive public transport users, information should be prioritised based on a heterogenous captive public transport user group, and on the different types of travel situations people may have reason to access.

Table 6.15. Prioritised information needs that are publicly accessible via recorded sources.

Attribute Level	MyCiTi	GABS	Metrorail	MBT
Arrival est.				*NA*
Arrival exact				*NA*
Departure est.				*NA*
Departure exact				*NA*
Fare est.				*NA*
Fare exact				*NA*
Frequency est.	*NA*	*NA*	*NA*	
Frequency exact	*NA*	*NA*	*NA*	
Safety onboard				
Safety waiting				
Safety walking				

Key:
NA indicates not applicable

Priority attribute level currently available	Secondary attribute level currently available	Priority attribute level currently unavailable	Secondary attribute level currently unavailable

7. DISCUSSION

7.1 INTRODUCTION

The purpose of this chapter is to form recommendations for enhancing informational capabilities through ICT to access informational capital and thereby enhance mobility equity for users by improving their capability to use the hybrid network to meet their preferences and needs. This entails a synthesis of the choice model results to understand where the CoCT should invest its resources to collect the necessary information. Together with an understanding of the ICT capabilities through the primary and secondary data analysis, the CoCT will be able to understand how information should best be packaged for which user groups. This approach responds to the following questions: Which information that is currently available, but currently inaccessible to certain user groups due to ICT capability barriers, should be repackaged to benefit users? Which information imbalances should be targeted to meet captive users' needs? Which previously unavailable information should the CoCT prioritise in making available to improve users' informational capabilities? How can the CoCT best deliver information to meet users' ICT capabilities currently and in the coming years?

This chapter opens with an analysis of the constraints of a future hybrid passenger information system (section 7.2) followed by the various components needed to respond to and lay foundations for the implementation and life of such a system (sections 7.3 – data needs, 7.4 – dissemination strategies, 7.5 – expanding ICT capabilities). Figure 7.1 outlines the flow of recommendations. Whereas most of the information needs addressed in this chapter have an abundance of precedents available around data collection and information dissemination, the provision of safety information has far less successful examples and requires a different approach to delivery, and therefore is addressed independently as a subsection within each section. The chapter closes with a discussion of the implementation challenges that lie ahead for enhancing informational capabilities of hybrid system users (section 7.6).

Figure 7.1. Recommendations for the City of Cape Town for establishing hybrid public transport information for the purposes of pre-trip planning.

7.2 CONSTRAINTS: OPPORTUNITIES AND CHALLENGES

7.2.1 Synthesising Informational Capital and ICT Capabilities for Informational Capabilities

To understand how to enhance informational capabilities, or an individual's capability to translate information accessed via ICT into their own context to expand their opportunities, within the context of this research requires a synthesis of the informational needs found through the main research objective 1 (Chapters 3 and 4) and prioritised in objective 3 (Chapter 6), and the ICT capabilities investigated through objective 2 (Chapter 5).

From the spatiotemporal and organising information types needed to plan non-routine journeys, currently only a limited number of these types are available in recorded formats, but unevenly so across the different scheduled modes with MBT services noticeably absent from recorded sources. To briefly reiterate, the basic spatiotemporal information types include (1) modes available, (2) operating times, (3) routes, (4) stops/landmarks, (5) transfer/interchange locations, (6) station/rank locations, (7) which routes depart from which stations/ranks, (8) vehicle-route identifiers, and (9) cancellations. While the CoCT has route geometry data on the MBTs as well as MBT rank locations from sources including transport plans and issued route licenses, these are sources of planned information and may not reflect reality on the ground. GoMetro, a data collection and transport information company, collected several data points on MBTs in 2017 which included route geometries and stops/landmarks, though this data has not been regularly updated and so might also no longer reflect present MBT operations (Coetzee et al., 2018).

To recap, from the choice models in which respondents were asked to select the information package with several types of organising information which would best enable them to plan a hybrid public transport journey for a non-routine trip, the resulting prioritised information needs were informed by the differential needs based on trip scenarios and sociodemographic variables of the captive public transport user group. These needs were: estimated frequencies, exact arrival times, exact fares, exact departure times, walking safety, waiting safety, and safety onboard. Regarding the information tested in the choice model, organising information available is even more imbalanced across modes or does not exist at all. For example, detailed fare information is available for MyCiTi and Metrorail, stratified by travel time (peak vs. off-peak), distance, and pass options available (daily, weekly, monthly). GABS does not publicly provide recorded fare information nor do the MBTs.

It should be noted that while real-time arrival and departure information are available for MyCiTi, this is not the case for the other scheduled modes. GABS provides only minimal information on Facebook about systemwide service disruptions, without specific information on the specific routes or departure schedules affected. An example of this is the following posted on their official Facebook page:

> "PASSENGERS PLEASE NOTE: Following the shooting incident that occurred this morning and further threats and intimidation having been made via social media, the normal GABS service schedule has regrettably been disrupted. Due to this disruption, reduced services will be operated to avoid any risks to the security and safety of passengers and staff."
>
> (Golden Arrow Bus Services, 2021)

Metrorail provides some departure information via Twitter that may help users estimate themselves how far the train is from their station and what time it might arrive. The information takes the form of the train line as a hashtag users can follow on Twitter to get direct updates on in their home feed, followed by whether the train is inbound or outbound, the train number and which station the train is at. This is posted on the Metrorail W/Cape twitter page along with an automatic timestamp:

Figure 7.2. Metrorail W/Cape tweet example. (Source: Metrorail W/Cape, 2021)

However, according to the Twitter page, these updates are only provided between peak hours (5:30am-10am and 2pm-7pm), leaving travellers in off-peak hours without status updates on estimated arrival and departure times. Where stations are in unsafe areas coupled with empty platforms due to reduced passenger flows, the lack of updates may contribute to a decrease in perceived safety.

Currently, the informational capabilities of captive public transport users to access non-routine trips purely on the basis of publicly available access to hybrid public transport information is theoretically low. Of the information needs found to be essential to planning a trip (the spatiotemporal information) the ability to plan a journey begins and ends with scheduled modes. Incorporating MBTs into a journey to form a hybrid trip requires either personal experience or knowledge from others, with information from the industry itself available only directly at the source – the MBT. The organising information proven to be important through the BWS and choice model studies is no easier to access given that it is largely absent from current public transport information sources.

Coupled with the current state of ICT capabilities amongst captive public transport users, the way transport information is presently provided, largely ensconced in transport-specific formats like map navigation tools and timetables or requiring mobile data to access, creates barriers to accessing the information that is available, further reducing informational capabilities for certain groups of users. Despite the high penetration rate of internet-enabled mobile devices in Cape Town amongst public transport users, ICT skills pose as a potential barrier to the uptake of ICT-communicated hybrid public transport information. This is especially problematic considering that the types of information needs revealed to be most important in the choice model were types that would require ICT to access. While static information can be communicated via printed formats at stations or as flyers for passengers to keep, real-time information on arrival and departure times are more dependent on technology for communication. This would most likely affect the users belonging to the passively and actively connected DPF groups because they either lack in the skills or mobile data needed to readily access information via their phones, and so with disruptions they are not able to adapt as quickly and replan their trips if they only have timetables and other static information at their disposal. However, these groups were also the most sensitive to needing exact arrival and departure information.

7.2.2 Safety Information

Safety information in relation to walking en route to a mode, onboard a vehicle, and at a station/stop was repeatedly expressed as necessary for hybrid public transport trip planning. Despite its prevalence as a key component to journey planning, safety information is currently neither collected nor offered for mobility decision-making purposes. Because of its complex nature and the lack of a tried-and-tested precedents for incorporating safety information into passenger public transport information provision, safety information is treated separately from the other information types.

In this research, safety was not explicitly defined but rather explained to respondents in the form of a question, e.g., 'For which option am I safest waiting?'. This meant that safety could be interpreted as either a safety or security concern. While 'safety onboard' can be taken as either a safety or security concern, given that 'safety' was used in the context of waiting and walking to access transport, and the association with crime that was brought up with the word 'safety' in the one-on-one interviews, the term 'safety' was most likely perceived as a personal security information need.

Safety and security are often grouped in the context of public transport, where together these mean that "personal security is an objective freedom from security and safety risks combined with a subjective freedom from fear and uncertainty" (Beecroft and Pangbourne, 2015a). Further research would be needed to disentangle safety and security to understand which and what aspects are information concerns for public transport passengers. Thus far, research into the safety and security of public transport users has been extensively studied in terms of individual perception (e.g., Delbosc and Currie, 2012; Nordfjærn and Rundmo, 2018) and gendered-dimensions around sexual harassment and assault (e.g. Vanderschuren et al., 2019), and how this in turn influences mode and operator choice (Sam and Abane, 2017), but has stopped short of understanding what information specifically passengers need to overcome barriers to perceived safety and/or security concerns in journey choice. In practice, safety, or freedom of physical harm due to say accidents, would demand that a different set of data be collected and information be communicated than security information, or freedom from crime or anti-social behaviour.

Both public transport providers and users can leverage ICTs to address safety and security concerns. For example, ICTs can be used to gather data on crime hotspots disaggregated by crime type and demographics that decision-makers can use to plan targeted interventions within resource constraints, to provide information to users to plan safer public transport journeys more confidently, and as a tool to monitor and access safer en route journeys. Overall, research into the potential and on-ground implementation of such ICTs is limited. While research has looked at the potential role of ICTs in security applications, this has primarily focused on counterterrorism or ticket enforcement (e.g. Bennetts and Charles, 2016; Beecroft, 2019). Though security information can reassure and give confidence to public transport users, few technologies have emerged to provide such information (Beecroft and Pangboure, 2015b). That said, the limited options for ICTs available is not necessarily restricted by user willingness to use mobile security applications, as McCarthy et al. (2016) found that respondents were willing to use security apps and even share their location data to report anti-social behaviour.

7.3 PUBLIC TRANSPORT INFORMATION AND DATA STRATEGIES

7.3.1 Information and Data Strategies

The CoCT needs a public transport passenger information strategy that informs the data strategy and, if desired, the open data strategy.

A public transport passenger information strategy is key for outlining a vision and plan for achieving and delivering integrated passenger information that responds to changing needs. For example, Transport for London currently has the *Customer Information Strategy and Programme* in place to address various aspects of the user information experience, including their vision, guiding principles, programme components, monitoring of impact, and financial implications (CSOPP, 2017). A similar strategy for Cape Town would not only address the need for information integration across different modes and operators, but also anticipate the information needs and capabilities of present and future users of the public transport system. The strategy should acknowledge how information needs vary by trip purpose, stage of trip, and user demographics, and how the strategy assesses and accommodates these needs in practice. Beyond content needs, the strategy should also touch on how such information will be disseminated, or at least lay out benchmarks for measuring what is successful distribution of information. Each component of the information strategy should be actionable, predictive, and inclusive. That is, the strategy needs to respond to the information people need to make decisions, anticipate how these needs change over space and time, and be empathetic of the different capabilities of its end users.

While a data strategy for Cape Town currently guides the collection of transport data, it is more focussed on gathering the data required by the CoCT to make strategic planning decisions and operational decisions as opposed to that required by passengers to make journey decisions (CoCT, 2018b). While some of the data needed for planning purposes overlaps with passenger information data needs, as this research has found, journey planning requires data that extends beyond the data currently collected. A data strategy for passenger information should first set out a vision for capturing data needs that responds to the needs of the stakeholders involved in delivering and receiving passenger information. This includes both the developers and other parties taking the data and transforming it into usable information and the passengers receiving and acting upon the information.

Key to realising integrated information through both the public transport information strategy and data collection strategy is a realistic approach to how to consolidate information from different operators at different levels of government. While on paper, it is the CoCT's nationally mandated responsibility to provide integrated information (see Chapter 2, section 2.3), in reality the fragmented nature of the network requires the collaboration of multiple stakeholders, not all of whom may believe it in their best interest to make information on their operations public knowledge. The information strategy needs to emphasise the role of collaboration and communication in integration efforts and make clear which parties are responsible for consolidating, maintaining, and disseminating the public transport information. Regarding information needs that extend beyond currently available information, it needs to be clear who is responsible for collecting these additional data points.

While the CoCT already has extensive data on the MyCiTi and provides static and real-time information to passengers, the same is not true for Metrorail, GABS or MBTs. The CoCT currently has a call centre where callers can obtain journey planning information for all three scheduled modes but is currently unable to provide integrated journey planning information for a trip using multiple modes. This reflects the limitations of different modes' data being housed in different sources and different formats. In the case of the data collection strategy, the challenge is in understanding who is responsible for collecting and standardising the data necessary. Does the CoCT assume full responsibility? Does the CoCT tender the role out? Or does the CoCT's role extend to providing guidelines to the other operators on how to ensure data compatibility? The CoCT would need to address in their strategy how these various data sources could standardise their formats, as well as what process would be in place for ensuring that the CoCT has the latest up-to-date data from the various operators. In the case of the MBT where neither the operators nor associations have a public-facing recording information database in place, the CoCT would likely need to take full responsibility over the collection of data.

There are numerous precedents for collecting and recording data around the collective spatiotemporal information needs for scheduled modes and more recently paratransit (e.g., Williams et al., 2015) as well as for data collection around the real-time equivalents of traditionally static time-related information (e.g., Corsar et al., 2017; Kumar et al., 2017; Vanderschuren, 2012). While the ICT capability constraints communication of these information types will have to be reimagined to accommodate limitations in mobile internet access and ability to interpret transport-specific information, the data collection of another information type that stood out as important in both the BWS and choice modelling surveys has remained elusive: safety information.

7.3.2 Gathering Data on Safety Information

The responsibility for ensuring the security of passengers is fragmented across different authorities and operators, making a coordinated approach through traditional methods like policing, that rely on external collaboration, difficult. The responsibility for passenger security is fragmented across different tiers of government and transport operators, as loosely defined in the *National Land Transport Act of 2009* (NLTA). At a national level, when considering any measures and strategic objectives related to public transport, the NLTA requires the Minister to promote the security of passengers. At the provincial level, in the case of violence, unrest or instability in the public transport sector or between operators in an area that risks the security of passengers, residents or others, the Member of the Executive Council, in consultation with relevant planning authorities, can suspend operations on the public transport routes or ranks concerned (NLTA Section 91(2)). Though it is the municipal governments' responsibility for promoting security in public transport, as well as making relevant information on public transport accessible (NLTA Section 11 (c)(xii) and (xiii)), current strategies to implement such measures are limited in scope. While the City of Cape Town's *Comprehensive Integrated Transport Plan 2018-2023* mentions safety as an access priority across all income groups on public transport, plans to address safety are limited to rail and then primarily to infrastructure safety such as addressing vandalism and infrastructure theft. There have been no attempts at communicating security information to passengers to help inform their journey choices and bolster confidence in the public transport system, despite the mandates the municipal governments have to implement such communication systems in the NLTA. Without clear implementation strategies to apply measures cohesively across the public transport network as a whole, the responsibility to provide safe and secure transport becomes muddled.

