MOBILITY AS A SERVICE FRAMEWORK WITHIN METROPOLITAN CITIES

By

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Declaration of Originality

This is to confirm that I, Nthabeleng Palesa Mpiwa (student number 213588354), have not previously submitted the mini dissertation "**Mobility as a Service Framework within Metropolitan Cities**" for the **MEng Engineering Management (MEEM18)** degree at the Tshwane University of Technology, to any other university. It is also my own work in terms of design and execution, and all references to published sources have been properly cited.

Signed at Tshwane University of Technology on this 20th day of November 2023.

Signature: [redacted]

Dedication

My parents, Mr. Maritshi and Mrs. Maserame Mpiwa have my sincere gratitude for their unwavering support, love, and encouragement during this study. And to the delight of my life, Lerato and Letlotlo Mpiwa, my little sister and son…

Acknowledgments

I want to honor and glorify Almighty God for providing me with the knowledge, courage, strength, and good health that allowed me to complete this lengthy but seemingly quick voyage by virtue of His Great Grace and Mercy.

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Abstract

In cities, especially in emerging nations, traffic congestion continues to be a visible phenomenon that aggravates residents. Delays, unpredictability in travel times, increased fuel consumption, lost labour hours, and, most crucially, lost revenue are the result. Inadequate traffic management systems, poorly planned road networks, rapid population growth, and rising affordability per household all contribute to traffic congestion. Mobility as a service (MaaS) will be investigated in this study as a solution to the problem. To mitigate urban traffic, this dissertation tries to develop a framework of MaaS to be provided within South African metropoles in the near future. Convincing drivers to switch from using their privately owned automobiles regularly to using MaaS-provided convenience will ensure comfortable and hassle-free travel throughout major cities. The study's methodology was qualitative research. Grounded theory was used for gathering data. Secondary data was gathered from various journals, books, and case studies focusing on the concept of MaaS in order to create a MaaS framework. After that, qualitative data analysis determined the merits, weaknesses, and effectiveness of MaaS, if correctly implemented. A conceptual framework for MaaS was developed using the information and knowledge gleaned from various literature sources. The conclusion was delivered as a thorough research report that featured a developed demo using Figma to construct a framework prototype for MaaS. The feasibility of the MaaS idea was determined based on the overall study results on alleviating the traffic jam issue.

Key: Mobility as a service mobile application, Traffic congestion mitigation, Transportation technology.

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Nomenclature

API	– Application Programming Interface
Demo	– Demonstration
MaaS	– Mobility as a Service
Metro	– Metropolitan
Tech	– Technology
UC	– Use Case

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Glossary of Terms

Alternative Flows – A different situation from the standard flow that enables a user to achieve their objective is referred to as an *alternate flow*. It is frequently regarded as an optional flow. It suggests that the user has opted to navigate the system differently.

Basic Flow – A methodical approach that aids in realising a software product idea. Regardless of how small or large the project is, this strategy can effectively reduce risks, prevent delays, and limit errors in the development process.

Demo – A visual product that, before spending money on the actual design and development stages, demonstrates the functionality of a piece of software.

Description – Software research, design, implementation, and management.

Exceptional Flows – Any behaviour that prevents a user from getting the desired outcome. The exception flow's primary advantage is that it focuses on potentially negative issues a user could encounter.

Figma – Figma is a cutting-edge design tool that simplifies and streamlines the developer handoff procedure.

Framework – A basic structure underlying concepts.

Metropolitan Cities – A region of overly populated urban agglomerations consisting of municipalities.

Mobile Application – A software application created to be utilised on mobile devices and is accessible remotely.

Mobility as a Service – A digital platform with integrated transportation systems from multiple transportation service providers enables the end user to plan, book and pay for multiple trips simultaneously on one platform.

Mobility Hub – In densely populated metropolitan centres, the usage of mobility hubs is suggested as a solution to improve sustainable and active modes of transportation. The goals of mobility hubs that can satisfy fundamental transportation demands and help drive their development were informed by preliminary research on the definitions of mobility hubs.

Mock up – Duplicate or imitate something.

Participating Actors – People or systems using the application who will interact with it.

Postconditions – A predicate or condition immediately following the execution of some code or completing an operation in a formal specification must always be true.

Preconditions – A predicate or condition immediately following an operation of some code in a formal specification, or the execution must always be true.

Prototype – A crude functioning model created for testing reasons or as part of the development process for a product or information system.

Qualitative Research Design – This is a method of research that is used to obtain data that cannot be proven through quantification but rather by simply making use of multiple elements, such as one-on-one interviews, focus groups, ethnographic research, case-study research, record-keeping, qualitative observation, etc, to arrive at a conclusion.

Real-Time Data – This is developed and collected data that is immediately available.

Simulation – Before making a tangible product, engineers can test their concepts using a simulation.

1. CHAPTER 1 – Introduction

1.1. Background

Being caught in traffic during the busiest time of the day is a nightmare. Even though there have been many studies on the primary causes of traffic congestion, there has been little emphasis on finding a solution to the daily traffic congestion that urban inhabitants experience. Civil engineering spans seven (7) disciplines but, for this research, we will concentrate on transportation engineering, which combines transportation technology and planning.Engineering principles will be used to locate and address problems with well-defined systematic transportation planning. One way to think of transportation technology is to see it as a tool for improving or resolving issues arising from the movement of people and goods.

Arons et al. (2009) stated that, as technology develops, it changes and transforms how we plan, design, build, and run transportation systems. Schroder-Hinrichs et al. (2019) claimed that automation and new technologies are affecting workers in the transportation industry, in the form of both job displacement and job creation.The South African transportation networks underwent significant transformation due to the political elections in April 1994. The Urban Transportation Act of 1977 supported urban transportation planning and providing suitable infrastructure. Olagunju (2015) argued that mobility is crucial for cities to operate well, since it impacts their socioeconomic activities.Despite rising transit demand and supply, many developing countries have inadequate traffic management. The MaaS conceptual framework will be carefully examined as a mitigation strategy for reducing traffic congestion in metropolitan cities instead of focusing on managing traffic congestion as a topic in this study.

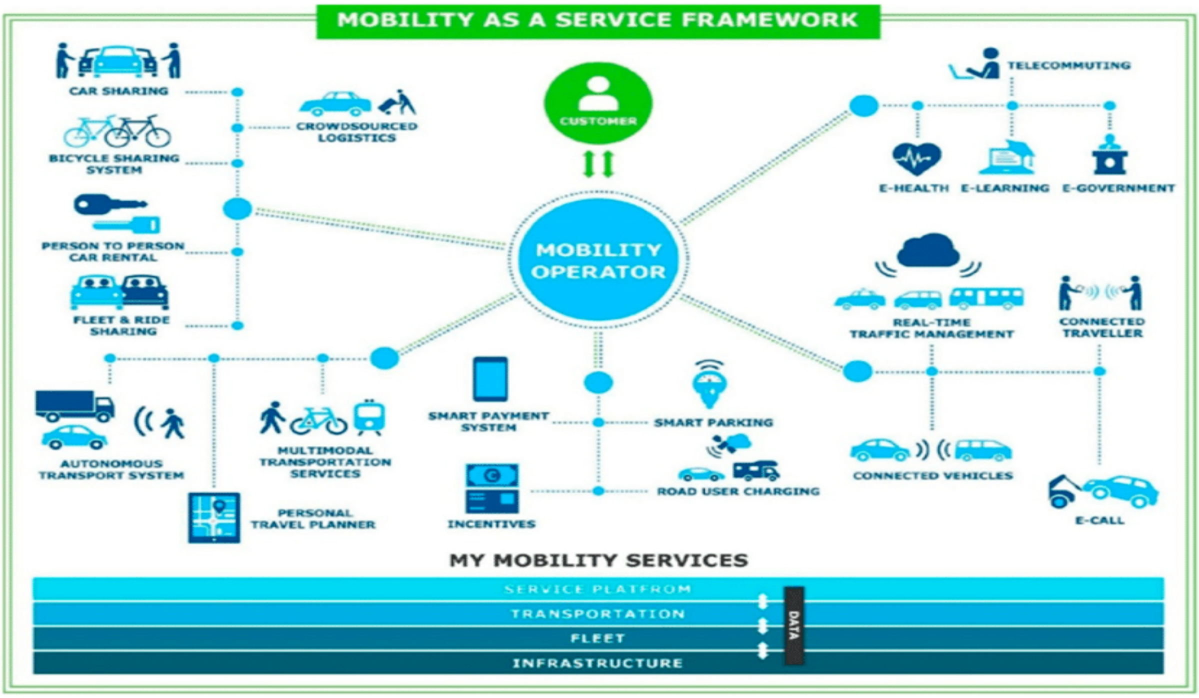

Figure 1.1: MaaS Framework (Klvimaki, 2014)

Paul et al. (2016) stated that there has recently been a rise in interest in transportation models, whereby individual components of transportation systems (individual vehicle dynamics and individual traveller behaviour) have been explored. The MaaS application was defined by Heikkilä (2014) as a combination of various personal transportation services from multiple service providers delivered through a single digital platform that enables the end user to plan, reserve, and pay for a trip simultaneously. In a study by Kamargianni et al. (2016), MaaS allowed for simple door-to-door transportation without using a personal vehicle to encourage drivers to use mobility services for convenience, comfort, and a pleasant ride rather than their vehicles. If properly implemented, this will lead to a decrease in traffic volume. However, studies have also identified certain benefits of MaaS in other nations. Traffic congestion is present everywhere, including in South Africa.