Data collection strategies might differ for providing safety and security information across the hybrid system from strategies for other transport data types given the fragmented responsibilities of government and transport stakeholders and the fact concerns around walking safety and waiting safety concern environments often outside the direct jurisdiction of transport authorities. That said, there are various ways ICTs can be used to assuage perceived safety and security risks that go beyond communicating the likely state of safety and security of an environment to actively accompanying a traveller en route with safety and security measures in the event of an incident (e.g., trip tracking, panic buttons, etc.) As for onboard safety and security concerns, vehicles can be uniquely associated with safety and security information (e.g., driver/vehicle ratings) to aid passengers with information to actively choose which vehicles to board. However, for the sake of equipping public transport users with information to mitigate safety and security risks through journey choices during the pre-trip planning process, an assessment of semi-static transport environments, i.e., stops/stations and access areas around onboarding and disembarking points, would aid in information about general areas. Given the dearth of safety and security data, the CoCT may want to take a crowdsource approach to safety and security to gather data needed to provide information about safety and security of the environments in question.

Data deficits are one of the greatest barriers to operationalising hybrid public transport information delivery. While there are many existing methods to collecting much of the data missing on Cape Town's scheduled systems and a lot of work is being done to improve data collection methods for static data on unscheduled systems, safety information is more elusive. It is time and place specific. Crowdsourcing is one potential method of producing knowledge through collecting data over time and vast areas with the help of volunteers, typically using internet-enabled phones (Young et al., 2021). This method works best in contexts where ICT does not bias who can participate. Where limitations to internet access act as a barrier to the full participation of all citizens in data collection processes, crowdsourced data at best lends to biased knowledge production (ibid.; Brown, 2016). The surveys from objective 2 (Chapter 5) into ICT capabilities revealed that crowdsourcing is a feasible method of collecting much needed data in Cape Town given transport users do have the ICT means and skills necessary to use crowdsourcing apps.

ICTs offer the opportunity to gather a more nuanced understanding of security concerns, provide passengers with valuable information, and even implement targeted strategies to reduce incidences onboard, at stations/stops, and en route. Crowdsourced data, in particular, can become a resource for users in information-scarce regions. One such successful example is Safetipin. Initially launched in Indian cities, the Safetipin app has since expanded to 16 cities including Johannesburg and Durban to provide women with a means to contribute to security audits of the various areas in their cities. App users contribute to safety audits by evaluating and reporting on lighting, visibility, walkability, how busy the area is, whether both males and females are in the area, availability of public transport, security presence, how enclosed the area feels, and personal perceptions of how safe the area feels. In Johannesburg, this app was used to conduct safety audits of various locations in the township Alexandra (Safetipin, 2021). While the data was subsequently used to form recommendations for on-ground interventions, these safety audits can lend information to users in their public transport journey planning. Users can share their tracked location with a trusted person who will be notified in the event that the user is in an unsafe area (as recognised by the collated security audits). Users can see nearby places (e.g., hospital, restaurant) they can safely wait for their pick-up in the case that they feel unsafe in their current waiting location. In theory, app users can also plan the safest route from one point to another, though this relies on having enough up-to-date user contributions.

While international precedents offer diverse crowdsourcing approaches to the multifaceted information challenges Cape Town public transport users face on a daily basis, several potential barriers to user adoption may limit the impact of these technologies. Gaining a critical mass of users to create value for other users through an accumulation of user-generated data is a particular a challenge in the Cape Town context. The high data costs relative to income mean that data use is more likely to be constrained to mobile applications users believe are valuable to them, as opposed to experimentally downloading and using an application without demonstrated value. The initial lack of perceived usefulness together with a low density of users across space presents a challenge particularly for mobile applications whose value is generated through critical mass use of the app (Corsar et al., 2018; Davis, 1989). Initially such apps, like the Safetipin app present little benefit for users as a place to actively acquire information. Without any real incentive to download the application and subsequently contribute data points, available information is limited. Furthermore, the low density sprawl that characterises Cape Town makes it more challenging to acquire the local active userbase necessary to accumulate widespread up-to-date data across the full city.

Though it is not clear without further research to what extent these safety and security concerns are perceived rather than actual issues plaguing users, safety and security was consistently raised as a concern preventing the use of alternative modes of public transport. This raises the question of whether the modes currently available that compose the hybrid public transport suffice as viable mode choices for public transport users or if alternative services should be incorporated more officially into information services enabling hybrid system planning? That is, in light of interview responses suggesting more comfort with e-hailing services as the mode of choice for evening trips over public transport, official sources of information around hybrid trip planning could incorporate such alternatives to make these visible to users. Alternatively, further research could investigate the current quality of the public transport modes present to determine shortcomings in responding to users' safety and security concerns while also looking at best practices within the sharing economy sector that can be borrowed to improve information concerning safety and security around public transport use. For example, ride-sharing companies have used driver verification features and driver rating systems to respond to users' concerns around entering a vehicle with only an unfamiliar driver. To improve trust in riding with strangers, driver verification enables passengers to match the identification details on the app to verify the driver is the same person. Rating systems can incentivise safer driving behaviour, as higher ratings for safer driving increase the likelihood that the driver will attract further customers (Acheampong, 2021). Such approaches would need to take into account to localised circumstances and transport operating structures, such as resistance to accountability and variation in which driver is operating which vehicle on which route, and be adapted to effectively respond to safety and security concerns.

7.4 DISSEMINATION: INFORMATION PROVISION STRATEGY

Regardless of which direction the information strategies take and what shape their outputs take, these strategies should support integrated multimodal information. Public transport planning takes place within a choice setting that includes the individual making the journey choice together with their cognitive and physical limitations. Information quality affects what access to choices the individual has available to them. According to Lyons, Hammond and Mackay (2019) mobility services have different levels of integration that require decreasing levels of cognitive effort when moving from no integration to full integration. Though their taxonomy was applied to Mobility as a Service (MaaS), it can be conceptually adapted to passenger information. While the most cognitive and affective (i.e., emotional) effort is demanded when no integration exists at all, a fully integrated information system with all modal information in one place and specific to a journey requires the least cognitive demand. To incentivise information use, reducing cognitive burden when engaging with information services is key, which is why fully integrated information in a single source is the most desirable method of information provision.

7.4.1 Precedents of Hybrid Transport Systems with Information Strategies

While several cities with hybrid systems do have policies/strategies for information provision or have, at minimum, expressed interest in having such policies/strategies, fragmented authority over various public transport services has acted as a barrier to the full realisation of these aspirations. Furthermore, these examples illustrate that responsibilities for passenger information need to be well defined in terms of what actions are required by whom for effective information systems to materialise. These examples from three metropolitan authorities illustrate examples of integrated information strategies at different stages of development and allude to the potential challenges and opportunities Cape Town may face with similar approaches.

In **Accra, Ghana**, in recognition that successful BRT implementation still requires paratransit as an essential component of the city's mobility, Departments of Transport (DoT) were established in several of Accra's municipalities and tasked with regulating paratransit operations within their municipalities (Ferro, Behrens, and Wilkinson, 2013). Paratransit operators needed to register their vehicles and routes with the DoTs which in turn gives the individual DoTs a general understanding of paratransit operations within their municipality, but not an overview of all municipalities, as the information is not consolidated (Saddier and Johnson, 2018). The feasibility of real-time vehicle tracking and location services for paratransit (amongst the city's other modes) for the purpose of ensuring more reliable operations has been considered in the context of low ICT literacy and limited access to ICTs (World Bank, 2011). GPS-enabled mobile phones were considered advantageous as many drivers already have these, or could be provided with one, and phones have been used in other contexts for collecting real-time location data. However, harnessing ICTs for location services faces several challenges concerning responsibilities for the implementation, management, and maintenance of the ICT infrastructure as there is no one clear regulatory body with a precedent for holding such responsibilities.

Johannesburg, South Africa is like Cape Town in that its BRT, rail, and MBT systems are fragmented across different spheres of authority, with only the BRT entirely under the jurisdiction of the municipality. The city published the *Strategic Integrated Transport Plan Framework for the City of Joburg draft* in 2013 where the need for integrated information is outlined in detail, particularly within the context of the municipal-run BRT system (CoJ, 2013). The policy does explicitly mention that quality public transport requires integration between different modes and that integration of passenger information is one such component. As part of the integrated passenger information strategy, the policy outlined a desire for a single website and journey planner with information across both scheduled and paratransit services, and integrated information available at stations by 2018 (Ibid.). However, in terms of the infrastructure planned in the 2013 framework to support information strategies, this is limited largely to investment in the BRT's information system. This reflects the limitations of the municipality's authority over operators outside of their jurisdiction and ease to which data on these operations can be collected in a standardised way and consolidated into an integrated information system.

Though **Mexico City, Mexico** has not proactively sought to integrate its publicly owned systems with privately owned services, its mandates for integrated information are worth mentioning. The city has a high degree of autonomy with an executive branch - the Public Administration - made up of secretaries, one of which is the Secretariat of Mobility which oversees mobility matters within the City of Mexico (CDMX). In 2014, the Legislative Assembly of Mexico City passed a new mobility law, *Ley de Movilidad del Distrito Federal* (translated to *Federal District Mobility Law),* emphasising the desire to move towards an integrated and inclusive multimodal mobility system (ALDF, 2014). Technological innovation is mentioned within the specific context of an adaptable system to support changing ICT needs. Specifically, a system that stores, processes, and distributes information which is a step towards acknowledging that ICT innovations are changing and rather than set out a specific communication type in a plan, to rather put in place the systems necessary to catering to evolving needs. The responsibility falls on corresponding entities to provide the information that feeds the system. Otherwise, the Secretariat is responsible for the planning, coordination, and execution of the processes necessary for passenger information services to ensure that passengers have the capability to choose freely from available modes the journeys that efficiently meet their travel needs. The law goes a step further to mandate that the Secretariat is responsible for communicating this information via electronic means to given passengers timely information. Though the CoCT does not have the consolidated authority that Mexico City has over mobility within its boundaries, one valuable lesson from CDMX is that clearly outlining informational responsibilities and the various aspects of enabling these is essential to their realisation. But while these responsibilities should be well defined, they also should not constrain what direction interventions (e.g., specifying 'website' or 'app') take given how quickly the ICT landscape is changing.

7.4.2 Open Data

In recent years, multiple cities, including Mexico City, have turned to open data portals to share mobility information and help promote the development of a diverse range of technological innovations to tackle mobility challenges. According to Klopp, Delattre and Chevre (2019: 9), open data is "data that can be freely used, re-used and redistributed by anyone". Data made freely available is not the same as making data openly available – open data requires full access, where access is defined in terms of context, connectivity, capabilities, and content (Williams et al., 2014). Open transport data is most used when challenges such as data interoperability do not pose high barriers to use (Colpaert et al., 2017). Multimodal journey planning solutions, in particular, rely on multiple datasets, and potentially from separate sources, to provide route planning advice. However, when two datasets are incompatible, for various reasons including legal, technical, file format, or other interoperability problems, it increases the effort and cost required to build solutions using the data (ibid.). One of the most effective open data portal cases, Transport for London (TfL), ensures interoperability of its 62 real-time and static datasets and has successfully promoted the use of its data with 362 apps drawing on the data in 2014 (Hogge, 2016). It is estimated that by opening its data rather than developing mobility apps in-house, TfL saved between £15m and £42m and indirectly provided a larger range of needed solutions than it could have managed on its own (ibid.). Across different examples of open data, data use has wider economic benefits and adds external value to cities in a variety of ways (Yadav et al., 2017; Leviäkangas and Molarius, 2020).

Since 2014, the CoCT has had an open data policy to realise the city's goal of providing a single open data portal to make data accessible to the public (CoCT, 2016). This policy supports the mandate within the South African constitution that states in Section 31(1)(a) that individuals have the right to access any information held by the government (ibid.). The Mayor of Cape Town at the time, Patricia de Lille, maintained that the open data would enable government, the public, and businesses to come together to solve pressing challenges facing the city through open access to data resources (Ricker et al., 2020).

The early versions (version 1 in 2014 and 2 in 2016) of the open data policy had several limitations that effected the usefulness of the open data portal. The City's Development Information and Geographic Information Systems Department was initially made responsible for implementing the policy, while a Steering Committee made up of representatives from various City departments met every quarter to field open data requests (CoCT, 2016). While the policy required that open data be included in a machine-readable format, freely for public use regardless of the purpose, datasets were not automatically made open to the public until the policy was updated in 2020 (CoCT, 2020). Though the vision of the policy was to encourage economic innovation, the ease with which data is made open was stymied by anxieties around data misuse within the CoCT (Willmers et al., 2015). The Steering Committee actively had to decide which data to include and which data requests to approve (CoCT, 2016). Data that belonged to a third party and was copyrighted or prohibited to publish, contained personal identifying or confidential information, or in any other way is determined by the Steering Committee to be a risk to publish, was excluded from the open data policy. This manual approach to approving datasets for publication on the portal required initiative of the government departments and the public to put through requests for datasets. While an open data strategy like that of the EU automatically requires datasets to be open and effort to explain why they should not be published (Colpaert et al., 2017), until recently the CoCT policy did the opposite, and therefore had the opposite effect of less data available online than what could have been possible.

The early limitations of the CoCT's open data policy reflect in the inadequacies of the datasets available through the open data portal. The open data portal was first launched with 29 datasets in 2015 and had 141 datasets as of mid-2021 (Ricker et al., 2020; CoCT, 2021). From the just four transportation datasets available, only data on the MyCiTi bus stops and routes, and minibus taxi routes are available. These dataset formats are standardised, and are available in formats for different applications, e.g., CSV, KML, Shapefile, and GeoJSON files. While publishing and update dates are included, further information on what within the dataset specifically was updated is not included. Furthermore, essential metadata such as how route shapes on the minibus taxis were gathered is not given. The accuracy of these routes will vary dependent on whether the routes were reconstructed from official licensed route permits (i.e., theoretical paths) or were manually gathered with onboard surveyors over a period of time (i.e., actual paths). These problematic limitations are echoed by private sector stakeholders. As an example, in the public participation responses on the ITPN 2018-23 on 26 September 2017, a transport planner at the V&A Waterfront development, commented that for the purpose of supporting businesses and entrepreneurs, data needed to be made available in accessible formats and should automatically be published publicly on the Open Data portal (CoCT, 2018).

The open data policy was revised in 2020 with feedback from the public and updated to reflect best practice and current open data standards (CoCT, 2020). The most notable change was the shift to automatically making data the CoCT collects public. The policy also added an amendment stating that work done with third parties should by default include datasets that can be uploaded to the portal. Furthermore, rather than resting responsibility for the management of the portal with an existing department, a new department, the Information and Knowledge Management Department, was made explicitly responsible for running the portal. Unlike the previous version, each city department would now have a data steward - a person specifically responsible for managing all data within their department relevant to the portal. These direct, consolidated responsibilities prioritise the publication of open data as opposed to previously where responsibilities were secondary functions to pre-existing roles and fulfilling the requirements of the open data policy could be reduced to ticking a checkbox of minimum datasets.

However, there are still shortfalls to the updated 2020 policy that need to be addressed in future revisions to ensure that transport data becomes a valuable asset for public transport users. The policy needs to outline more unambiguous standards on the quality of the datasets to be included to ensure that all contributing parties are held accountable to universal quality standards and data made available online has a low barrier to use. To encourage ICT solutions, the policy should encourage developer friendly file formats (e.g., GTFS) along with metadata on how the data was collected. This is particularly important for mobility data which, if inaccurate, will lead to dissatisfaction and mistrust in the information provided (and likely that a user will not come back to using that information source). The open data portal currently contains only the bare minimum in terms of transport data. For example, the City has GTFS and real-time data on MyCiTi systems that are currently not available to the public. The policy is forward-looking in its inclusion of datasets from future data collection projects, but there is no mention on whether and how previous datasets might be included. The CoCT also has data from a data collection project done to map the MBT routes and other service data which is not publicly accessible. Though the updated policy stipulates research work must now include datasets as a default deliverable, would something like the MBT collection project have been considered research? The policy needs to be more explicit on what constitutes research to avoid copyright issues that may arise with the involvement of third parties in the collection of mobility data, and tenders for mobility data should automatically specify that the dataset will be included in the open data portal.

7.4.2.1 Building on Open Data

Open data has been successfully used to power diverse information solutions. In the case of Cape Town where the population has diverse information needs and ICT capabilities, a one-size-fits-all solution does not exist, and so making data publicly accessible allows for a multitude of solutions to take shape. There are many successful precedents of ICT solutions that rely on open data to create value for end users, including Google Maps, Transit App, Moovit and CityMapper. CityMapper, for one, is a free application available in several cities across five continents that draws on open data to provide journey planning information. Like other free journey planning applications, the app was not available to users in cities with paratransit as data on unscheduled systems was not publicly accessible. Only recently with access to paratransit data has CityMapper expanded into Mexico City and Istanbul, but access to open transport data in Africa has thwarted CityMapper's and undoubtedly other apps' abilities to expand services into African cities. Moovit also draws on open data, and where open data does not exist, it attempts to crowdsource information from its app users, however this is not without the disadvantage that the information provided in cities is piecemeal and error prone.

A subset of open data is a public transport API which can break down the barrier to entry for developers building journey planning apps. An API essentially is a software that bridges between two different applications, like a database and an application. So when a question is asked on an app, the API delivers the request to the database and then delivers the reply back to the app. Unlike open data portals, APIs can provide additional services like route planning using different modes. Swiss public transport API and OpenTripPlanner are examples of open transport APIs. Cities like London, Berlin and Vienna have or are moving towards APIs (Ambrosino et al., 2016). APIs however are not a replacement strategy to open data portals as they are not as useful for directly accessing datasets, especially for non-developer end users. Furthermore, APIs demand a lot of resources to manage the API which can be unfeasible for already resource-constrained city authorities (Boyd 2014). However, opening up data does allow existing open APIs to integrate this data into their platform and provide services to the public without city authorities having to shoulder the burden of an API.

7.4.3 Privatised Initiatives

The alternative to opening the data to the public is privatising information provision, either assuming responsibility in-house for the development of ICT solutions or tendering the work out. The CoCT has previously tendered the development of a MyCiTi journey planning mobile app out to third parties – the first launched in 2014 with only static information and the second new app with real-time information in 2019. The advantage of this procurement process was that the City was able to guarantee a journey planning app would be built and meet minimum quality standards the City set out. Opening data does not guarantee that solutions will necessarily be built, especially solutions without a clear business model to incentivise developers to invest resources into lengthy development and maintenance commitments. Transport for London, despite maintaining an open data portal and journey planning API, does have its own journey planning app for the purpose of providing uninterrupted access to integrated information across their services.

The downside of tendering out ICT solutions development is that tendering implies specifications to ensure that minimum design and functional standards are met, but at the cost of creativity and improvements to the design that may have come out of development process without strict specifications. Furthermore, neither the third-party developer nor the city authority may have the same level of vested interest that a private developer might have if they independently built a solution, because for the former the objective may be primarily to check a box while for the latter a high-quality design is critical to the life of their solution. Concerns such as growing active users, technological fixes, and overall evolution of the solution may not be as paramount for tendered ICT developments as they are for privately built initiatives that rely on user satisfaction to survive. For example, the second app that the CoCT tendered for and launched in 2019 has not been updated by the third-party developer since November 2019 leaving multiple user complaints with the app on the Google Playstore unattended.

In the case that the information dissemination is to be tendered to a third party, information needs need to be directly addressed in the tender process. According to Goede and Nijkamp (2002), the tender should already include travel information with necessary conditions: information must be available at all points along a trip in every possible format (e.g., visually and orally) to ensure accessibility.

An additional consideration is how receptive potential users may be to government-provided technologies. Studies have found paramount for user uptake of information technologies is trust in the institutions that provide them (e.g. Alam et al., 2020; Burkhard et al., 2013; Thusi and Maduku, 2020). Burkhard et al. (2013) studied whether people's trust in the government as an information source affected their intentions to use the government's online public transport information service. They found that trust in information provided digitally correlates with trust in the public transport service reliability. In South Africa where service unreliability is common, this finding may bear implications for the effectiveness of relaying information on public transport service attributes, particularly where the information is CoCT-branded.

7.5 EXPANDING ICT CAPABILITIES TO GROW INFORMATIONAL CAPABILITIES

Though mobile phone penetration in cities is likely high enough within the captive public transport user group to position smartphones as an effective method of communicating transport information, mobile data may prove a barrier to access. As of 2019, all urban areas have full 2G coverage, and more than 98% 3G and LTE coverage (ICASA, 2020). Though the necessary infrastructure is abundant, data affordability and local mobile phone storage space present potential challenges to the uptake of mobile security applications. As opposed to regions where mobile data is readily available and relatively inexpensive compared to income, in areas where data is expensive or limited, users will restrict and optimise their data use (Mathur et al., 2015). In South African cities, readily available fibre and broadband tend to be restricted to higher income areas, leaving internet connectivity options in low-income areas limited to mobile data. The lack of widely available public Wi-Fi exacerbates the dependency on mobile data in urban townships (Phokeer et al., 2016). Mobile data contract plans are restricted to those who can provide proof of a stable monthly income and bank statements, which makes such plans inaccessible to informal workers. Because of this, low-income mobile users rely on expensive prepaid data plans or out-of-bundle data. Given two-thirds of respondents in the surveys stated they have limited or no access to mobile data, communicating transport information via mobile phones would need to take these data limitations into account. To this end, national and municipal policies have actively addressed the removal of barriers to physical ICT access.

7.5.1 ICT Policy in South Africa

South Africa has a long history of ICT policy to reaffirm the national government's commitment to ensuring all citizens have access to the information opportunities digital technologies provide. Universal access to telecommunication services across all socio-demographic groups in South Africa was first embraced in the *1996 White Paper on Telecommunications* (Department of Communications, 2014). Outdated with the advent and widespread use of the internet and portable ICTs, this was replaced with the *2016 National Integrated ICT Policy White Paper*, which notably acknowledged the convergence of current and traditional ICTs whereby multiple functionalities are combined into single devices, and the need for data to guide policy direction and monitor progress (DoTPS, 2016). This new White Paper followed the review of ICT policies that commenced in 2012 with the aim of understanding how to better position policies to bring about inclusive access to ICTs, an objective that so far had not be satisfactorily met.

This review process was captured in several papers including the *Framing Paper* and the *National Integrated ICT Policy Green Paper* in 2013. In line with the National Development Plan 2030 objective of developing an inclusive information society, the *2013 Framing Paper* aimed to understand how to better position policies to bring about inclusive access to ICTs. While no particular group is mentioned as the primary target group for these policies, the paper maintains that all South Africans have the right to "benefit equitably from the ability of the communications sector to facilitate social development and improve the quality of life of individuals" (Department of Communications, 2014: 9). The *2013 Green Paper* made several recommendations following input on the objectives and goals of telecommunications policy, most notably of which was for a national broadband policy to improve the affordability, availability and accessibility of internet through infrastructure rollout.

However, these various papers have focussed primarily on supply-side challenges and approaches as opposed to demand-side needs to access ICTs. Equality is a key part of the *2016 White Paper*, where it is stated "All South Africans must have affordable access to communications infrastructure and services and the capacity and means to access, create and distribute information, applications and content in the language of their choice" (DoTPS, 2016: 11). While the paper addresses barriers to internet access, it only mentions ICT capabilities in the context of bolstering the technological education needed to fill an ICT skills gap in the workplace as opposed to gaps in skills to use everyday applications of ICTs to expand on a range of capabilities.

In line with these national policies, the Western Cape Government published a *Broadband Strategic Framework* in mid-2011 to guide the province in achieving their 2030 mission to provide every citizen with affordable infrastructure and skills to access internet (WCPDoEDT, 2011). To increase internet access, and in line with the thinking of the 2013 SA Connect national broadband policy, the Province has been rolling out the WCG-LTSA Wi-Fi Hotspot project. Through this project, 178 government buildings across the province have been externally fitted with Wi-Fi devices to provide people with 3GB of free data per device per month, 24 hours a day. Unlimited free access is granted to any *.gov.za* website to ensure citizens can reach public interest services. In Cape Town, these hotspots are heavily concentrated in the township and low-income areas.

While efforts are demonstrably being made to expand ICT capabilities through access to physical infrastructure requirements within low-income areas, these efforts still fall short of expanding ICT capabilities in such a way that captive public transport users are empowered with the infrastructure and skills needed to tap into a hybrid public transport information for pre-trip planning. Rather, to use present ICT capabilities to expand informational capabilities, the CoCT can leverage the prevailing methods of information acquisition captive users already have the means and knowledge to access.

7.5.2 Expanding Informational Capabilities Through Existing ICT Capabilities

Tapping into existing resources and utilising these to disseminate public transport information could break down some of the potential barriers to the uptake of hybrid public transport information. There are two primary sources captive users currently rely on as sources of public transport information when planning trips to new destinations: online and transport personnel.

Given that almost all captive users reported access to an internet-capable mobile phone, expanding hybrid public transport information access via existing online resources would make use of existing ICT capabilities. Social media, websites and/or mobile apps were used by two-thirds of all captive public transport users sampled in the survey to access information to plan a journey to a new destination. Tapping into these sources that people already are comfortable and familiar with using would not only help overcome challenges to source adoption, but also would not necessitate new app downloads. Many of these online resources are already offered for free through network providers or have data-conservative versions.

The major mobile network providers often provide customers with free access to specified websites, generally limited to health, government, education, and employment pages. Access is contingent on the network subscriber having some mobile data loaded on their phone and may be capped to a certain data usage limit. Mobile network providers often also offer free websites if the user has some mobile data loaded to their phone. For example, Cell-C already offers free access to Facebook and Facebook Messenger. Across several providers, Facebook offers a free mode, without access to images or videos, that users can access on their phones. While not all popular social media offer mobile data cost-free versions, apps like Twitter have data-saving modes to reduce the impact of data use by images and videos, and other apps like WhatsApp automatically compress images and videos. While these platforms are already used either officially by operators or unofficially between passengers for information on isolated services, the CoCT could use these or similar social media channels to communicate information across the hybrid network.

Though three-quarters of respondents did report in the primary data collection surveys that they have access to the internet at places other than at home or via their phones (e.g., internet café, school, work), their flexibility in where and when they are able to access information is limited compared to those with unlimited access to mobile data. While planning trips from, for example, home to work or work to non-routine destination may be possible from these regular locations, planning a trip from one non-routine place to another is more difficult away from internet. In other words, users might need to plan trips in advance while at an internet access point and do not have the flexibility to access information to replan in the case of service disruptions or to access live time-based information, thereby limiting their ability to confidently plan non-routine journeys.

The DG Murry Trust (2018), which specifically is concerned with advancement of education and employment opportunities for underprivileged South African youth, found that mobile data prices would need to fall below ZAR 15 per megabyte to be affordable to the majority of South Africans. A more realistic option would be to zero-rate key information services, which in turn can lend to socio-economic benefits. Zero-rating is when a user can download and use an application or website without incurring mobile data costs either for unlimited use or to a specified data cap. As of 2020 due to the need to open access to online resources during the COVID-19 pandemic, roughly 1000 local South African websites were zero-rated for the duration of the official state of disaster (ISPA, 2020). A process is currently in place to allow applications from the health and educational sectors to zero-rate their websites with approval from the respective national departments. Zero-rating websites with integrated multimodal information for journey planning would enable a large portion of transport users who have access to internet-capable phones, but limited access to mobile data to plan journeys from any point.

Another source for the dissemination of hybrid information that would mitigate the need for individual access to mobile data is transport personnel. Just over half of survey respondents reported referring to either the vehicle driver or station personnel for journey planning advice. Transport personnel could be equipped with ICTs such as tablets or phones to query transport information and relay this to passengers. Though this takes the onus off the transport user to have their own means to access information, it would require equipping personnel with devices and internet. The challenge would less be technological and more so questions of whom in the industry to equip with these resources, how this will be funded given the multi-modal reach, buy-in to use such a multi-modal information system to offer information on all modes even if they are perceived as competitors, training of the personnel such that they themselves have the ICT capabilities needed to use and convey the information to the passenger, and how this information will be communicated – will the passenger rely on the personnel to communicate the right information or can they interact with the information directly and interpret the options. The obvious pitfall of this approach is that journey planning is limited to stations/ranks or at a vehicle which not only can be inconvenient but also have safety implications if depending on the time of day and area the potential public transport user is located.