1.2. Justification

The researcher chose a MaaS framework to be introduced into South African metropolitan cities as a broad area of interest, since mobility is essential to the effective operation of cities because it influences their socioeconomic activities. As technology advances, a clever way to move people and things is crucial. As new roads were built, the number of privately owned cars increased sharply, and they have now been recognised as insufficient to meet demand. Building more roads to fulfil demand is challenging because there is not enough suitable land, especially in cities.

Introducing the MaaS system then makes it possible to investigate coming up with a new way for individuals to travel multiple distances with various modes of transportation while using a cell phone and the internet to get from point A to point B (ie, similar to the introduction of new banking systems, which recently introduced a new method of banking remotely and servicing retail needs by using ecommerce).

1.3. Problem Statement

Afrin and Yodo (2020) stated that densely populated places frequently experience traffic congestion because of current roads' inability to handle rising vehicles. Djahel et al. (2014) averred that the rapid increase in the number of automobiles on the roads has led to numerous issues due to the expanding size of cities and rising population mobility, such as air pollution, more accidents, and traffic congestion for road traffic management authorities to deal with. To successfully achieve sustainable urban mobility, it was necessary, according to Okraszewska et al. (2018), to ensure that safe, dependable, integrated multi-modal, conducive, and environmentally friendly transportation systems were introduced. MaaS has to combine several personal transportation services from multiple providers, ensuring convenience and comfort, to move drivers away from using privately owned automobiles to alleviate traffic congestion.

1.4. Aim and Objectives

The aim of the research is as follows:

To simulate a MaaS transportation application demonstration for South African metropoles to alleviate the problems those cities experience due to poor transportation systems.

The objectives are as follows:

a) To analyse the historical background of urban mobility in South Africa and technology's role in transforming it.

b) Consider the main variables (traffic congestion, unpredictable forecasted travel times, emissions of greenhouse gases, and the resulting human frustration and impact on welfare) affecting South Africa's poor transportation networks that affect the country's economy, environment, and society.
c) To conscientiously explore the various transport systems and applications currently used in South Africa, the idea of MaaS, and the potential alterations and benefits it might bring.
d) To examine the benefits and drawbacks and authors' perspectives on MaaS, guided by various studies, to comprehend better the potential that MaaS holds for the future.
e) To create an interactive prototype to show how mobility is provided as a service in South African metros by integrating various service providers with various types of transportation.
f) To deliver a comprehensive framework demonstration on MaaS and a use-case manual (for users and drivers).

1.5. Research Question

1. Primary Research Question
    a. How would implementing MaaS in South Africa help with the current issues and backlog in the transportation system and what would be the potential effects on the economy, environment, and society in metros?
2. Secondary Research Questions
    a. How do current transportation networks function in comparison to MaaS (comparing the two networks is an argument for why the MaaS approach would be more suitable than the present system)?
    b. Who does MaaS aim to serve? (By focusing on the MaaS market, it is possible to more effectively integrate the resources and transit options presently available to meet the needs of each individual).
    c. What parameters are necessary for simulating the framework demonstration in this study? (The simulation must include parameters from other widely available transport systems to establish the framework in this study. This will prevent us from deviating from the

framework and allow us to try to improve on what is currently available).

1.6. Importance/Benefits of the Study

This research will be advantageous to South Africa's main cities. The research study's conclusions and discussions will concentrate on the benefits, which can be summed up as follows:

- By providing a safe, dependable, effective, and environmentally friendly transportation system, MaaS can enhance quality of life. Significantly decreasing or perhaps doing away with privately owned vehicles altogether in metros is possible.
- Adopting MaaS can help us drastically reduce the number of cars on the roads, hence reducing the amount of carbon dioxide—the most prevalent human-caused greenhouse gas—that is released.
- Adopting MaaS will help business owners save money by reducing man-hour losses, travel delays, fuel usage, and driver angst.
- All the urban areas will greatly benefit from this study in terms of lessening traffic and allowing users to independently plan, reserve, and pay for numerous types of work or personal journeys.
- The Tshwane University of Technology and other institutions will benefit from this study, which academic institutions and academics will use as a research tool.

1.7. Delimitation of the Study

The research considers the idea of MaaS to be the cornerstone of a solution which will have multiple implications for alleviating urban problems caused by poor transportation systems. Several important findings were revealed after navigating the complex terrain of urban mobility via the existing literature. MaaS is not merely a fad. It is a paradigm change that can alter traffic patterns in major cities. Inductive qualitative data analysis was rigorously applied to the data gathered for this study. This analytical strategy was deliberately adopted; it allowed the data to "speak", showing patterns, commonalities, and original discoveries that would have otherwise remained hidden in a more prescriptive analytical strategy. The Hoyle step of data analysis involves gathering information through reviewing previous studies, sorting, categorising, summarising, simulating a prototype, and converting the raw data into information that allows researchers to arrive at an analysis.

However, no quantitative investigation of real decision-making took place. This results in the absence of information from service providers currently using various forms of transportation, and only a small sample of users was available to test the application before recommending it be used daily. Consequently, quantitative data was excluded, as it was deemed unsuitable for the project.

1.8. Conclusion

The study’s background was covered in this chapter, which also gave a statement of the research topic, the study’s goal, and its justification. Additionally, the main research topic and its sub-questions were developed.

After outlining the context of the study, the following section talks about the literature review and conceptual framework that served as its foundation.

2. CHAPTER 2 – The Literature Review

2.1. Introduction

Transport dynamics in urban areas have continuously evolved, presenting a complex interplay of progress, obstacles, and possible remedies. The extant body of literature provides a comprehensive portrayal of the evolution of urban mobility, cumulation in the current state, and potential future developments in this field.

The review explores the essential concepts, influential publications, and pioneering research that formed the foundation of the concept of MaaS and revealed its implications for urban traffic congestion.

The survey results served as a crucial framework and scholarly foundation for the study. The following sections will extensively explore the archives of scholarly study, uncovering valuable insights, highlighting areas of deficiency, and establishing the current dialogue around the topic.

2.2. Project Concept Overview

This study began by justifying the need for transitioning from private vehicles to mobility being offered as a service within metro cities. The study carefully investigated MaaS (mobility as a service). Using the Figma Software, a simulation framework was created to mitigate the transportation planning and technological challenges South African metropolitan areas face.

This framework was based on data from numerous studies that examined the MaaS concept around the globe. In order to enhance the application's features and make it more useful and user-friendly, this framework was left open for future consolidation based on emerging circumstances.

Li and Voege (2017) stated that the novel idea called MaaS holds promise for a new era featuring urban mobility. Kamargianni et al. (2016) claimed that MaaS had only recently come to light and enabled efficient door-to-door mobility without the need for a private vehicle, which came about due to improvements in information and communication technology. There is a sizeable and expanding body of work on MaaS, which is succinctly defined as a form of service that allows consumers to plan, book, and pay for many types of mobility services using a single digital channel (Hensher et al., 2023).

Zhang and Kamargianni (2023) said that new mobility technology and services might address several problems associated with transportation, such as contaminants, traffic jams, unsatisfactory journeys, and first- and last-mile link gaps. For the new mobility technologies and services to be implemented, they suggested that it was essential to understand the key factors of demand and supply.