7.6 IMPLEMENTATION CHALLENGES AHEAD

As ICT capabilities and informational capital needs vary across the captive public transport user population, enhancing informational capabilities cannot be addressed with a one-size-fits all solution. Furthermore, information needs and ICT capabilities are malleable, changing with and responding to external circumstances, such that the challenges and opportunities of today will not be the same as those of tomorrow. This necessitates long-term sustainable strategies that have the flexibility to accommodate present and future informational capabilities. Passenger information, data collection, and open data strategies with well-defined responsibilities are needed to ensure that, despite fragmented authorities over Cape Town's public transport system, public transport users receive the information necessary to use it as a single movement system rather than as isolated modes.

Outside of technological barriers to the realisation of the success of these strategies, localised circumstances and transport operating structures can pose challenges to the implementation of intervention precedents from foreign contexts if these are not adapted to Cape Town's context. Researchers conducting data collection exercises on paratransit systems to create the GTFS files needed to integrate basic journey planning information with scheduled systems have already found that the flexible nature of paratransit operations requires rethinking standardised file formats born in Western contexts (Williams et al., 2015). Another example are screens with live transit information that are growing increasingly popular in Western countries and already used inside of MyCiTi stations. While digital screens can provide location-specific information without requiring the user to own their own device or internet, placed in unmonitored locations, they may be subject to cable theft and vandalism. Interventions should first be piloted on a small scale for a period of time before expanding information solutions across the full system.

By nature of the hybrid network composed of services that at times are in competition with each other, acceptance and adoption of integrated multimodal travel information amongst the disparate operators may prove to be one of the greatest barriers to realising enhanced informational capabilities of captive public transport users. Though the CoCT could in theory circumvent operators to gather static data on service operations to feed an integrated information system, the information system's success relies on the operators to support the system. Real-time information which often requires the use of vehicle-tracking devices would require the cooperation of the operators to provide this information to the CoCT. There are of course methods around working directly with operators that entail the use of mobile applications to crowdsource real-time locations of vehicles, but this depends on a critical mass of users actively using the applications or the drivers to willingly share their locations, not to mention accompanying privacy concerns. Additionally, given the strong reliance on on-ground personnel for journey information, these personnel could be invaluable to not only orally communicating hybrid travel tips, but also to the promotion of ICT initiatives.

Given the potential beneficiaries of access to open data, but burden such a resource-intensive endeavour would place on a single responsible entity, cross-sectoral partnerships involving public and private sector participation could be formed to respond to the challenges of data collection and maintenance. Particularly cooperation between various public and private stakeholders responsible for the operations of the transport services is key to ensuring access to data on their operations. Furthermore, collaboration with civil society organisations (e.g., World Bank and

Digital Transport for Africa) who have experience with managing data collection projects in emerging cities, from the collection of passenger information to the standardisation of data to open data initiatives, may be beneficial. However, forming such partnerships does not come without challenges, including but not limited to questions of who is responsible for financing the collection and maintenance of data given multiple transport services are involved that are under the jurisdiction of three different levels of government and benefit differentially from improved information access, willingness to participate given opposing political party interests at different tiers of government, and conflicting agendas.

Ultimately the barriers to enhancing informational capabilities of captive public transport users do not start and stop with their information needs and ICT capabilities but extend to the successful implementation of the policies and strategies outlined for the evolving nature of informational capabilities and to the cooperation of the stakeholders directly and indirectly involved in the hybrid system itself.

8. CONCLUSION

Public transport information, though unevenly scattered, is so ubiquitous and examples of transport ICTs so common, that there is a tacit assumption as evidenced by the lack of research that further investigation of passenger needs is not necessary – that rather the challenge is about addressing the data gap. And so, without any prior investigation into the needs of passengers in the Global South, whether for scheduled modes, unscheduled modes, or the combination of the two, technologies have proliferated to combat preconceived notions of data deficits and to provide information on predetermined needs. In light of the global and local trends to move towards ICTs for the provision of multimodal public transport information, the purpose of this research was to rethink passenger information within the context of Cape Town's hybrid system and investigate how to enable equitable access to information via ICTs to enhance equitable access to mobility for captive public transport users.

The overarching research aim was investigated through the framework of Amartya Sen's capability approach within Björn-Sören Gigler's adaptation to ICTs with research objectives broken down by *informational capital*, *ICT capabilities*, and *informational capabilities*. While the capability approach has previously been applied in transport studies (e.g., Beyazit, 2011; Hickman et al., 2017) and separately to the assessment of technology for development (e.g., Zheng and Stahl, 2011; Kleine, 2013), it has not been applied to the study of ICTs for public transport information. Framing the research process within the capability approach lent itself to tying together sensitivities to information needs and access to ICTs as individual and linked components and determining how these feed into improving informational abilities to access the hybrid system. Given this framework, the following research questions were pursued:

1) What information do users need to facilitate hybrid journey planning and is this already available?

2) What level of access and ability do users have to use different ICT infrastructures as related to transport information?

3) What is the minimum information required to meaningfully make use of the hybrid network to access and expand mobility opportunities?

4) How does an understanding of informational capital deficits and ICT capabilities as barriers to hybrid network use translate into recommendations for enhancing informational capabilities?

Through the investigation of these research objectives, this thesis has made the following original contributions to knowledge regarding the role of ICTs for hybrid network use. The application of the capability approach as a conceptual framework to investigate the relevant information content and access to information sources needed to improve individual capabilities to access mobility in the hybrid network was not previously done. In terms of information content, or passenger information needs, there was no existing research that directly investigated what information users in emerging regions desire to navigate a hybrid network composed of scheduled and unscheduled modes. This thesis employed semi-structured interviews, a best-worst scaling study, and a stated preference choice model to identify user information needs for pre-trip planning across a hybrid system. Though safety concerns have arisen in travel satisfaction surveys, these concerns have not been translated into passenger information - this research found that several aspects of safety are key information requirements in planning non-routine hybrid journeys in Cape Town. Simultaneously, there has been little prior understanding of the ICT capabilities of users to access transport related information which this thesis has sought to investigate as potential barriers and opportunities to the dissemination of pre-trip information on hybrid networks via technologies to inform recommendations for the enhancement of informational capabilities.

Despite the mandate that metropolitan authorities provide public transport information to aid passengers in decision-making, very little research has been done into the information needs of passengers generally and more specifically in the context of Cape Town's hybrid system. Instead, surveys in Cape Town have tended to focus on factors affecting mode choice (e.g., Ugo, 2014; General Household Surveys). While Teffo et al. (2019) investigated priority needs of public transport users living in informal settlements, these needs were in relation to transport infrastructure and regulations. Across studies that did deal with information needs, these needs were pre-determined as important by the researchers (e.g., Grotenhuis et al., 2007; Meng et al., 2017). However, this restricted findings to a subset of the information needs the research believed to be important for users as opposed to a subset of what users believed to be important. In framing the research within the capability approach, this research stepped back to first gain a comprehensive understanding of information needs users may have in planning a hybrid journey before determining which needs were most important across the population. By commencing with qualitative interviews, this research found diverse information needs such as seating availability, payment methods, and, importantly, safety. Though safety and security often has arisen as a barrier to mode choice and infrastructure use, these concerns have not translated into appearing in studies of information needs (e.g., Teffo et al. (2019) found that safety walking accessing public transport and personal safety in transport environments were consistently high priority needs).

Information types deemed to be essential for journey planning because they determined whether a trip was possible between two points at a given time of day by a specified point were separated out from the original comprehensive list. These spatiotemporal pieces of information should be provided regardless of the needs that people may have to determine which journey options best meet their preferences. They form the basis of any basic information provisions. The remaining information types were categorised as organising information, or information that enables people to make a choice between different journey possibilities. For the purposes of translating these organising information needs into realistic passenger information intervention goals that the CoCT could feasibly pursue, a best-worst scaling method was used to prioritise needs based on a representative list of 'most important' information types. At this stage, the research turned towards explicitly defining information needs within non-routine trip scenarios. As journey planning for routine and non-routine trips likely require different sets of information, this research focussed on the information required to make non-routine trips that otherwise might have been forgone without access to the pre-trip information needed to reinforce perceived behavioural control. From a list of 17 items included in the BWS study, fare, time, and safety information were the three main information categories most desired to plan non-routine hybrid journeys.

In the final investigation of which types of information and quality of those types are most important to hybrid journey decision-making, the choice model incorporated uncertainty as attribute levels. While uncertainty has previously been incorporated in a subset of attributes, the role of uncertainty was used to study its impact on choice (e.g., Zhongwei et al., 2012; Li et al., 2016; Wijayaratna and Dixit, 2016). This study sought to understand where uncertainty might be acceptable for decision-making as opposed to its impact on decision-making. Furthermore, this study sought to understand which information people need to make a journey choice as opposed to the impact of information availability on journey choice (e.g., Meng et al., 2017; Wijayaratna and Dixit, 2016; Ben-Elia et al., 2008; Chorus et al., 2007). The incorporation of uncertainty in a study investigating the information quality desired for public journey pre-trip planning demanded sensitivity to perceptions of utility – in other words choosing based on the desired quality of information to make a journey choice rather than conflating information quality as a specific journey option. While the latter has been extensively studied in various situations (albeit not within the hybrid public transport context), the former has not been investigated in any context through a choice model.

From the MMNL choice models disaggregated by individual characteristics and trip scenarios, heterogenous information needs were found, with significant differences in the needs of males and females, between leisure and appointment-based trip purposes, and among groups based on their digital poverty level. To address differential information needs equitably given diverse travel needs and demographics, the information quality with the most utility across the consolidated MMNL model results was prioritised. All information types tested were significantly more useful to journey planning than no information at all, but that for frequency information where only estimates were required. Exact information quality was preferred for arrival times, departure times, fares, safety onboard, safety walking to a stop/station, and safety waiting at a stop/station.

Packaging this information in a way that captive public transport users could access the information required a deeper understanding of ICT capabilities that extended beyond physical access to technologies to encompass the ability to use the technologies. Like previous research and national surveys (e.g., *RIA 2017-18*), this research found that the penetration of mobile phone ownership amongst urban captive public transport users is high compared to other technologies. This makes mobile phones valuable means of directly communicating transport information with users. The outstanding question was how to leverage technologies to deliver this. Currently, pre-trip planning information via technologies is restricted in the range of formats available. Municipalities tend to rely on journey planning information heavily embedded in map-based apps as their primary means of communicating public transport information (e.g., the official MyCiTi app released in 2019; Gauteng Province's Gauteng on the Move app released in 2018). Otherwise, official social media platforms are primarily used for service updates. Official operator websites contain timetables that require an understanding of stop names to interpret the arrival and departure times (the stop names are either known through experience or deduced by reading a route and stop map, if available). Recently, research into the digital divide in South Africa has embraced the access to technologies for the expansion of opportunities not just as a matter of ownership but also as a question of skills (e.g., Jiyane and Mostert, 2010; Fasasi and Heukelman, 2017; Allen, 2018). While skills for everyday use cases of ICTs provide a proxy for ICT capabilities, the skills required to access transport information are not necessarily the same. Specialised skills are needed to understand how to read maps, pinpoint one's location, and interact with other means of information access that are specific to mobility.

This thesis lends original insight into ICT skills for accessing transport information, revealing that there is in fact a disjuncture in users' abilities to access information and the popular methods used to provide users with information. Though overall ICT skills as related to transport information are relatively high across the population, when separated into specific use cases of transport information commonly found in the market, only about half of the target captive public transport user population have no difficulty at all in accessing information via websites or journey planning apps. However, if considering less popular means of officially disbursing transport information like messaging apps and chatrooms, the means that are commonly used to share information informally between fellow passengers, then transport information has the potential to reach a far greater proportion of users. While there are different avenues to overcoming barriers to internet access, such as the expansion of Wi-Fi hotspots and zero-rating information services, transport-specific methods of communicating information are exclusionary, necessitating specialised skills like map reading and navigational proficiency. Rather, communications can build on pre-existing sources of transport information and look to currently popular methods of information gathering that users are comfortable with such as social media and word-of-mouth sources that do not enshroud information in transport-specific formats.

Through the research process and methodologies employed, this research found that none of the information types at the quality level desired are currently evenly available across the hybrid public transport system. Nor do official information sources have the capacity to reach the majority of captive public transport users given current ICT capabilities. The combination of gaps in information provision and lack of adequate means of communicating information that meet the capabilities of captive public transport users hinders the informational capabilities of these users to plan journeys that best meet their needs and preferences, and consequentially limits their access to opportunities through mobility.

Given the pace that technologies are evolving and people's capacities to use these technologies, approaching the current information challenges captive users face for planning hybrid public transport journeys with an established solution like a mobile app would not be sustainable in the long-term. Strategies for understanding information needs, collecting the data necessary, and opening this data to the public through portals provide the adaptability and flexibility needed to deliver solutions despite rapidly changing circumstances. Pursuing such strategies would create the foundation needed for innovations to take root outside of those the CoCT explicitly provides.

Like many cities with scheduled and unscheduled systems that are not all under the sole authority of a municipality, implementation challenges to providing the integrated multimodal information necessary to expanding informational capabilities are complicated by the fragmentation of power. Though the CoCT is mandated with the task of providing integrated information to enable travellers to make effective journey decisions, providing this information without authority to gather the data required from services outside of the CoCT's regulatory power complicates matters. Safety information is an especially complex type of information that is both absent for all modes and extends beyond the direct jurisdiction of any operator. However, it is deeply entwined with passengers' perceptions of journey options, as national and metropolitan level surveys have revealed, and therefore is a key component of hybrid journey planning that is just as necessary to provide as any service-related attribute. Overcoming these hurdles to data collection and access to support passenger information needs will require cooperation amongst stakeholders and an agreement that passenger information across the hybrid system is not in competition with one's own services but enables the passenger to make better use of multiple services to access the city.

To address the factors that currently pose as barriers to the implementation of integrated hybrid public transport information, further research is needed in several areas. To confront the potential conflict of interest stakeholders may feel in supporting integrated passenger information initiatives, further research may be needed to study the effect of enhanced passenger multimodal information on modal choice within a hybrid system, and how this affects competition between services as compared to modal choices made within the current information landscape whereby information across services is not integrated. In line with this, while the research touched a bit on this point in the interviews, it would be useful to have a deeper understanding of how access to current information versus the new information found through this research affects people's abilities to access different opportunities within the city. An evidence-backed understanding of the impact of information in a hybrid system would give grounds for diverting and investing resources into expanding and maintaining passenger information. Safety information, in particular, will require significant attention as precedents for data collection and dissemination are largely absent. Safety information for the purposes of this study was vaguely defined, but explained to the respondents as questions, e.g., "for which option am I the safest onboard the vehicle?". Further research is needed to break down this attribute to discern what kind of safety is of most concern to transit users, e.g., road safety, the condition of the vehicle, or personal security from crime or assault. Additionally, further research is needed to see if additional information indeed resolves safety and security concerns and incentivises acceptance of alternative public transport modes, or if this concern merits consideration of further integration with alternative modes, not unlike the MaaS concept that integrates public transport and alternatives like e-hailing, to enable more equitable mobility access. Boutueil and Aguiléra (2019) suggest that ICT-enabled mobility services have the potential to fill unmet mobility needs and thereby improve accessibility where present services were lacking.

Several limitations to the scope of this study necessitate further research to address informational capabilities in other scenarios and for different user groups. This study was specifically concerned with the Cape Town context, and so safety concerns may have been more accentuated than in other cities. The information needs found are those needed to support non-routine trip planning – the information needs for routine trips will likely differ. Furthermore, this study focused on the first stage of journey information, the pre-trip stage, and needs may differ at other stages of the trip, such as en route or at transfer points. As all of this was studied within the context of the needs and capabilities of captive public transport users, information needs will likely differ for choice users and for people who believe they cannot access public transport because of perceived barriers. This study focussed specifically on demand side aspects of information provision, but further research would need to be done into understanding constraints from the supply side to meet these demands. Limitations presented in not having considered supply side on information provision include, but are not limited to, the feasibility of collecting data, feasibility of sharing data and ensuring it is up to date, and responsibilities around who should provide and maintain which data, which all determine the extent to which service providers can deliver to user needs.

Though the study focussed on recommendations for enhancing the informational capabilities of captive users in Cape Town, the findings of this study do have broader implications for hybrid system information globally. Hybrid public transport systems, though around for decades now, were only in the recent decade officially embraced as means of accommodating mobility needs in diverse urban landscapes. Their mix of scheduled and unscheduled systems present unique information challenges that demand rethinking our understanding of multimodality within the context of hybridity. While information and technologies for integrated multimodal systems have been extensively studied, this research has been largely limited to the context of scheduled public transport services in North American or European environments. There is room for deeper investigation into how ICTs can be leveraged to address inadequate information supply impacting users' ability to realise their mobility needs in other urban regions in the Global South (Boutueil and Aguiléra, 2019; Dzisi et al., 2022). For example, the safety and security concerns revealed through this research are not unique to Cape Town, but relevant to other cities where public transport users have cited similar concerns (in Indonesia: Kubota and Joewono, 2007; in Colombia: Quinones (2020); in Nigeria: Badiora, Wojuade, and Adeyemi (2020); in Ethiopia: Kacharo, Teshome, and Woltamo (2022), for example). This points to the need to rethink current information provision and the role of ICTs in the context of these cities' unique mobility environments to respond to localised challenges to user capabilities. Growing internet penetration rates, high mobile phone ownership, and low satisfaction rates with public transport service quality are prevalent characteristics in numerous emerging cities where the research approach outlined can lend insight into improving the informational capabilities of users while harnessing the existing mobility network (Boutueil and Aguiléra, 2019). Returning to Sen's capability approach, the capabilities an individual can theoretically access are specific to the mobility means available to enable these capabilities. The conversion factors needed to translate mobility into capabilities are specific to the individual and the mobility means. It is because of this nuanced relationship between means, conversion factors, and capabilities that taking the information needs and solutions from multimodal scheduled systems to a hybrid system context will not necessarily translate to expanded capabilities. This study revealed that there is a gap between information currently provided and that which users need to navigate a hybrid system, and thereby argues for contextualised research to lay the foundations for hybrid system information requirements that drive data collection initiatives and the development of technologies across emerging cities.

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APPENDICES

A. Ethics approval for objective 1 – interviews

Application for Approval of Ethics in Research (EiR) Projects
Faculty of Engineering and the Built Environment, University of Cape Town

ETHICS APPLICATION FORM

Please Note:
Any person planning to undertake research in the Faculty of Engineering and the Built Environment (EBE) at the University of Cape Town is required to complete this form **before** collecting or analysing data. The objective of submitting this application *prior* to embarking on research is to ensure that the highest ethical standards in research, conducted under the auspices of the EBE Faculty, are met. Please ensure that you have read, and understood the **EBE Ethics in Research Handbook** (available from the UCT EBE, Research Ethics website) prior to completing this application form: http://www.ebe.uct.ac.za/ebe/research/ethics1

APPLICANT'S DETAILS		
Name of principal researcher, student or external applicant		Bianca Ryseck
Department		Civil Engineering – Transport Studies
Preferred email address of applicant:		bbryseck@gmail.com
If Student	Your Degree: e.g., MSc, PhD, etc.	PhD
	Credit Value of Research: e.g., 60/120/180/360 etc.	360
	Name of Supervisor (if supervised):	Roger Behrens
If this is a research contract, indicate the source of funding/sponsorship		
Project Title		Enabling Equitable Access to Public Transport Information through ICTs to Enhance Hybrid Network Use in Cape Town, South Africa

I hereby undertake to carry out my research in such a way that:

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

APPLICATION BY	Full name	Signature	Date
Principal Researcher/ Student/External applicant	Bianca Ryseck	[signature]	17 Oct 2019
SUPPORTED BY	Full name	Signature	Date
Supervisor (where applicable)	Roger Behrens	[signature]	17 Oct 2019
APPROVED BY	Full name	Signature	Date
HOD (or delegated nominee) Final authority for all applicants who have answered NO to all questions in Section 1; and for all Undergraduate research (Including Honours).	Dyllon Randall	[signature]	18 Oct 2019
Chair: Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the questions in Section 1.			

Page **1** of **1**

B. Survey instrument for objective 1 – interviews

Consent Page

To be read out loud to participants and consent gained verbally.

The purpose of this research is to understand what information public transport users need to make a public transport journey in Cape Town that involves at least one transfer between different types of transport. This research is being conducted as part of my doctoral studies in Transport Studies at the University of Cape Town.

Your participation in this research study is voluntary and you may withdraw at any time.

I will ask you several questions about your current travel patterns and hypothetical situations and this will take approximately 20 minutes.

All information that you provide will be kept strictly confidential and secure. No information will be kept that will personally identify you. The results of this study will be used for academic purposes only.

If you have any questions about the research study, please feel free to ask me.

Do you voluntarily agree to participate in this research study?

Pre-screening Questionnaire:

1. Are you between the ages of 18 and 55? **Y / N**
2. Do you have access to a functioning car in your household? **Y / N**

*If **yes** to the first question, and **no** to the latter, then the participant is a suitable candidate for this study.*

Semi-Structured Questionnaire

1. **Establish current pattern of behaviour from routine origin to destination.**
    a. How do you usually travel from home to your work/place of study?
        i. What modes do you use? Do you transfer?
        ii. Which parts of Cape Town are you travelling between?
    b. Are there alternative public transport options available to get from home to your work/place of study?
        i. What are your main reasons for not using those other options to get from home to your work/place of study?

2. **Set up hypothetical scenarios to discern info needs (strike + work/study + leisure).**
    a. Imagine it's a Monday morning and you hear that there's a strike on the << mode interviewee has said they use first >>.
        i. How do you figure out how to use alternative public transport to get to work?
        ii. What information would you look for to plan this journey?
    b. Imagine you needed to get from home to Bellville/Table View/Kalk Bay for work. This trip will involve at least one transfer.
        i. What information would you look for to plan this journey?
        ii. Where would you look for information to plan this journey?
    c. Imagine you wanted to get from home to Hout Bay to get fish and chips for lunch. This trip will involve at least one transfer.
        1. What information would you look for to plan this journey?
        2. Where would you look for information to plan this journey?
    d. And now imagine you wanted to go from Hout Bay to Tokai to go to the movie theatre.
        1. What information would you look for to plan this journey?
        2. Where would you look for information to plan this journey?
    e. The movie has finished at 10 pm and it's dark out. You want to get from the movie theatre in Tokai to home.
        1. What information would you look for to plan this journey?
        2. Where would you look for information to plan this journey?

Response Recording Tool

Tick where appropriate based on interviewee responses.

Q 1: Baseline

What modes do you use?

__ MBT   __ Golden Arrow   __ MetroRail   __ MyCiTi   __ OTHER

Do you transfer?

Yes / No

Which parts of Cape Town are you travelling between?

Home: ____________________________

Place of Work/Study: ____________________________

Information Type	Question Type						
	Alt. Mode + Usual Destination	Reason for Not choosing Alt travel mode for usual destination	**STRIKE**: Alt. Journey + Usual Destination	**WORK**: Home to New Destination	**LEISURE**: Daytime + New Destination	**LEISURE**: Daytime + New Destination to New Destination	**LEISURE**: Nighttime + New Origin to Home
Fare cost							
Payment Method							
Travel time							
Waiting time							
Total walking time/distance							
Real time departure							
Operating times							
Departure times							
Arrival times							
Cancellations, delays							
Route							
Number of transfers							
Transfer locations							
Stops/landmarks							
Map							
Seat availability							
Safety onboard							
Safety at stop/station							
OTHER:							
OTHER:							

OTHER:							
OTHER:							
OTHER:							
OTHER:							
OTHER:							
Information Source							
Bus or minibus-taxi driver							
Interchange/rank personnel							
Other passengers							
Kiosks at Station							
Transport Information Centre							
Other call centre							
Website							
Social Media: Facebook							
Social Media: Twitter							
Social Media: Other							
Whatsapp Groups							
Mobile app							
Map at station/stop							
Timetable at station/stop							
OTHER:							
OTHER:							
OTHER:							

Notes:

C. Ethics approval for objective 1 – best-worst scaling survey

Application for Approval of Ethics in Research (EiR) Projects
Faculty of Engineering and the Built Environment, University of Cape Town

ETHICS APPLICATION FORM

Please Note:
Any person planning to undertake research in the Faculty of Engineering and the Built Environment (EBE) at the University of Cape Town is required to complete this form **before** collecting or analysing data. The objective of submitting this application *prior* to embarking on research is to ensure that the highest ethical standards in research, conducted under the auspices of the EBE Faculty, are met. Please ensure that you have read, and understood the **EBE Ethics in Research Handbook** (available from the UCT EBE, Research Ethics website) prior to completing this application form: http://www.ebe.uct.ac.za/ebe/research/ethics1

APPLICANT'S DETAILS		
Name of principal researcher, student or external applicant		Bianca Ryseck
Department		Transport Studies, Civil Engineering
Preferred email address of applicant:		bbryseck@gmail.com
If Student	Your Degree: e.g., MSc, PhD, etc.	PhD
	Credit Value of Research: e.g., 60/120/180/360 etc.	360
	Name of Supervisor (if supervised):	Roger Behrens
If this is a researchcontract, indicate the source of funding/sponsorship		
Project Title		Best-Worst Scaling Survey Design to Assess Public Transport User Needs

I hereby undertake to carry out my research in such a way that:

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

APPLICATION BY	Full name	Signature	Date
Principal Researcher/ Student/External applicant	Bianca Ryseck	[signature]	10/12/2019
SUPPORTED BY	Full name	Signature	Date
Supervisor (where applicable)	R Behrens	[signature]	10 Dec 2019

APPROVED BY	Full name	Signature	Date
HOD (or delegated nominee) Final authority for all applicants who have answered NO to all questions in Section 1; and for all Undergraduate research (Including Honours).	G. VICATOS	[signature]	10/12/19
Chair: Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the questions in Section 1.			

Page **1** of **1**

D. Survey instrument for objective 1 – best-worst scaling survey (example version shown, C1)

CONSENT

To be read out loud to participants and consent gained verbally.

The purpose of this research is to understand what information public transport users need to make a public transport journey in Cape Town that involves at least one transfer between different types of transport. I will ask you a few questions about what information is most and least useful to you in planning a journey. This will take 3 to 6 minutes.

This survey is part of doctoral research at University of Cape Town and the results are for academic purposes only.

Your participation in this research study is voluntary and you may withdraw at any time. All information that you provide will be kept strictly confidential and secure. No information will be kept that will personally identify you.

If you have any questions about the research study, please feel free to ask me.

Do you voluntarily agree to participate in this research study?

PRE-SCREENING QUESTIONS

Ask before proceeding to interview questions.

Do you have access to a functioning car in your household?
Only proceed if NO

Do you use public transport in Cape Town?
Only proceed if YES

Are you between the ages of 18 and 55?
Only proceed if YES

Notes to surveyors:

1. *Uber, Taxify / Bolt, etc. are not public transport.*
2. *For question #5, if the respondent gives a general suburb like "Southern suburbs" or "Khayelitsha" ask them "which suburb specifically?" so that they give a more specific answer like "Rondebosch" or "Makhaza".*

Survey Version C1

Most - Least Useful Public Transport Information Survey

A. FIELD INFORMATION

To fill out prior to the survey

Survey ID
First and last initials followed by survey number ☐ ☐ ☐ ☐ ☐

Date
DD/MM ☐ ☐ / ☐ ☐

Time
HH:MM ☐ ☐ . ☐ ☐

Location

B. GENERAL PUBLIC TRANSPORT USE

READ ALOUD: **For the following, please consider the period prior to March 2020 and the lockdown.**

1.1. How often did you use public transport in Cape Town?

Tick one box only.

- ☐ 5-7 days a week
- ☐ 2-4 days a week
- ☐ Once a week
- ☐ 1-3 times a month

1.2. Which types of public transport did you use most often?

Tick all that apply.

- ☐ Minibus taxi
- ☐ Golden Arrow Bus
- ☐ MyCiTi Bus
- ☐ Metrorail train

1.3. Which types of public transport have you used at least once in Cape Town?

Read all options out loud and tick all that apply.

- ☐ Minibus taxi
- ☐ Golden Arrow Bus
- ☐ MyCiTi Bus
- ☐ Metrorail train

C. LEAST-MOST USEFUL INFORMATION

2. For the following, consider that you are at home and need to go to a new destination in Cape Town. There are several travel options to get there, which will require using one minibus taxi and at least one different type of public transport, such as MyCiTi, the train or Golden Arrow. Please consider this travel is in the period prior to March 2020 and the lockdown.

What would be the LEAST and MOST useful questions you would want answers to, to plan this journey before leaving home?
Tick one 'most useful' and one 'least useful'.

2.1.

Most Useful	Question	Least Useful
	Which option's services run most frequently?	
	Which option has the least transfers?	
	Which option departs closest to the time I want to leave from home?	
	Which option has the shortest travel time?	

2.2.

Most Useful	Question	Least Useful
	For which option am I the safest onboard the vehicle?	
	Where in the station or rank does my vehicle depart?	
	What is the cheapest travel option?	
	Which option has the shortest waiting time?	

2.3.

Most Useful	Question	Least Useful
	Which option has the least transfers?	
	Which option arrives closest to the time I want to arrive at my destination?	
	Which option has the least walking?	
	What are the different fare payment options?	