2.3. The Historical Context of Urban Transportation in South Africa

The historical backdrop of urban transport in South Africa is characterised by complex transformations and upheavals, which mirror the country's socio-political shifts and pursuit of modernity and progress. South Africa had the challenge of addressing the needs of its expanding urban population while also adjusting to the dynamic shifts in the global transportation landscape. Consequently, the development of its metropolitan transportation networks also saw notable transformation.

The transport networks in major centres in South Africa, similarly to those in the rest of the country, have transformed basic modes of transport into advanced complex systems. Throughout history, the dominant means of transportation has been determined by factors such as economic feasibility, cultural factors, and, significantly, the urgent requirements of the population.

Establishing a unified and effective transport system became paramount as urban centres expanded and South Africa entered a multifaceted relationship with industry (Maseko, 2018).

Nevertheless, with the exponential growth of urban populations and the resulting strain on city infrastructure due to rapid urbanisation, an urgent need arose for a more systematic and structured approach to transportation.

The urgency of this issue was heightened by the nation's turbulent political past, characterised by the marginalisation of substantial segments of its population and their limited access to fundamental resources, such as transportation (Masuku & Nzewi, 2021). A systematic intervention was deemed necessary to address the discrepancies in access to transport services, particularly in densely populated urban regions.

The Urban Transportation Act of 1977 marked a significant turning point in the transport history of South Africa. The objective of the Act was to guarantee that urban transport planning and infrastructure development progressed in synchronisation with the increasing needs of metropolitan regions. The infrastructure development process included more than just the construction of roads or the implementation of bus systems.

It entailed integrating the socioeconomic elements inside urban areas to guarantee equitable transportation access for all individuals, regardless of socioeconomic standing (Rulashe & Ijeoma, 2022). The consequences of the Urban Transport Act were significant. Infrastructure initiatives were implemented to bridge the gap between marginalised segments of society and the thriving economic centres inside urban areas.

The impacts of this law were readily apparent. Metropolitan areas saw the establishment of more interconnected and unified transport systems, prioritising inclusivity and accessibility for disadvantaged and economically vulnerable populations. The enactment of the Act also prompted metropolitan communities to consider matters outside the scope of transportation infrastructure, such as roads and bridges.

The focus on sustainable transportation has increased, resulting in the investigation of alternative options, such as public transit systems and the encouragement of non-motorised modes of transportation (Schalekamp & Klopp, 2018).

Concurrently with the Act's implementation, a significant transition occurred in South Africa's urban transport landscape, characterised by the emergence of the informal transport sector, particularly the minibus-taxi networks. The implementation of the 1977 Act resulted in a more structured transport system. However, the discrepancy between demand and supply, particularly in heavily populated metropolitan regions, created favourable conditions for the growth and success of minibus-taxi services.

Despite their mostly casual nature, the minibus-taxi systems served as a crucial support system for many individuals in South Africa, offering an adaptable travel option that was sometimes more readily available than other forms of transport (Herko, 2019). However, when global transportation paradigms underwent a transition due to technological breakthroughs and digital transformation, South Africa experienced the effects of these changes.

The concept of MaaS has garnered increasing attention in academic and industry discussions. The concept proposed was groundbreaking, as it aimed to establish a comprehensive transport system encompassing all modes of travel under a unified digital platform. This innovative approach can potentially address the persistent challenges of traffic congestion and transport inefficiencies in South Africa (Smith et al., 2021).

Developed nations swiftly embraced the concept of MaaS. However, South Africa had many obstacles, due to its socioeconomic inequalities and the significant contribution of the informal transportation industry. Nevertheless, recent research by Loubser (2020) showed a discernible interest in MaaS within South Africa. This finding suggests a prospective trajectory for developing urban transport systems in the nation.

2.4. Development of the MaaS Concept

MaaS is more than just a contemporary buzzword in transportation circles. It represents an ambitious vision for the future of urban mobility, which transcends traditional silos of transportation modes and integrates them under a unified digital platform. As cities worldwide grapple with congestion, pollution, and inadequate transportation infrastructure issues, MaaS offers hope, promising more fluid, efficient, and sustainable urban movement.

At its core, MaaS encapsulates a user-centric transportation model where various travel services are bundled together, from buses to bikes and everything in between. Heikkilä (2014) defines it as 'a combination of public and private transportation services within a given regional environment, that is unified through a single interface accessible to the end-user.' This interface, typically a smartphone application, allows users to plan, book, and pay for multiple transport modes seamlessly, offering real-time solutions tailored to individuals' preferences and needs.

Several key principles characterise MaaS. One of its most salient attributes is its inherent flexibility. Unlike the traditional, rigid transportation systems, MaaS provides users with options based on time, cost, convenience, and even environmental impact.

Integration is another pivotal aspect of MaaS, bringing together disparate transportation providers under a cohesive digital framework, thus fostering cooperation and coordination (Okraszewska *et al.*, 2018). Moreover, the user-centric nature of MaaS means that it places a premium on personalisation and real-time responsiveness, adapting to the ever-changing urban mobility landscape.

Historically, the germination of the MaaS concept can be traced back to the recognition of inefficiencies within traditional, siloed transportation models. Congestion, redundancy, and a lack of real-time adaptability were rife in these models, prompting urban planners and technology experts to envision a more integrated solution (Afrin & Yodo, 2020).

The early 2010s marked the embryonic stages of MaaS, primarily in technologically advanced cities in Europe. Helsinki, for instance, is often credited as a pioneer in the MaaS arena. As Heikkilä (2014) said, the Finnish capital started experimenting with integrating various modes of transport under a unified digital framework, aiming to make personal car ownership obsolete by 2025.

Subsequent years saw the MaaS phenomenon gaining traction globally, notably in North America and parts of Asia. Cities began to invest in MaaS infrastructure, recognising the unsustainable nature of traffic congestion and transportation inefficiencies. Research, such as that undertaken by DeSoto (2022), began to delve into the potential impacts of MaaS, analysing its effectiveness using sophisticated methodologies like agent-based simulation.

However, as MaaS began to permeate global consciousness, its implementation varied across regions. In developing countries, where informal transportation systems were rampant and digital infrastructure was often nascent, the adoption of MaaS faced unique challenges.

Loubser's (2020) exploration into the potential demand for MaaS in South Africa, a developing nation, shed light on these complexities. While the demand and the need for MaaS were palpable, integrating the informal transportation sector, typified by entities like minibus taxis, into the MaaS framework required innovative approaches (Schalekamp & Klopp, 2018).

2.5. MaaS Concept

The idea of MaaS is to use one app for accessing and paying for different forms of transportation within a town or beyond its immediate environs, with a mobile application able to provide options to let a passenger choose the best mode of transportation for his or her needs.

The study proceeds to show that the proposed MaaS framework calls for the management of a shared access platform by a bidding authority where competitively tendered MaaS collaboration proposals are examined, and various successful bidders are chosen to ensure the inclusion of all multiple modes of transportation and multiple transportation services provided items throughout the winning bid. In this instance, by offering users various options, such a strategy promotes competition in the MaaS industry.

Giesecke, Surakka and Hakonen (2016) presented the following:

MaaS trip phases: from preparation to travel:

1. Preparation: Map the route door to door.
2. Booking: The commitment to use a particular mode of transportation service, including a beginning and an end.
3. Paying: Paying the mobility provider the fare, either trip-based or time-based (for example, hour, day, week, month).
4. Ticketing: Provide documentation of the trip arrangement regularly in electronic form.
5. Trip: The actual outing, including the travel itinerary.

These five phases can convey both people and things. Flexible modes of transportation must be created to achieve this goal, but they must also be specifically tailored to the demands and characteristics of each customer. Through a website or app, the user may choose a single trip that integrates transportation options from numerous public and private providers (Musolino et al., 2023).

MaaS needs to create a blueprint of the transportation supply (in terms of routes, frequencies, schedules, etc), the management of demand, the assessment of policies, intelligent planning, and evolution.

Pandit and Sharma (2022) explicitly explained that versatile transport systems (VTS), typically informal and run by individual transit drivers in developing nations, are available. Due to the lack of regulation for most of these services, they are operated in a poorly organised way, thus providing poor service.

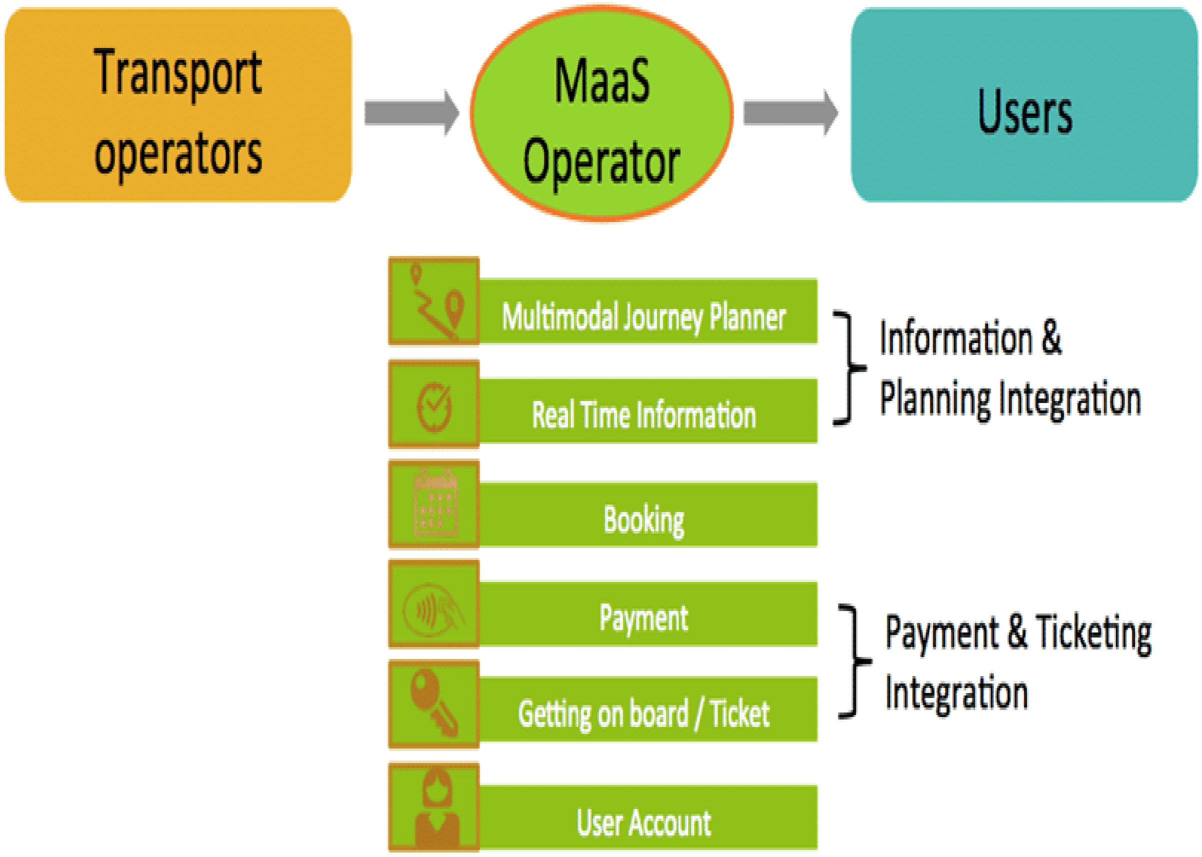

Figure 2.1: Functions of a MaaS operator (UCL MaaSLab, 2015)

The initial enrolment of providers and worker unions significantly hampers the growth of MaaS in developing nations. This is because most types of transportation in these nations are unregistered and independently owned. Therefore, it can be said that an important sign of the MaaS ecosystem's success or failure is the willingness of transport operators to engage in it (Dzisi, et al., 2023).

Chen, Fu and Chen (2023) expressed how current MaaS research primarily concentrates on people's daily mobility instead of tourists' mobility when visiting places. The tourist sector, however, is a promising but hitherto neglected MaaS market. Seven MaaS bundle qualities, including price, public transportation, shared bikes, shared e-motorcycles, shared cars, discounts on shopping and tourist tickets, are used to create the choice tests.

2.6. Global Acceptance of MaaS

Urban transportation systems are changing as a result of social and technological advancements in the field of transportation that attempt to address global challenges like urbanisation processes, the rising demand for transportation, climate change, and sustainability objectives (Nemoto et al., 2023).

Enoch and Potter (2023) continue to clarify that this idea is effective because it directly connects travellers with a variety of transportation companies in a vibrant market where the availability of transportation can be far more flexible to user requirements than previously. One of several suspected limitations for not fully embracing MaaS, even though the technology is advancing quickly, is how MaaS providers and the providers of certain activities can collaborate to supply MaaS and how this could impact the larger transportation system. The idea is that the user, with his particular mobility needs, comes first when designing trip solutions.

Rongen et al. (2022) suggested that the mobility hub idea, a novel component of passenger transportation systems, has recently drawn more attention in worldwide transport planning. In Europe, several regions have begun implementing mobility-hub programmes in urban regions, such as Utrecht, Bremen, and Vienna, and rural regions, such as Flanders, Groningen-Drenthe, and Karlsruhe.

Kayikci and Kabadurmus (2022) stated that emerging trends, such as urbanisation, digital transformation, and decarbonisation, have made innovative approaches to the urban transportation system necessary. In Helsinki’s study of 2014, MaaS was put up as a fresh, sustainable transportation concept as a response to the issues of the increasingly digitalised urban transportation environment. Residents of a large growing city can use the MaaS idea to provide a quick, effective, cost-effective, and environmentally responsible method of transportation to a large city.

Pritchard (2022) stated that some see the introduction of MaaS as a way to provide integrated multiple modes of transportation and transportation service providers with the ability to take on the usage of a private vehicle as a solution to the issues that now plague a car-centric lifestyle. MaaS may serve as an alternate, integrated replacement for the private car in a setting where several public and private entities provide mobility services (Musolino *et al.*, 2023).

Key factors of MaaS demand:

Mobility as a Service

Welfare:

Providing secure, dependable, and efficient transportation system.

Human frustration:

- Since everyone is rushing to get to their work and socially scheduled meetings, congested roads lead to driver irritability, which can lead to road rage and possibly cause accidents.
- Drivers spend the majority of their time in traffic, which cuts into their rest time and causes them to make careless decisions that puts other travellers in risk.

Traffic congestion:

- Drastically reduces the volume of automobiles on roads daily.
- Eliminating demand of new/more roads.

Green transportation system:

By drastically reducing the number of cars on the road, mobility as a service can help us minimize the quantity of carbon dioxide- the most common greenhouse gas created by humans- that released.

Forecasted travel-time:

Due to less automobiles on the roadways, users can better manage their time and get close – to – accurate journey times by planning their trips in advance and using self-scheduling.

Welfare

In numerous emerging cities, public transportation is widely viewed as low quality. Johannesburg is a typical example of a city with limited government-funded public transportation services and limited levels of mobility and accessibility. The South African government wants to adopt a significant modal shift towards public transportation and more environmentally friendly modes (Luke & Heyns, 2020). Huang and Loo (2023) stated that urban residents feel the effects of increased transportation expenses, deteriorating air quality, lengthier commutes, and traffic congestion.

How will having a reliable, secure, and efficient transport system affect social and economic factors?

According to Olayode et al. (2021), the use of roads is considered crucial for human daily activities, regardless of a nation's social or economic standing. There is a need for an efficient transportation system because the need for improved transportation services is increasing at an alarming rate. Kadyraliev et al. (2022) stated that, because it serves as a means of bridging space for the movement of people and goods, transportation infrastructure can be seen as a factor that ensures growth and economic development. How society utilises the services provided by infrastructural facilities will significantly impact how the transportation infrastructure affects the economy.

High-income cities have paid far more attention to the economic costs of traffic congestion. The most often used phrases about strategies for reducing traffic congestion were those that focused on encouraging the use of public transportation and active transportation, followed by measures of restriction and control and, finally, the use of intelligent transportation systems (ITS) or 'smart mobility' (Huang & Loo, 2023). One of the key determinants of a population's living conditions is infrastructure, which spurs socioeconomic development. The article goes on to explain that inefficient public-transit alternatives, too many cars on the road, congested roads, and bus drivers' attitudes are all shown to be contributing factors. This congestion causes high-stress levels for road users as well as daily economic loss. Fattah, Morshed and Kafy (2022) stated that traffic congestion is one of the main obstacles to developing economies' economic growth, which has negative social and economic effects.