2.4.

Most Useful	Question	Least Useful
	Which option's vehicles are the least full?	
	For which option am I the safest waiting at the stop or station?	
	Are there delays on the route?	
	How safe is the area that the vehicle goes through?	

2.5.

Most Useful	Question	Least Useful
	What is the cheapest travel option?	
	For which option am I safest walking to and from the vehicle?	
	Which option arrives closest to the time I want to arrive at my destination?	
	Which is the right vehicle for me to get on for my destination?	

2.6.

Most Useful	Question	Least Useful
	Which option has the least walking?	
	Which option’s vehicles are the least full?	
	Which option’s services run most frequently?	
	What is the cheapest travel option?	

2.7.

Most Useful	Question	Least Useful
	For which option am I the safest waiting at the stop or station?	
	Which option has the least walking?	
	For which option am I safest walking to and from the vehicle?	
	Which option has the shortest travel time?	

2.8.

Most Useful	Question	Least Useful
	Which option has the shortest travel time?	
	Which option has the shortest waiting time?	
	How safe is the area that the vehicle goes through?	
	Which is the right vehicle for me to get on for my destination?	

2.9.

Most Useful	Question	Least Useful
	What are the different fare payment options?	
	For which option am I the safest onboard the vehicle?	
	Which option’s services run most frequently?	
	Are there delays on the route?	

2.10.

Most Useful	Question	Least Useful
	Where in the station or rank does my vehicle depart?	
	What are the different fare payment options?	
	How safe is the area that the vehicle goes through?	
	For which option am I safest walking to and from the vehicle?	

2.11.

Most Useful	Question	Least Useful
	Which option has the least transfers?	
	Which option departs closest to the time I want to leave from home?	
	Which option's vehicles are the least full?	
	Where in the station or rank does my vehicle depart?	

2.12.

Most Useful	Question	Least Useful
	Which option departs closest to the time I want to leave from home?	
	Are there delays on the route?	
	Which option has the shortest waiting time?	
	Which option arrives closest to the time I want to arrive at my destination?	

2.13

Most Useful	Question	Least Useful
	Which is the right vehicle for me to get on for my destination?	
	For which option am I the safest onboard the vehicle?	
	Which option has the least transfers?	
	For which option am I the safest waiting at the stop or station?	

D. FINAL DEMOGRAPHICS

3. **How old are you?** ☐

4. **Sex** Male / Female
   Select one.

5. **In which suburb do you live in Cape Town?** ☐

6. **What is your occupation?** ☐

7. Which of the following technologies do you own?
Select all that apply.
- ☐ Apple Smartphone
- ☐ Android Smartphone
- ☐ Other Phone with Internet
- ☐ Other Phone without Internet
- ☐ Computer
- ☐ Tablet
- ☐ None

E. Ethics approval for objectives 2 and 3 – ICT capabilities and choice model

Application for Approval of Ethics in Research (EiR) Projects
Faculty of Engineering and the Built Environment, University of Cape Town

ETHICS APPLICATION FORM

Please Note:
Any person planning to undertake research in the Faculty of Engineering and the Built Environment (EBE) at the University of Cape Town is required to complete this form **before** collecting or analysing data. The objective of submitting this application *prior* to embarking on research is to ensure that the highest ethical standards in research, conducted under the auspices of the EBE Faculty, are met. Please ensure that you have read, and understood the **EBE Ethics in Research Handbook** (available from the UCT EBE, Research Ethics website) prior to completing this application form: http://www.ebe.uct.ac.za/ebe/research/ethics1

APPLICANT'S DETAILS		
Name of principal researcher, student or external applicant		Bianca Ryseck
Department		Civil Engineering - Transport Studies
Preferred email address of applicant:		bbryseck@gmail.com
If Student	Your Degree: e.g., MSc, PhD, etc.	PhD
	Credit Value of Research: e.g., 60/120/180/360 etc.	360
	Name of Supervisor (if supervised):	Roger Behrens
If this is a researchcontract, indicate the source of funding/sponsorship		
Project Title		Choice and ICT Access Survey to Assess Informational Capabilities

I hereby undertake to carry out my research in such a way that:

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

APPLICATION BY	Full name	Signature	Date
Principal Researcher/ Student/External applicant	Bianca Beatrice Ryseck		30 Oct 2020
SUPPORTED BY	Full name	Signature	Date
Supervisor (where applicable)	R Behrens		30 Oct 2020

APPROVED BY	Full name	Signature	Date
HOD (or delegated nominee) Final authority for all applicants who have answered NO to all questions in Section 1; and for all Undergraduate research (Including Honours).	Dyllon Randall		3 Nov 2020
Chair: Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the questions in Section 1.			

Page **1** of **1**

F. Survey instruments for objectives 2 and 3 – ICT capabilities and choice model

CONSENT

To be read out loud to participants and consent gained verbally.

The purpose of this research is to understand what information public transport users need to make a public transport journey to a new place in Cape Town and how best to communicate that information via technology. I will ask you a questions about what information is most and least useful to you in planning a journey and your technology abilities. This will take 10 to 20 minutes.

This survey is part of doctoral research at University of Cape Town and the results are for academic purposes only.

Your participation in this research study is voluntary and you may withdraw at any time. All information that you provide will be kept strictly confidential and secure. No information will be kept that will personally identify you.

If you have any questions about the research study, please feel free to ask me.
Do you voluntarily agree to participate in this research study?

PRE-SCREENING QUESTIONS

Ask before proceeding to interview questions.

Do you have access to a functioning car in your household?
Only proceed if NO

Do you use public transport in Cape Town?
Only proceed if YES

Are you between the ages of 18 and 55?
Only proceed if YES

Prompt:

B. CHOICE QUESTIONS
Read out loud.

When you travel to a new place you've never been before, you need information to decide how to get there. Especially if you use public transport, you need information to know what all of your options are, and which travel option is best for you.

I'm going to give you make-believe travel situations. For each situation, there are many different ways you could combine transport to get there. (For example, you could walk 100m to the bus and then transfer to a train or you could walk 1km to a bus and take it direct.) Each situation presents different sets of information. You need to choose which set of information you would most want to help you decide which journey option to take. (For example, do you want to know which bus has air conditioning or which taxi has the most available seats?)

Each set has different information types with different levels of accuracy. For example, for arrival and departure times, you can either get:

- no information at all,
- or the scheduled times based on the timetables,
- or the actual live times that a vehicle really does arrive and depart.

For the following questions, assume you already have information on stop locations, transfer points, and operating hours.

Before the first choice task, talk through the different information types.
The different information types include:

- **fares**
  - What is the cheapest travel option?
- **departure times** - *the time the vehicle departs the stop*
  - Which option departs closest to the time I want to leave from home?
- **arrival times** - *the time the vehicle arrives at the stop*
  - Which option arrives closest to the time I want to arrive at my destination?
- **frequencies** - *how often vehicles arrive, especially minibus taxis*
  - Which option's services run most frequently?
- **onboard safety**
  - For which option am I the safest onboard the vehicle?
- **safety walking to and from the vehicle**
  - For which option am I safest walking to and from the vehicle?
- **safety while waiting at the station or stop**
  - For which option am I the safest waiting at the stop or station?


Montague Gardens
Elsies River
Hangberg
Meadowridge
Cape Town
MILNERTON
CENTURY CITY
BELLVILLE
BRACKENFELL
KRAAIFONTEIN
GREEN POINT
DE WATERKANT
OBSERVATORY
GOODWOOD
Table Mountain National Park
RONDEBOSCH
Kirstenbosch National Botanical Garden
MATROOSFONTEIN
KUILS RIVER
DELFT
BLUE DOWNS
GUGULETU
WYNBERG
OTTERY
PHILIPPI
LLANDUDNO
HOUT BAY
KHAYELITSHA
MITCHELLS PLAIN
MACASSAR
EERSTE RIVER
Stellenbosch Farms
STRANDFONTEIN
MUIZENBERG
NOORDHOEK
Google

A. FIELD INFORMATION

To fill out prior to the survey

Survey ID ☐ ☐ ☐ ☐ ☐

First and last initials followed by survey number

Date *DD/MM* ☐ ☐ / ☐ ☐

Time *HH:MM* ☐ ☐ : ☐ ☐

Location ☐

B. GENERAL PUBLIC TRANSPORT USE

1. How many days a week do you use public transport in Cape Town?

Tick one.

- ☐ 5-7 days a week
- ☐ 2-4 days a week
- ☐ Once a week
- ☐ 1-3 times a month
- ☐ Less than once a month

2. Which public transport do you use most often?

Tick one.

- ☐ Minibus taxi
- ☐ Golden Arrow Bus
- ☐ MyCiTi Bus
- ☐ Metrorail train

3. Have you used ...*insert below mode*... at least once previously?

Read and fill in all options out loud. Tick ALL that apply.

- ☐ Minibus taxi
- ☐ Golden Arrow Bus
- ☐ MyCiTi Bus
- ☐ Metrorail train

C. CHOICE QUESTIONS

Read out loud.

When you travel to a new place you've never been before, you need information to decide how to get there. Especially if you use public transport, you need information to know what all of your options are, and which travel option is best for you.

I'm going to give you make-believe travel situations. For each situation, there are many different ways you could combine transport to get there. (For example, you could walk 100m to the bus and then transfer to a train or you could walk 1km to a bus and take it direct.) Each situation presents different sets of information. You need to choose which set of information you would most want to help you decide which journey option to take. (For example, do you want to know which bus has air conditioning or which taxi has the most available seats?)

Each set has different information types with different levels of accuracy. For example, for arrival and departure times, you can either get:

- no information at all,
- or the estimated times based on schedules,
- or the actual live times that a vehicle really does arrive and depart.

For the following questions, assume you already have information on stop locations, transfer points, and operating hours.

The following is an example of what these choice tasks might look like. Remember, **there is no right or wrong answer.** The only thing that matters, is choosing what information you personally need to plan a journey using public transport in Cape Town.

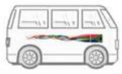
Task 0

You need to go from **Elsies River** to **Hangberg** to attend a **job interview**. You must use both **minibus taxis** and **trains** to get there. Which package would give you the public transport information you need to most confidently plan this journey?

START

Elsies River →

Metrorail Train



Minibus taxi

→ Hangberg

END

Job Interview

Block 1, Situation 8

INFORMATION TYPE	Package A	Package B
Onboard safety	Information Given	Information Given
Safety walking to vehicle	Information Given	Information Given
Safety waiting at stop	Information Given	Information Given
Departure times	Estimated Times	Live Actual Times
Arrival times	Estimated Times	Live Actual Times
Frequencies	Estimated Times	Live Actual Times
Fare	Estimate Amount	Exact Amount
Choose one	☐ A	☐ B

Now ask the respondent:

Why did you choose that information package?

Acceptable answers should explain how the information in the package chosen would give the respondent information to confidently plan a journey from Elsies River to Hangberg using the train and the taxi.

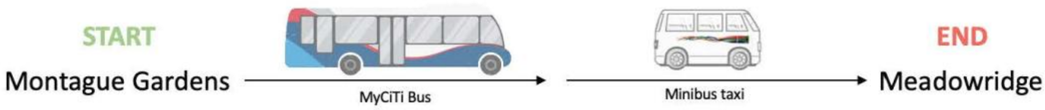
Examples of acceptable answers:
"I chose package A, because safety information is the most important to me – the rest doesn't matter to me."
"I chose package B, because it has the most accurate information."

Examples of unacceptable answers:
"I don't know"
"They are both the same"
"I chose Package A because it has the best fare information" (wrong, because Package A only has estimate fare information, Package B has exact fare information)

C.1	**OBSERVE ONLY (do not read out loud)** **Based on the respondent's response, which of the following statements is accurate?** *Choose one.*
☐	a. The respondent understands the task.
☐	b. The respondent does NOT understand the task.

Task 1

You need to go from **Montague Gardens** to **Meadowridge** to **meet with friends**. You must use both **minibus taxis** and **MyCiTi buses** to get there. Which package would give you the public transport information you need to most confidently plan this journey?



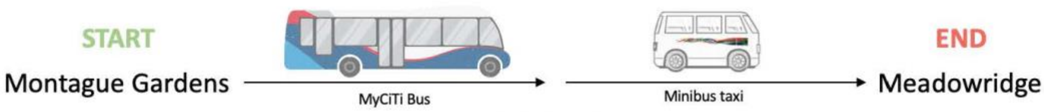
Meet with Friends

Block 1, Situation 2

INFORMATION TYPE	Package A	Package B
Onboard safety	Information given	Information given
Safety walking to vehicle	Information given	Not available
Safety waiting at stop	Not available	Information given
Departure times	Estimated times	Not available
Arrival times	Not available	Estimated times
Frequencies	Estimated times	Not available
Fare	Exact amount	Estimated amount
Choose one	☐ A	☐ B

Task 2

You need to go from **Montague Gardens** to **Meadowridge** to attend a **job interview**. You must use both **minibus taxis** and **MyCiTi buses** to get there. Which package would give you the public transport information you need to most confidently plan this journey?



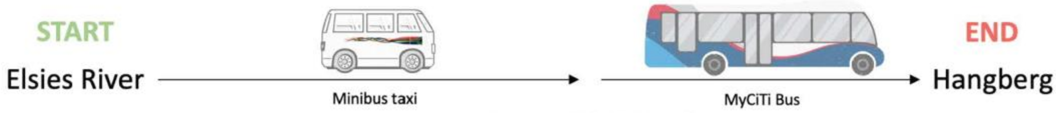
Job Interview

Block 1, Situation 4

INFORMATION TYPE	Package A	Package B
Onboard safety	Information given	Not available
Safety walking to vehicle	Information given	Not available
Safety waiting at stop	Not available	Information given
Departure times	Not available	Estimated times
Arrival times	Live actual times	Not available
Frequencies	Not available	Live actual times
Fare	Exact amount	Estimated amount
Choose one	☐ A	☐ B

Task 3

You need to go from **Elsies River** to **Hangberg** to **meet with friends**. You must use both **minibus taxis** and **MyCiTi buses** to get there. Which package would give you the public transport information you need to most confidently plan this journey?