Traffic Congestion

Kibangou, Moyo and Musakwa (2021) explained that, in terms of a physical situation in traffic streams, congestion is characterised by slowed speeds, constrained movements, protracted delays, and network paralysis. Extreme traffic jams result from the burgeoning economies of industrialised countries, the acceleration of development, the rise in the number of automobiles on the road, and the explosive growth of the urban population (Olayode, Tartibu & Okwu, 2021).

How will MaaS assist in drastically reducing the volume of vehicles using road infrastructure and the demand for new road infrastructure to equally meet the volume of vehicles?

MaaS seeks to wean communities off using privately owned vehicles by ensuring that most people adopt them. As technology develops and more and more people begin to grasp how to use a smartphone and the installed applications, they will realise how beneficial it is to arrive at a place on time and without being stopped in traffic; fewer and fewer people will want to drive themselves around.

Mobility apps are designed to assure accessibility, consistency, safety, and comfort. Therefore, it is a win-win situation because winning over the masses will remove many people from the road without inconveniencing them. Due to the declining demand for new infrastructure, transportation systems will be better able to concentrate on and invest in next-generation smart transportation, which will eventually be incorporated into the MaaS app for universal accessibility.

Forecasted Travel-Time

Due to the congested roadways in South Africa's urban areas, particularly on the highways during rush hours, it can be challenging to estimate travel times. If you leave your house just in time for your next commitment, you risk missing it. However, as mobility is a service, it helps with interval-time booking to prepare for any unforeseen delays on the road. Moving across cities without worrying about being late for work or other obligations becomes simpler and more rational, especially if the general population adopts MaaS.

Green Transportation System

Dasgupta, Lall and Wheeler (2021) emphasised the gravity of health concerns attributed to environmental pollution in the growing urban regions of developing nations. The transportation sector is one of the largest contributors and most rapidly growing sources of greenhouse gas (GHG) emissions worldwide, due to its extensive dependence on environmentally harmful infrastructure and the huge usage of fossil fuels. Decarbonising the transportation industry is crucial for reducing human impacts on the environment (Hasselwander et al., 2023).

Human Frustration

Congested roadways result in driver frustration, leading to road rage and possibly causing accidents because everyone is racing to get to their work or socially scheduled meetings. Most of a driver's time is spent in traffic, which reduces their opportunity for rest and leads them to make irresponsible decisions that endanger other road users.

2.7. Benefits and Challenges of MaaS

The emergence of MaaS has been greeted with a sense of expectancy, curiosity, and a certain degree of scepticism. The concept of MaaS has the potential to revolutionise urban travel by consolidating many forms of transport into a unified digital platform. However, the implementation of MaaS faces several obstacles, including limitations to infrastructure and concerns over public reception. Achieving equilibrium between the advantages and obstacles, MaaS requires a holistic understanding of the MaaS environment.

One of the most appealing advantages of MaaS lies in its inherent efficiency. According to Heikkilä (2014), integrating many transportation modes, including buses, taxis, bicycles, and e-scooters, into a single platform enables users to efficiently strategise, reserve, and financially transact for their trips. This simplified method enhances the customer experience and maximises the utilisation of existing transportation resources, thereby minimising inefficiencies associated with underutilised capacity. Metropolitan areas that have challenges with traffic congestion and the accompanying financial burdens might potentially see significant benefits from the implementation of MaaS.

The issue of transportation congestion, often intertwined with urban narratives, may be significantly improved by the effective deployment of MaaS. Afrin and Yodo (2020) provided real-time information on travel alternatives and their corresponding aspects, such as length, cost, and carbon footprint. Using MaaS may effectively promote the use of more sustainable and efficient modes of transportation by users. Cities should see a decrease in congestion and hence achieve quicker travel times by implementing measures to diversify transportation use and decrease the reliance on private automobiles.

The environmental advantages of MaaS are another noteworthy benefit. The efficient utilisation of resources reduces the number of cars idling in traffic, decreasing emissions. Moreover, it is worth noting that several MaaS platforms have included environmentally friendly transportation options, such as electric cars and bicycles, indicating a noticeable inclination towards fostering a more sustainable transportation system (Okraszewska *et al.*, 2018).

Nevertheless, despite these benefits, implementing MaaS is accompanied by other obstacles. Integrating informal transport sectors, particularly in emerging nations, is a substantial challenge. Schalekamp and Klopp (2018) stated that minibus-taxi systems in countries such as South Africa facilitate urban transportation. Incorporating informal systems into standardised MaaS architecture necessitates implementing new solutions to ensure that the advantages of MaaS extend beyond official transportation modalities.

The preparedness of infrastructure is an additional significant hurdle. Technologically sophisticated cities may have a comparatively smoother transition to MaaS, but some cities, particularly those in low-income nations, have challenges due to antiquated transport infrastructure and poor digital penetration (Herko, 2019).

The success of MaaS relies heavily on the presence of a strong digital connection and the availability of real-time data. Therefore, the development of infrastructure is a necessary condition for the effective implementation of MaaS. The consideration of public approval is also of paramount importance and should not be disregarded. MaaS signifies a departure from the conventional and compartmentalised method of managing transport systems.

Persuading individuals to shift from personal car ownership to dependence on a shared and integrated transportation system necessitates cultivating trust, assuring safety, and maintaining dependability. Loubser (2020) emphasised the significance of comprehending the specificities of local settings, preferences, and concerns while examining the potential demand for MaaS in South Africa.

2.8. Traffic Congestion: Causes, Impacts, and Mitigation Strategies

The ramifications of traffic congestion in urban environments are complex and multifaceted. Not only does congestion affect the daily lives of city inhabitants, but it also has broader implications, ranging from economic to environmental concerns.

2.9. Understanding the Primary Causes of Traffic Congestion

The causes of traffic congestion are rapid urbanisation, increased vehicles, inefficient public transportation, and poor infrastructure (Olagunju, 2015). In many developing countries, particularly in Africa, the informal transport sector can contribute significantly to traffic gridlocks, primarily because of unregulated movements and stops (Schalekamp & Klopp, 2018). Another cause, especially in places like Buffalo City, South Africa, is socioeconomic exclusion from basic service provision, which leads many to rely heavily on road-based transport (Masuku & Nzewi, 2021).

2.10. Economic, Environmental, and Societal Impacts of Prolonged Traffic Congestion

Traffic congestion costs economies billions annually in wasted fuel, decreased productivity, and late deliveries. Cities like Johannesburg experience these economic setbacks firsthand, as the efficiency of service delivery mechanisms is impeded (Maseko, 2018). Moreover, the environmental implications are glaring. Increased idling and slower speeds result in higher emissions and a larger carbon footprint, thus contributing to environmental degradation (Afrin & Yodo, 2020). Societally, congestion leads to a reduced quality of life. Longer commuting times rob individuals of leisure, strain mental wellbeing, impact local economies and can even deter tourists (Smith *et al.*, 2021).

2.11. Previous Attempts and Strategies to Mitigate Congestion

A plethora of strategies have been attempted globally to tackle congestion. For instance, the development of bus rapid transit (BRT) systems and the innovation in minibus-taxi reforms in South African cities were seen as a leap towards decongesting urban centres (Schalekamp & Klopp, 2018). Similarly, MaaS has been eyed as a potential solution, aiming to integrate various transport modes and promote more efficient travel behaviours (Heikkilä, 2014).

However, while technological advancements, like the potential use of blockchain infrastructure in transport, may offer promising solutions in some cities, their application in low-income countries remains challenging (Herko, 2019).

Other mitigation efforts, such as congestion pricing, carpooling, and the promotion of non-motorised transport, have also been considered, each with varying degrees of success (Djahel *et al.*, 2014). In some North American prototypes, agent-based simulations were used to evaluate the impacts of MaaS, yielding insights into its potential benefits and challenges (DeSoto, 2022).

However, not all strategies have been uniformly successful. Some interventions have faced hurdles related to public acceptance, infrastructure readiness, and implementation gaps. For instance, in the City of Ekurhuleni, South Africa, policy frameworks occasionally fail to address the core issues, sometimes exacerbating the problems they seek to solve (Makhubu & Vyas-Doorgapersad, 2022).