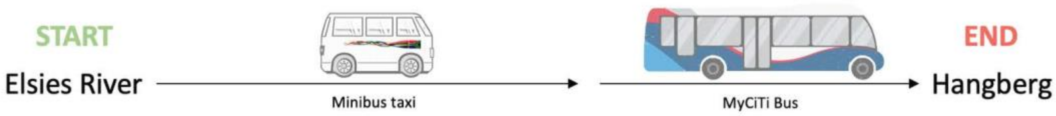
Meet with Friends

Block 1, Situation 9

INFORMATION TYPE	Package A	Package B
Onboard safety	Not available	Information given
Safety walking to vehicle	Information given	Information given
Safety waiting at stop	Information given	Not available
Departure times	Live actual times	Estimated times
Arrival times	Not available	Live actual times
Frequencies	Live actual times	Estimated times
Fare	Exact amount	Not available
Choose one	☐A	☐B

Task 4

You need to go from **Elsies River** to **Hangberg** to attend a **job interview**. You must use both **minibus taxis** and **MyCiTi buses** to get there. Which package would give you the public transport information you need to most confidently plan this journey?



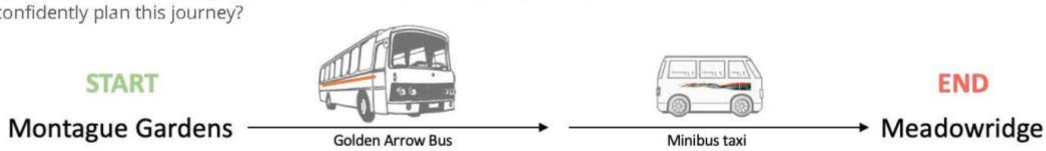
Job Interview

Block 1, Situation 18

INFORMATION TYPE	Package A	Package B
Onboard safety	Not available	Information given
Safety walking to vehicle	Not available	Not available
Safety waiting at stop	Information given	Not available
Departure times	Live actual times	Not available
Arrival times	Live actual times	Estimated times
Frequencies	Not available	Live actual times
Fare	Not available	Estimated amount
Choose one	☐A	☐B

Task 5

You need to go from **Montague Gardens** to **Meadowridge** to **meet with friends**. You must use both **minibus taxis** and **Golden Arrow buses** to get there. Which package would give you the public transport information you need to most confidently plan this journey?



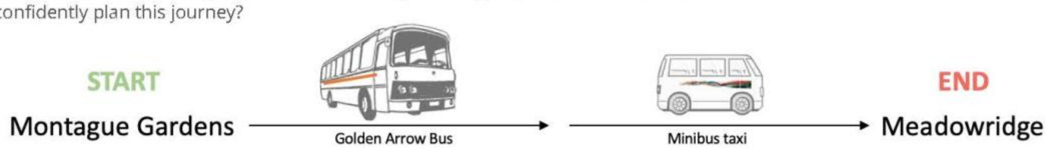
Meet with Friends

Block 1, Situation 2

INFORMATION TYPE	Package A	Package B
Onboard safety	Information given	Information given
Safety walking to vehicle	Information given	Not available
Safety waiting at stop	Not available	Information given
Departure times	Estimated times	Not available
Arrival times	Not available	Estimated times
Frequencies	Estimated times	Not available
Fare	Exact amount	Estimated amount
Choose one	☐ A	☐ B

Task 6

You need to go from **Montague Gardens** to **Meadowridge** to attend a **job interview**. You must use both **minibus taxis** and **Golden Arrow buses** to get there. Which package would give you the public transport information you need to most confidently plan this journey?



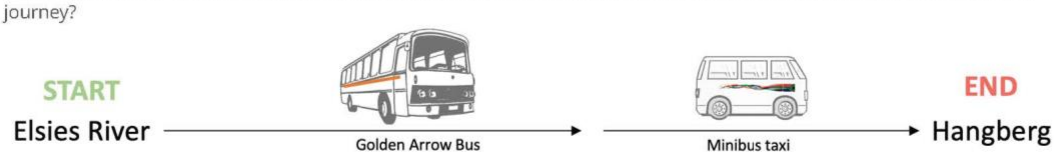
Job Interview

Block 1, Situation 4

INFORMATION TYPE	Package A	Package B
Onboard safety	Information given	Not available
Safety walking to vehicle	Information given	Not available
Safety waiting at stop	Not available	Information given
Departure times	Not available	Estimated times
Arrival times	Live actual times	Not available
Frequencies	Not available	Live actual times
Fare	Exact amount	Estimated amount
Choose one	☐ A	☐ B

Task 7

You need to go from **Elsies River** to **Hangberg** to **meet with friends**. You must use both **minibus taxis** and **Golden Arrow buses** to get there. Which package would give you the public transport information you need to most confidently plan this journey?



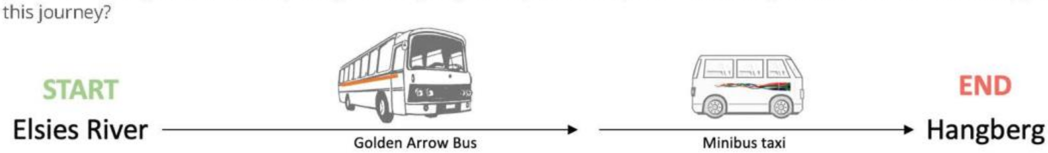
Meet with Friends

Block 1, Situation 9

INFORMATION TYPE	Package A	Package B
Onboard safety	Not available	Information given
Safety walking to vehicle	Information given	Information given
Safety waiting at stop	Information given	Not available
Departure times	Live actual times	Estimated times
Arrival times	Not available	Live actual times
Frequencies	Live actual times	Estimated times
Fare	Exact amount	Not available
Choose one	☐ A	☐ B

Task 8

You need to go from **Elsies River** to **Hangberg** to attend a **job interview**. You must use both **minibus taxis** and **Golden Arrow buses** to get there. Which package would give you the public transport information you need to most confidently plan this journey?



Job Interview

Block 1, Situation 18

INFORMATION TYPE	Package A	Package B
Onboard safety	Not available	Information given
Safety walking to vehicle	Not available	Not available
Safety waiting at stop	Information given	Not available
Departure times	Live actual times	Not available
Arrival times	Live actual times	Estimated times
Frequencies	Not available	Live actual times
Fare	Not available	Estimated amount
Choose one	☐ A	☐ B

Task 9

You need to go from **Montague Gardens** to **Meadowridge** to **meet with friends**. You must use both **minibus taxis** and **trains** to get there. Which package would give you the public transport information you need to most confidently plan this journey?

START → END

Montague Gardens → Meadowridge

Minibus taxi

Metrorail Train

Meet with Friends

Block 1, Situation 2

INFORMATION TYPE	Package A	Package B
Onboard safety	Information given	Information given
Safety walking to vehicle	Information given	Not available
Safety waiting at stop	Not available	Information given
Departure times	Estimated times	Not available
Arrival times	Not available	Estimated times
Frequencies	Estimated times	Not available
Fare	Exact amount	Estimated amount
Choose one	☐ A	☐ B

Task 10

You need to go from **Montague Gardens** to **Meadowridge** to attend a **job interview**. You must use both **minibus taxis** and **trains** to get there. Which package would give you the public transport information you need to most confidently plan this journey?

START → END

Montague Gardens → Meadowridge

Minibus taxi

Metrorail Train

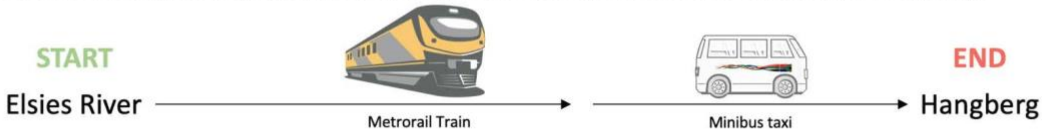
Job Interview

Block 1, Situation 4

INFORMATION TYPE	Package A	Package B
Onboard safety	Information given	Not available
Safety walking to vehicle	Information given	Not available
Safety waiting at stop	Not available	Information given
Departure times	Not available	Estimated times
Arrival times	Live actual times	Not available
Frequencies	Not available	Live actual times
Fare	Exact amount	Estimated amount
Choose one	☐ A	☐ B

Task 11

You need to go from **Elsies River** to **Hangberg** to **meet with friends**. You must use both **minibus taxis** and **trains** to get there. Which package would give you the public transport information you need to most confidently plan this journey?



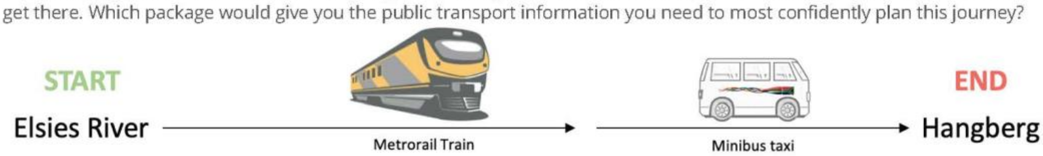
Meet with Friends

Block 1, Situation 9

INFORMATION TYPE	Package A	Package B
Onboard safety	Not available	Information given
Safety walking to vehicle	Information given	Information given
Safety waiting at stop	Information given	Not available
Departure times	Live actual times	Estimated times
Arrival times	Not available	Live actual times
Frequencies	Live actual times	Estimated times
Fare	Exact amount	Not available
Choose one	☐ A	☐ B

Task 12

You need to go from **Elsies River** to **Hangberg** to attend a **job interview**. You must use both **minibus taxis** and **trains** to get there. Which package would give you the public transport information you need to most confidently plan this journey?



Job Interview

Block 1, Situation 18

INFORMATION TYPE	Package A	Package B
Onboard safety	Not available	Information given
Safety walking to vehicle	Not available	Not available
Safety waiting at stop	Information given	Not available
Departure times	Live actual times	Not available
Arrival times	Live actual times	Estimated times
Frequencies	Not available	Live actual times
Fare	Not available	Estimated amount
Choose one	☐ A	☐ B

D. Access to Communication Technology

1.1	**Which of the following technologies do you own?** *Read all the options. Select ALL that apply.*
☐	Apple Smartphone
☐	Android Smartphone
☐	Other Mobile Phone with Internet
☐	Other Mobile Phone without Internet
☐	Landline telephone
☐	Computer or laptop
☐	Tablet
☐	Radio
☐	None
	If the respondent said they own an (1) Apple smartphone (2) Android smartphone, and/or (3) other mobile phone with internet, then ask 1.2, otherwise go to 2.1
1.2	**Which of the following best describes your level of access to mobile data?** *Read all the options. Tick ONE only.*
☐	a. I have unlimited access to mobile data.
☐	b. I have limited access to mobile data, but I don't feel I am constrained in my mobile data usage.
☐	c. I have limited access to mobile data and I do feel it is too little for my needs.
☐	d. I do not have access to mobile data because it is too expensive.
☐	e. I do not have access to mobile data because I do not need it.
2.1	**Have you ever used the Internet?** *Tick one.*
☐	Yes
☐	No
2.2	**Which of the following internet services do you use?** *Read all the options. Select ALL that apply.*
☐	a. Internet connection in the household
☐	b. Internet in a library/community hall/Thusong centre
☐	c. Internet at a school/university/college
☐	d. Internet at place of work
☐	e. Internet cafe 2km or less from the household
☐	f. Internet cafe more than 2km from the household
☐	g. Internet via a mobile cellular telephone
☐	h. Internet via other mobile access services
Other (specify)	

2.3	**What, if any, are the main limitations for your use of the internet?** *Tick all that apply.*
☐	c. Nothing, no limitation
☐	d. Lack of time
☐	e. Data cost
☐	f. Lack of content in my language
☐	g. Speed of internet
☐	h. Privacy concerns
☐	i. Worried about getting virus/malware
☐	j. Not allowed to use it more (family, spouse, parents)
☐	k. I find it difficult to use
Other (specify)	
3.	**Which sources of travel information do you consult when planning a trip to a new destination using public transport?** *Tick all that apply.*
☐	a. Bus or minibus-taxi driver
☐	b. Interchange/rank personnel
☐	c. Other passengers
☐	d. Transport Information Centre
☐	e. Other call centre
☐	f. Website
☐	g. Social Media
☐	h. Mobile app
☐	i. Kiosks at Station
☐	j. Map at station/stop
☐	k. Timetable at station/stop
Other (specify)	

4. Do you have difficulty in doing any of the following related to the following uses of transport information... ***Read all the options.*** *Tick (X) to indicate the degree of difficulty.*	No difficulty	Some difficulty	A lot of difficulty	Unable to do	I have never seen this
a) Following verbal navigation directions					
b) Following written navigation directions					
c) Understanding a route map, like MyCiTi's or Metrorail's					
d) Understanding a timetable for departures and arrivals					
e) Using Google Maps or a similar navigation tool to get directions					
f) Locating your current location on a paper map					
g) Locating your destination on a paper map					

5. Do you have difficulty in doing any of the following related to the following uses of technology... ***Read all the options.*** *Tick (X) to indicate the degree of difficulty.*	No difficulty	Some difficulty	A lot of difficulty	Unable to do	I have never done/seen this
a) Searching for information online					
b) Sending a message using WhatsApp, Messenger or similar messaging service					
c) Making a phone call					
d) Uploading a photo or file to an email, message or other application on a phone or computer					
e) Communicating with others via social media					
f) Installing mobile applications on your phone					
g) Using an e-hailing application like Uber or Bolt					
h) Transferring money on a mobile banking app like Capitec or Absa					
i) Making an online payment					

E. FINAL DEMOGRAPHICS

1. Sex (observed)

Tick one.

- [ ] Male
- [ ] Female

2. How old are you?

3. What is your ... first / second / third ... language?

Indicate with a '1', '2', and '3' below. Fill in 'Other' where appropriate.