2.12. The Role of Technology in Transforming Urban Mobility

The relentless march of technological progress has significantly influenced various sectors, and urban mobility is no exception. From the ways we plan our routes to the modes of transport we use, technology's transformative impact on urban transportation is profound.

2.13. How Advancements in Technology are Reshaping Urban Transportation

Technological innovations are revolutionising urban mobility by offering smarter, more efficient, and sustainable transportation solutions. In many cities worldwide, age-old problems like congestion, inefficient public transportation, and high emissions are tackled using cutting-edge technologies (Djahel *et al.*, 2014). These cities are improving their residents' daily commute and addressing broader societal and environmental issues. One key development in this space is the increasing integration of various transportation modes facilitated by digital platforms. This approach, often termed MaaS, leverages technology to offer travellers real-time information, dynamic pricing, and diverse transport options, thus enabling more efficient and flexible travel behaviours (Heikkilä, 2014).

2.14. Overview of Different Transportation Technologies

1. **Smart Traffic Systems:** Advanced traffic management systems utilise sensors, cameras, and data analytics to monitor and manage traffic flow in real-time. These systems can adapt to changing conditions, for example, by altering traffic-light patterns during heavy congestion or reducing gridlocks in response to accidents (Djahel *et al.*, 2014).
2. **Artificial Intelligence (AI) in Transportation Planning:** AI and machine learning make transportation planning more predictive. AI can forecast traffic patterns by analysing historical traffic data, weather conditions, and other variables and suggest optimal public and private transportation routing. This minimises congestion and enhances the efficiency of public transit systems (Kamargianni *et al.*, 2016).
3. **Data Analytics:** The importance of data cannot be overstated. With the proliferation of smartphones and connected devices, a deluge of transportation-related data is generated every second. Analysing this data provides insights into commuter behaviours, peak traffic times, popular routes, and more. Cities can harness this information to enhance public-transport services, plan infrastructure projects, and implement dynamic-pricing mechanisms (Smith *et al.*, 2021).
4. **Blockchain in Transport:** Blockchain's decentralised and transparent nature offers potential solutions for transport challenges in developed and developing cities. For instance, ticketing systems based on blockchain can ensure fare transparency and prevent fraud, especially in countries where regulatory mechanisms might be weak (Herko, 2019).

5. **Autonomous Vehicles (AVs):** While still nascent, AVs promise to reshape urban landscapes. With the potential to reduce accidents, optimise traffic flow, and even lower emissions (when combined with electric powertrains), AVs could be the future of urban mobility (Schroder-Hinrichs *et al.*, 2019).

2.15. Case Studies: MaaS Implementations Globally

The concept of MaaS exemplifies the profound impact of contemporary technology in effectively handling the intricate transportation requirements of expanding metropolitan areas. MaaS fundamentally consolidates diverse transport modalities into a unified digital framework to enhance effectiveness, adaptability, and ecological soundness. As the examination of its practical implementations progresses, discernible patterns about innovation, obstacles, and instances of achievement become apparent.

Helsinki, Finland is widely recognised as the original hub of the MaaS idea and has enthusiastically adopted this integrated mobility solution. Heikkilä (2014) stated that the urban undertaking resulted in the creation of “Whim”, a digital platform that integrated various modes of transportation, such as buses, trams, taxis, auto rentals, and bikes. By using real-time data, the application provides the most efficient routes and enhances the efficiency of ticketing and payment procedures.

Helsinki saw a significant change in its paradigm as inhabitants embraced the service, and the city observed a considerable decrease in automobile ownership rates. Whim’s triumph highlights the need to integrate services with a user-centric approach, use dynamic pricing strategies, and foster cooperation between public and commercial transportation organisations.

Relocating to another geographical setting, namely, the urban centre of Johannesburg in the Republic of South Africa, offers a multifaceted viewpoint on the concept of MaaS within the context of a country undergoing developmental progress. In this context, many issues are prevalent, including socioeconomic disparities and limitations to infrastructure, as expounded upon by Maseko (2018) and Loubser (2020). Although Johannesburg’s initiatives may not align with a conventional MaaS platform, its advancements in transforming the minibus-taxi system exemplify the core principles of MaaS. Schalekamp and Klopp (2018) stated that the city has made efforts to formalise this crucial transport service and integrate it with the wider public-transportation networks.

Implementing this initiative not only enhanced the overall experience for commuters but also introduced a sense of regularity and reliability to the transportation timetables, thereby positively impacting the financial status of minibus-taxi operators. The main lesson derived from Johannesburg's experience is that, in areas with a prominent informal transport industry, the first action towards MaaS involves acknowledging and incorporating these services into a structured framework.

In North America, a study by DeSoto (2022), at the Massachusetts Institute of Technology, provided valuable and enlightening findings. The researcher used agent-based simulations to project the potential effects of hypothetical MaaS deployment in several city prototypes. This analysis considered metropolitan sprawl, population density, and pre-existing infrastructure. The findings provide a nuanced perspective.

The transformational potential of MaaS depends upon the unique qualities of the urban environment in which it is implemented. For example, heavily populated metropolitan regions have more significant advantages, particularly in reducing congestion and increasing the use of public transportation. After synthesising these case-study insights, several prominent best practices and lessons emerge. Smith *et al.* (2021) emphasised the need to prioritise users in a MaaS solution by focusing on delivering a smooth, transparent, and integrated experience. The need to foster cooperation between stakeholders in the public and commercial transport sectors is indisputable, as shown by the case of Helsinki.

Furthermore, deploying MaaS must consider each location's socioeconomic and infrastructural conditions. Data plays a pivotal role in MaaS, serving as a fundamental component. Real-time analytics are used to facilitate dynamic routing, optimise traffic flow, and boost overall efficiency.

2.16. Barriers and Drivers for MaaS Adoption in South African Cities

The urban mobility framework in South Africa is characterised by complexity and fluidity, reflecting the nation's distinctive socio-political background and economic development. MaaS is an emerging mobility paradigm that presents novel opportunities and complexities. Gaining insight into the obstacles and catalysts influencing the implementation of sustainable and inclusive mobility in South Africa's urban areas is paramount for visualising a future that promotes long-term viability and equitable access for the country. The transport system in South African cities is shaped by profound cultural norms and historical legacies, contributing to their vast cultural variety. The minibus-taxi system, widely seen in metropolitan areas such as Johannesburg and Cape Town, serves as a means of transportation and symbolises the community's resilience and entrepreneurial spirit. Schalekamp and Klopp (2018) stated that it is important to consider socio-cultural importance when formalising or integrating this system into wider MaaS models. In these cities, the obstacles encompass technical and economic factors and a need to preserve the cultural ethos inherent in these informal institutions.

From a technological standpoint, it is evident that South Africa has some areas with highly developed digital infrastructure. However, it is important to acknowledge the existence of a distinct digital divide inside the country. Metropolitan areas like Johannesburg may provide favourable conditions for implementing technologically driven MaaS platforms. However, there are still significant challenges in more remote locations, characterised by limited internet connectivity and lower levels of technical proficiency. Masuku and Nzewi (2021) examined the provision of services in the Buffalo City Metropolitan Municipality, highlighting how deficiencies in infrastructure might impede the widespread adoption of new solutions.

From an economic standpoint, the income difference seen countrywide in South Africa gives rise to a wide range of mobility requirements. While the affluent segment may prefer app-based private ride-sharing services, a considerable portion of the population relies on cost-effective public-transportation options. The interaction between economic barriers and infrastructure obstacles is important. Maseko (2018) stated that urban areas such as Johannesburg are challenged to balance financial sustainability to provide accessible service delivery via alternate channels.

Key stakeholders are essential participants in the story of adopting MaaS. Public bodies, such as city governments and transport agencies, provide the regulatory framework and lay the foundation for infrastructure development. The partnership between public and commercial organisations, ranging from emerging technology companies to well-established transport providers, catalyses the development of integrated MaaS platforms. Academic and research institutions have a crucial role in providing insights based on empirical evidence, as shown by research conducted at the University of Johannesburg.

The involvement of community leaders and organisations, particularly those representing the informal transport sector, plays a crucial role in facilitating the process of adoption. The participation and support of stakeholders guarantee that MaaS models are designed and implemented to consider the local context's specific characteristics and requirements. Several factors contribute to the drivers for adopting MaaS in cities in South Africa. The current demography of the country, which consists of a youthful and technologically adept population, along with the growing prevalence of smartphones, creates an audience that is receptive to digital transportation solutions. The increasing prevalence of urban congestion and the need for sustainable mobility alternatives make MaaS very desired and indispensable. In addition, the government's efforts to promote smart cities, as shown by regulatory frameworks, provide institutional backing for breakthroughs in MaaS.

2.17. Future Trends and Predictions for Urban Mobility

The field of urban mobility is undergoing fast transformation, as emerging trends and technology improvements are significantly altering the transportation infrastructure of metropolitan areas worldwide. This phenomenon is also evident in South Africa, where these developments reshape the transportation landscape. The ascent of autonomous cars is a prominent and noteworthy trend in transportation. Self-driving vehicles, supported by sophisticated AI, provide the potential for enhanced road safety, improved traffic control, and a transformed passenger experience. According to Kamargianni *et al.* (2016), incorporating autonomous cars in metropolitan areas promises to significantly mitigate traffic congestion and provide a more streamlined commuting experience.

The transformational wave does not conclude with driverless cars. The emergence of drone delivery is poised to revolutionise urban logistics, presenting a potential redefinition of the field. These airborne machines have a purpose beyond the simple delivery of items, since they represent a significant advancement in the development of urban transportation. According to Djahel *et al.* (2014), integrating drones into traffic management systems for smart cities has the promise of enhancing traffic monitoring emergency response and perhaps establishing air-based public-transit systems.

Shared mobility platforms represent a novel aspect of the transformation of urban transport. These platforms, ranging from ride-sharing to bike-sharing, address the increasing need for mobility options that are both adaptable and ecologically sustainable. Smith *et al.* (2021) provide a comprehensive analysis of the transition in focus from car ownership to service accessibility. The emerging paradigm emphasises individual mobility and prioritises communal efficiency, sustainability, and accessibility.

When examining South Africa, it is evident that its urban mobility environment is influenced by its distinct socio-cultural and economic complexities. The potential of autonomous cars is considerable, yet they will face the challenge of operating within a landscape characterised by diverse infrastructure standards, as shown by Masuku and Nzewi's (2021) research on the Buffalo City Metropolitan Municipality. Similarly, Maseko (2018) has highlighted the socioeconomic disparities linked to providing essential services in urban areas such as Johannesburg.

This underscores the need for shared mobility platforms to prioritise equity and inclusivity to serve the varied population's needs. The minibus-taxi system's importance in incorporating current transportation dynamics into MaaS solutions is crucial in South African cities (Schalekamp & Klopp, 2018). According to Herko (2019), blockchain architecture has the potential to establish a system for shared platforms that is characterised by enhanced transparency, accountability, and efficiency. This solution can mitigate the trust deficit between consumers and suppliers.

The future of urban mobility in South Africa is anticipated to include a convergence of global tendencies and local circumstances. The legal and policy frameworks will significantly influence the future, as shown by the Constitution of the Republic of South Africa (1997). The integration of these technologies will be determined by their alignment with national goals such as sustainability, inclusion, and economic development. Furthermore, it has been shown by Loubser's (2020) study at the University of Johannesburg that there is a projected increase in the demand for MaaS in developing nations. This implies that South African cities may see a more significant transition towards integrated mobility platforms in the near future.

2.18. Conclusion

Several pertinent insights emerge after traversing the multifaceted landscape of urban mobility through the existing body of literature. MaaS is not a mere trend but a transformational paradigm shift, potentially reshaping metropolitan cities’ traffic dynamics. While numerous studies have lauded its potential benefits, others have highlighted challenges and areas still ripe for exploration. This review has not only consolidated key findings but has also unveiled gaps in the current understanding, underlining the need for continuous research in the domain. As the narrative of urban mobility continues to evolve, scholars, policymakers, and stakeholders must remain informed, adaptive, and forward-thinking. By synthesising these myriad perspectives, this literature review has laid a robust foundation upon which this study seeks to build, innovate, and contribute.

3. CHAPTER 3 – Research Methodology

3.1. Introduction

The methodology section is a pivotal component in any research endeavour, often regarded as the bridge between the research question and the results. This chapter sheds light on the research processes meticulously employed throughout the study on MaaS and its potential ramifications for the ceaseless traffic congestion observed in metropolitan areas. The resonance of this research study's importance lies in the urban dweller's quest for efficiency, balanced with a sustainable approach.

Rooted deeply in the belief that methodologies are not mere procedures but are constructed out of deliberate and informed choices, this study sought inspiration from pioneering works such as Newman and Gough's (2020) comprehensive treatise on systematic reviews and Pandey and Pandey's (2021) insightful perspective on research tools and techniques. Adopting this systematic methodology was envisioned to elevate the research from mere data collection to holistic, actionable insights that can significantly contribute to urban planning and development discourses.

3.2. Research Design

Delving into the heart of the research, the design is comparable to an architect's blueprint, detailing the entirety of the research journey from inception to fruition. Resonating with Creswell's (2007) insights, this study's design was neither accidental nor arbitrary. Each element was intentionally structured, beginning with carefully formulating the research questions. These questions served as the North Star, guiding the trajectory of the entire project. An extensive data collection phase was designed to harvest rich, qualitative data from diverse sources.

The culmination saw a meticulous data-analysis phase, transforming raw data into tangible findings and insights comprehensively presented in the final report. In their seminal work, Newman and Gough (2020) underscored the importance of such a structured design, emphasising that research devoid of a solid design often flounders, lost in a sea of data and ambiguity. This research design illuminated the path and ensured that every step was purposeful, moving inexorably towards a clear research goal.

3.3. Research Approach

The essence of any research is profoundly influenced by its approach. This study chose a qualitative research approach as the lens through which the topic would be explored. This choice was informed by Anderson's (2010) elucidation, which suggests that qualitative research, in its depth and detail, seeks to understand phenomena in their natural setting, aiming to make sense of or interpret them in terms of the meanings people attach to them.

Given the human-centric focus on mobility and urban congestion, the qualitative method offered a rich tapestry of insights, narratives, and experiences that numbers alone could not capture.

Delving deeper, the study incorporated grounded theory for its data-collection phase. Khan (2014) poignantly remarked that grounded theory, in its essence, allows a theory to emerge organically from the data itself, ensuring that the findings are deeply rooted in the very fabric of the data collected. Such an approach enabled the study to remain flexible, allowing for the incorporation of new data and insights as they emerged.

However, this decision to employ grounded theory was not taken in isolation. It was informed by thoroughly examining various qualitative research approaches, drawing insights from Hunter, MaCallum and Howes (2019), who thoroughly explored methodologies like phenomenology, ethnography, and action research.

The decision was further bolstered by the extensive methodologies documented by Mishra and Alok (2022), which offered a comprehensive overview of the various techniques and their applicability.

3.4. Target Population and Sampling

A study's potency often lies in its specificity and, for this study, the locus of attention was metropolitan cities that grapple with the ubiquitous challenge of traffic congestion, particularly during the relentless rush of peak hours. These metropoles are microcosms of urban challenges, with their dynamic populations, multifaceted transport systems, and evolving urban landscapes. They offer a unique intersection of infrastructure, policy, human behaviour, and technological interventions, making them fertile ground for investigation.

Case studies of selected metropolitan areas were pursued to glean insights into the nuances of urban congestion and potential solutions. These studies were not arbitrarily selected because they implemented or contemplated applying MaaS frameworks. This strategic sampling aimed to derive lessons from their successes, challenges, innovations, and pitfalls. Pandey and Pandey (2021) underscored the undeniable importance of judiciously delineating a target population, in their seminal work. They also expound on the art and science of sampling in qualitative research, emphasising that a well-chosen sample can illuminate broader patterns, trends, and implications.

3.5. Data Collection

The bedrock of any qualitative study is its data and, for this research, the emphasis was on depth, breadth, and authenticity. Data was scrupulously gathered from multiple case studies, which delved into the intricacies of traffic congestion within selected metropolitan realms. Additionally, existing frameworks and initiatives on MaaS within comparable urban settings were explored. Each piece of data, whether an anecdote, a policy document, a user testimony, or a statistical insight, was like a puzzle piece, contributing to the larger narrative of urban mobility challenges and solutions.