Afrikaans	English	Ndebele	Northern Sotho	Southern Sotho	Swati	Tsonga	Tswana	Venda	Xhosa	Zulu	Other (specify)

3. In which suburb do you live in Cape Town?

4. Population group (observed)

- [ ] Black African
- [ ] Coloured
- [ ] Indian / Asian
- [ ] White

Other (specify)

G. Pilot 2 MNL estimation results

Attribute level	Estimate	Rob.std.err.	Rob.t-ratio
ASC_1	0.4839	0.1092	4.4333
ASC_2	0.2517	0.0824	3.0552
ASC_3	0	NA	NA
Fare (none)	-0.751	0.1586	-4.7354
Fare (exact)	-0.0255	0.1058	-0.2409
Departure (none)	-0.7546	0.1443	-5.2283
Departure (exact)	0.1733	0.1176	1.4737
Arrival (none)	-1.2204	0.1449	-8.4235
Arrival (exact)	-0.101	0.1246	-0.8105
Frequency (none)	-0.7384	0.1321	-5.5892
Frequency (exact)	0.0863	0.0875	0.9867
Safety onboard (none)	-0.4716	0.1414	-3.3364
Safety walking (none)	-0.8017	0.1418	-5.6558
Safety waiting (none)	-0.7763	0.1404	-5.5301

H. Utility equations used in Apollo for the final survey analysis's MNL and MMNL models

Table 6.5. Comparison of three basic models for estimating parameters across all respondents and choice situations

MNL + MMNL Model (without ASCs) utility equations (same used)

```
V[['A']]  =  (fare_est*(alt1.fare==2)
            +fare_exact*(alt1.fare==1)
            +departure_est*(alt1.departure==2)
            +departure_exact*(alt1.departure==1)
            +arrival_est*(alt1.arrival==2)
            +arrival_exact*(alt1.arrival==1)
            +frequency_est*(alt1.frequency==2)
            +frequency_exact*(alt1.frequency==1)
            +safeon_exact*(alt1.safeon==1)
            +safewalk_exact*(alt1.safewalk==1)
            +safewait_exact*(alt1.safewait==1))
V[['B']]  =  (fare_est*(alt2.fare==2)
            +fare_exact*(alt2.fare==1)
            +departure_est*(alt2.departure==2)
            +departure_exact*(alt2.departure==1)
            +arrival_est*(alt2.arrival==2)
            +arrival_exact*(alt2.arrival==1)
            +frequency_est*(alt2.frequency==2)
            +frequency_exact*(alt2.frequency==1)
            +safeon_exact*(alt2.safeon==1)
            +safewalk_exact*(alt2.safewalk==1)
            +safewait_exact*(alt2.safewait==1))
```

MMNL Model with ASCs utility equation

```
V[['A']]  =  (asc_1
            + fare_est*(alt1.fare==2)
            +fare_exact*(alt1.fare==1)
            +departure_est*(alt1.departure==2)
            +departure_exact*(alt1.departure==1)
            +arrival_est*(alt1.arrival==2)
            +arrival_exact*(alt1.arrival==1)
            +frequency_est*(alt1.frequency==2)
            +frequency_exact*(alt1.frequency==1)
            +safeon_exact*(alt1.safeon==1)
            +safewalk_exact*(alt1.safewalk==1)
            +safewait_exact*(alt1.safewait==1))
V[['B']]  =  (asc_2
            +fare_est*(alt2.fare==2)
            +fare_exact*(alt2.fare==1)
            +departure_est*(alt2.departure==2)
            +departure_exact*(alt2.departure==1)
            +arrival_est*(alt2.arrival==2)
            +arrival_exact*(alt2.arrival==1)
            +frequency_est*(alt2.frequency==2)
            +frequency_exact*(alt2.frequency==1)
            +safeon_exact*(alt2.safeon==1)
            +safewalk_exact*(alt2.safewalk==1)
            +safewait_exact*(alt2.safewait==1))
```

Table 6.6. MMNL model with normal distribution with sociodemographic coefficients

```
V[['A']]  =  (asc_1
            + (fare_est + female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) +
age_30to39*(age_range==2))*(alt1.fare==2)
            +(fare_exact+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) +
age_30to39*(age_range==2))*(alt1.fare==1)
            +(departure_est+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) +
age_30to39*(age_range==2))*(alt1.departure==2)
            +(departure_exact+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) +
age_30to39*(age_range==2))*(alt1.departure==1)
            +(arrival_est+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) +
age_30to39*(age_range==2))*(alt1.arrival==2)
            +(arrival_exact+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) +
age_30to39*(age_range==2))*(alt1.arrival==1)
```

+(frequency_est+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) + age_30to39*(age_range==2))*(alt1.frequency==2)
+(frequency_exact+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) + age_30to39*(age_range==2))*(alt1.frequency==1)
+(safeon_exact+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) + age_30to39*(age_range==2))*(alt1.safeon==1)
+(safewalk_exact+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) + age_30to39*(age_range==2))*(alt1.safewalk==1)
+(safewait_exact+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) + age_30to39*(age_range==2))*(alt1.safewait==1))

V[['B']] = (asc_2
+ (fare_est+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) + age_30to39*(age_range==2))*(alt2.fare==2)
+(fare_exact+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) + age_30to39*(age_range==2))*(alt2.fare==1)
+(departure_est+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) + age_30to39*(age_range==2))*(alt2.departure==2)
+(departure_exact+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) + age_30to39*(age_range==2))*(alt2.departure==1)
+(arrival_est+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) + age_30to39*(age_range==2))*(alt2.arrival==2)
+(arrival_exact+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) + age_30to39*(age_range==2))*(alt2.arrival==1)
+(frequency_est+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) + age_30to39*(age_range==2))*(alt2.frequency==2)
+(frequency_exact+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) + age_30to39*(age_range==2))*(alt2.frequency==1)
+(safeon_exact+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) + age_30to39*(age_range==2))*(alt2.safeon==1)
+(safewalk_exact+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) + age_30to39*(age_range==2))*(alt2.safewalk==1)
+(safewait_exact+female*(sex==1) + pop_black*(pop_group==2) + age_18to29*(age_range==1) + age_30to39*(age_range==2))*(alt2.safewait==1))

Table 6.7. MMNL model where sex is an individual parameter for each attribute level

V[['A']] = (asc_1
+(fare_est + fare_est_shift_sex*(sex==1))*(alt1.fare==2)
+(fare_exact + fare_exact_shift_sex*(sex==1))*(alt1.fare==1)
+(departure_est + departure_est_shift_sex*(sex==1))*(alt1.departure==2)
+(departure_exact + departure_exact_shift_sex*(sex==1))*(alt1.departure==1)
+(arrival_est + arrival_est_shift_sex*(sex==1))*(alt1.arrival==2)
+(arrival_exact + arrival_exact_shift_sex*(sex==1))*(alt1.arrival==1)
+(frequency_est + frequency_est_shift_sex*(sex==1))*(alt1.frequency==2)
+(frequency_exact + frequency_exact_shift_sex*(sex==1))*(alt1.frequency==1)
+(safeon_exact + safeon_exact_shift_sex*(sex==1))*(alt1.safeon==1)
+(safewalk_exact + safewalk_exact_shift_sex*(sex==1))*(alt1.safewalk==1)
+(safewait_exact + safewait_exact_shift_sex*(sex==1))*(alt1.safewait==1))
V[['B']] = (asc_2
+(fare_est + fare_est_shift_sex*(sex==1))*(alt2.fare==2)
+(fare_exact + fare_exact_shift_sex*(sex==1))*(alt2.fare==1)
+(departure_est + departure_est_shift_sex*(sex==1))*(alt2.departure==2)
+(departure_exact + departure_exact_shift_sex*(sex==1))*(alt2.departure==1)
+(arrival_est + arrival_est_shift_sex*(sex==1))*(alt2.arrival==2)
+(arrival_exact + arrival_exact_shift_sex*(sex==1))*(alt2.arrival==1)
+(frequency_est + frequency_est_shift_sex*(sex==1))*(alt2.frequency==2)
+(frequency_exact + frequency_exact_shift_sex*(sex==1))*(alt2.frequency==1)
+(safeon_exact + safeon_exact_shift_sex*(sex==1))*(alt2.safeon==1)
+(safewalk_exact + safewalk_exact_shift_sex*(sex==1))*(alt2.safewalk==1)
+(safewait_exact + safewait_exact_shift_sex*(sex==1))*(alt2.safewait==1))

Table 6.9. MMNL model for interaction effects of each scenario

V[['A']] = (asc_1
+ (fare_est + b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt1.fare==2)
+(fare_exact + b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt1.fare==1)
+(departure_est+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt1.departure==2)
+(departure_exact+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt1.departure==1)

+(arrival_est+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt1.arrival==2)
+(arrival_exact+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt1.arrival==1)
+(frequency_est+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt1.frequency==2)
+(frequency_exact+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt1.frequency==1)
+(safeon_exact+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt1.safeon==1)
+(safewalk_exact+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt1.safewalk==1)
+(safewait_exact+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt1.safewait==1))
V[['B']] = (asc_2
+ (fare_est+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt2.fare==2)
+(fare_exact+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt2.fare==1)
+(departure_est+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt2.departure==2)
+(departure_exact+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt2.departure==1)
+(arrival_est+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt2.arrival==2)
+(arrival_exact+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt2.arrival==1)
+(frequency_est+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt2.frequency==2)
+(frequency_exact+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt2.frequency==1)
+(safeon_exact+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt2.safeon==1)
+(safewalk_exact+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1))*(alt2.safewalk==1)
+(safewait_exact)+ b_mode_myciti*(mode==1) + b_mode_gabs*(mode==2) + b_purpose*(purpose==1) + b_OD_pair*(OD_pair==1)*(alt2.safewait==1))

Table 6.10. MMNL model for interaction effects of trip purpose as an individual parameter with each attribute level

V[['A']] = (asc_1
+(fare_est + b_purpose_fes*(purpose==1))*(alt1.fare==2)
+(fare_exact + b_purpose_fex*(purpose==1))*(alt1.fare==1)
+(departure_est + b_purpose_des*(purpose==1))*(alt1.departure==2)
+(departure_exact + b_purpose_dex*(purpose==1))*(alt1.departure==1)
+(arrival_est + b_purpose_aes*(purpose==1))*(alt1.arrival==2)
+(arrival_exact + b_purpose_aex*(purpose==1))*(alt1.arrival==1)
+(frequency_est + b_purpose_fqes*(purpose==1))*(alt1.frequency==2)
+(frequency_exact + b_purpose_fqex*(purpose==1))*(alt1.frequency==1)
+(safeon_exact + b_purpose_son*(purpose==1))*(alt1.safeon==1)
+(safewalk_exact + b_purpose_swalk*(purpose==1))*(alt1.safewalk==1)
+(safewait_exact + b_purpose_swait*(purpose==1))*(alt1.safewait==1))
V[['B']] = (asc_2
+(fare_est + b_purpose_fes*(purpose==1))*(alt2.fare==2)
+(fare_exact + b_purpose_fex*(purpose==1))*(alt2.fare==1)
+(departure_est + b_purpose_des*(purpose==1))*(alt2.departure==2)
+(departure_exact + b_purpose_dex*(purpose==1))*(alt2.departure==1)
+(arrival_est + b_purpose_aes*(purpose==1))*(alt2.arrival==2)
+(arrival_exact + b_purpose_aex*(purpose==1))*(alt2.arrival==1)
+(frequency_est + b_purpose_fqes*(purpose==1))*(alt2.frequency==2)
+(frequency_exact + b_purpose_fqex*(purpose==1))*(alt2.frequency==1)
+(safeon_exact + b_purpose_son*(purpose==1))*(alt2.safeon==1)
+(safewalk_exact + b_purpose_swalk*(purpose==1))*(alt2.safewalk==1)
+(safewait_exact + b_purpose_swait*(purpose==1))*(alt2.safewait==1))

Table 6.12. MMNL model with DPF levels as coefficients

V[['A']] = (asc_1
+ (fare_est + dpf_passive_fes*(DPF==2) + dpf_active_fes*(DPF==3) + dpf_poor*(DPF==1))*(alt1.fare==2)
+(fare_exact + dpf_passive_fex*(DPF==2) + dpf_active_fex*(DPF==3) + dpf_poor*(DPF==1))*(alt1.fare==1)
+(departure_est + dpf_passive_des*(DPF==2) + dpf_active_des*(DPF==3) + dpf_poor*(DPF==1))*(alt1.departure==2)
+(departure_exact+ dpf_passive_dex*(DPF==2) + dpf_active_dex*(DPF==3) + dpf_poor*(DPF==1))*(alt1.departure==1)
+(arrival_est+ dpf_passive_aes*(DPF==2) + dpf_active_aes*(DPF==3) + dpf_poor*(DPF==1))*(alt1.arrival==2)
+(arrival_exact+ dpf_passive_aex*(DPF==2) + dpf_active_aex*(DPF==3) + dpf_poor*(DPF==1))*(alt1.arrival==1)

```
        +(frequency_est+ dpf_passive_fqes*(DPF==2) + dpf_active_fqes*(DPF==3) + dpf_poor*(DPF==1))*(alt1.frequency==2)
        +(frequency_exact+ dpf_passive_fqex*(DPF==2) + dpf_active_fqex*(DPF==3) + dpf_poor*(DPF==1))*(alt1.frequency==1)
        +(safeon_exact+ dpf_passive_son*(DPF==2) + dpf_active_son*(DPF==3) + dpf_poor*(DPF==1))*(alt1.safeon==1)
        +(safewalk_exact+ dpf_passive_swalk*(DPF==2) + dpf_active_swalk*(DPF==3) + dpf_poor*(DPF==1))*(alt1.safewalk==1)
        +(safewait_exact+ dpf_passive_swait*(DPF==2) + dpf_active_swait*(DPF==3) + dpf_poor*(DPF==1))*(alt1.safewait==1))
V[['B']]  =  (asc_2
        + (fare_est + dpf_passive_fes*(DPF==2) + dpf_active_fes*(DPF==3) + dpf_poor*(DPF==1))*(alt2.fare==2)
        +(fare_exact + dpf_passive_fex*(DPF==2) + dpf_active_fex*(DPF==3) + dpf_poor*(DPF==1))*(alt2.fare==1)
        +(departure_est + dpf_passive_des*(DPF==2) + dpf_active_des*(DPF==3) + dpf_poor*(DPF==1))*(alt2.departure==2)
        +(departure_exact+ dpf_passive_dex*(DPF==2) + dpf_active_dex*(DPF==3) + dpf_poor*(DPF==1))*(alt2.departure==1)
        +(arrival_est+ dpf_passive_aes*(DPF==2) + dpf_active_aes*(DPF==3) + dpf_poor*(DPF==1))*(alt2.arrival==2)
        +(arrival_exact+ dpf_passive_aex*(DPF==2) + dpf_active_aex*(DPF==3) + dpf_poor*(DPF==1))*(alt2.arrival==1)
        +(frequency_est+ dpf_passive_fqes*(DPF==2) + dpf_active_fqes*(DPF==3) + dpf_poor*(DPF==1))*(alt2.frequency==2)
        +(frequency_exact+ dpf_passive_fqex*(DPF==2) + dpf_active_fqex*(DPF==3) + dpf_poor*(DPF==1))*(alt2.frequency==1)
        +(safeon_exact+ dpf_passive_son*(DPF==2) + dpf_active_son*(DPF==3) + dpf_poor*(DPF==1))*(alt2.safeon==1)
        +(safewalk_exact+ dpf_passive_swalk*(DPF==2) + dpf_active_swalk*(DPF==3) + dpf_poor*(DPF==1))*(alt2.safewalk==1)
        +(safewait_exact+ dpf_passive_swait*(DPF==2) + dpf_active_swait*(DPF==3) + dpf_poor*(DPF==1))*(alt2.safewait==1))
```