In orchestrating this extensive data-collection process, guidance was sought from the tenets propounded by Flick (2015). Flick (2015) emphasises the value of immersion in qualitative research, ensuring that data collection is not just a procedural step but a phase of deep engagement and understanding. By adhering to these principles, the research ensured that the data amassed was extensive and profoundly insightful, capturing the multifaceted essence of urban congestion and mobility solutions.

3.6. Ethical Considerations

Undertaking research in the realm of social sciences and urban studies brings with it a multitude of ethical responsibilities. Ensuring the integrity of the research process became paramount in this study. Every step, from data collection to analysis, was coloured with a deep sense of ethical obligation. First and foremost, utmost respect was accorded to all data sources. All information from a published study or an interviewee was appropriately acknowledged and credited. This upheld the sanctity of intellectual property and enhanced the study’s credibility. Confidentiality and anonymity were recognised when dealing with human participants, especially those from metropolitan areas, sharing their experiences and insights. Regardless of whether participants expressed concerns, all personal identifiers were carefully redacted or anonymised. This measure ensured participants could speak freely and honestly without fear of repercussions or exposure.

The pitfalls of bias, whether implicit or explicit, are well-documented in research circles. This study went to great lengths to eschew any form of biased data interpretation. Every piece of data was approached with an open mind, ensuring that conclusions were driven by the data, not preconceived notions or desired outcomes. In this vein, the philosophical insights of Al-Ababneh (2020) proved invaluable. His discourse on the intricate relationship between the ontology of knowledge and the methodology of its discovery stresses the duty of researchers. The duty to be accurate and ethical became a guiding light, ensuring that the study remained morally sound in its pursuit of knowledge.

3.7. Conclusion

The methodology chapter has been more than just a procedural recounting; it is a testament to the rigorous and ethically conscious approach that defined this research journey. It underscores the commitment to veracity, integrity, and depth and showcases the study's unwavering dedication to methodological excellence. With each step anchored in principles set forth by an array of esteemed scholars in research methodology, the chapter not only elucidates the processes employed but also reinforces the study's foundational strength and credibility. The study hopes to offer findings that contribute meaningfully to the discourse on mobility in metropolitan cities through these meticulous methods.

4. CHAPTER 4 – Data Analysis and Interpretation

4.1. Introduction

In its raw form, data is like an uncut gemstone; its true value is unveiled only after careful refinement. The data collected for this study underwent rigorous inductive qualitative data analysis. This analytical approach was chosen intentionally; it allowed the data to "speak," revealing patterns, commonalities, and unique insights that might have remained obscured in a more prescriptive analytical approach. This methodology was instrumental in sifting through the data, identifying trends, recognising patterns, and discerning recurrent experiences and sentiments. Leveraging the methodological framework delineated by Mishra and Alok (2022), the research aimed to go beyond superficial observations, seeking to unearth deeper connections, causation, and implications. Furthermore, the study meticulously adhered to the analytical steps MacMillan and Schumacher (2010) advocated to ensure the analysis was systematic and exhaustive. This regimented approach ensured that every piece of data was scrutinised, every trend was validated, and every conclusion was rooted in empirical evidence, resulting in robust and revelatory findings.

4.2. Data Analysis

Hoyle (2015:756) stated that analysis is a method of thought. It is unbiased. Monitoring and measuring results can be analysed to determine their meaning and whether they match our expectations. The measurements are interpreted and explained, then presented in a way that discloses knowledge of what the statistics are trying to tell us. The following Hoyle's steps of data analysis were utilised in chapters 2 and 3 of this study:

- Gathering information through reviewing existing studies.
- Sorting, categorising, summarising, simulating a prototype, and converting the raw data into useful information for the evaluators; and
- Give the evaluators access to the material presented throughout the study.

The analytical portion concentrated on evaluations of the various transportation systems in South Africa, including their usability, safety, and convenience. It breaks down important metrics and compares them for use in South Africa.

4.2.1. Current Transportation System in South Africa

Many transportation apps were released before initiatives and tactics to address transportation system problems in South Africa were presented, particularly in the country's metropoles. We can state with certainty that transportation issues are an issue of yesterday now! Although this has increased competition in the market, it has also allowed service providers to be more hands-on when giving customers high-quality services. All that is needed is a smartphone, internet access, and the ability to download one of the many South African transport apps.

According to Nowek (2023), driving is frequently the sole practical choice for people in South Africa commuting daily. Despite being marketed as the safest alternative, it may not always be the safest method of transportation. One of the highest carjacking rates in the world has long been revealed in South Africa, and this tendency does not appear to be abating. He explains that there are few, out-of-date, or no official websites or apps for many of South Africa's public transit options. Additionally, some official apps have poor reviews and are poorly made.

Table 4.1: Different Transport Systems/Services Available in South Africa

	Categories		
	Roadways	**Railways**	**Airways**
Modes of Transportation	1. Buses: • Metrobus • Rea Vaya • A Re Yeng • Putco • Tshwane Bus Service 2. Cars: • Taxis • Bolt • InDrive • Orange Cabs • Taxi Live Africa • Uber • Yookoo Ride	1. Passenger Rail Agency (PRASA) 2. Metrorail 3. Gautrain	1. South African Airways 2. Airlink 3. FlySafair 4. Kulula.com

4.2.2. South Africa's Potential Developments because of MaaS

The transportation app offered by MaaS contrasts with other apps that are currently on the market in South Africa, such as Bolt South Africa, Uber App South Africa, Yookoo Ride, In Drive South Africa, Orange Cabs, Zebra Cabs, Taxi Live Africa, and many others.

MaaS will be the first transportation application in South Africa to integrate multiple services from various service providers with various modes of transportation available for users based on convenience, affordability, competitive rates, and, occasionally, discounted rates for regular users. MaaS, because it is a fresh innovation with a potential capability that will be put into practice, tested, integrated, and maintained depending on users' responses and feedback for improvement, the MaaS application is therefore considered a future-friendly application. ITS, which increases roadway transportation systems' safety and effectiveness, is a significant component of new innovative transportation systems (such as MaaS). A thorough demonstration of MaaS was built in this chapter as the initial design based on the different publications read in Chapter 2. The demonstration will be reviewed, assessed, tested, and improved later.

4.3. Chapter 4 Illustrations of the summarised MaaS Framework Screens exported from the project simulation/demo.

User Phases Exported from the Figma Project Simulation/Demo

Phase 1: Downloading the App

Download the MaaS application on your smartphone's application store available for your smartphone (users need to ensure they have internet access and sufficient mobile storage; their primary bank card will be used for payment deduction for all services requested). If you are already registered but forgot your log-in password, you can click on *forgot password* to recover your account password.

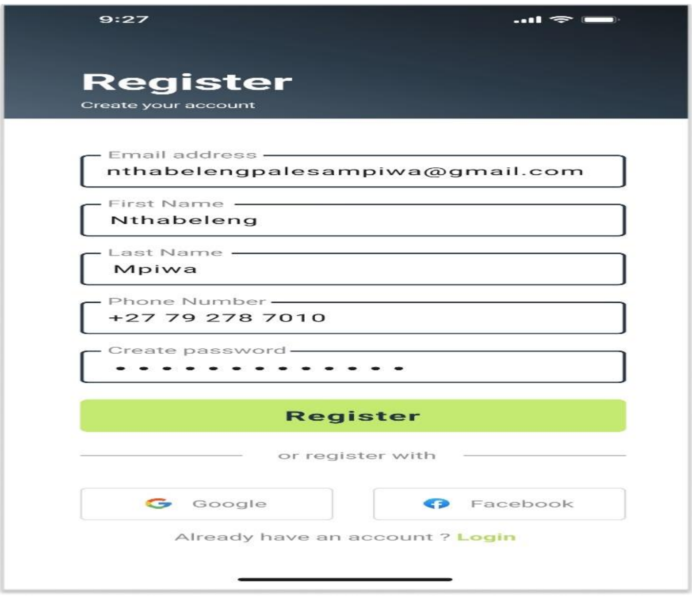

Figure 4.1: User downloading app screen.

Phase 2: Registering as a User

If you are a new user, you will follow through the step of registering your personal identification information with a valid South African cell phone number in order to get an authenticity verification code SMS for confirmation of the registration and a valid email address in order to always receive e-tickets every time you make bookings via the application.

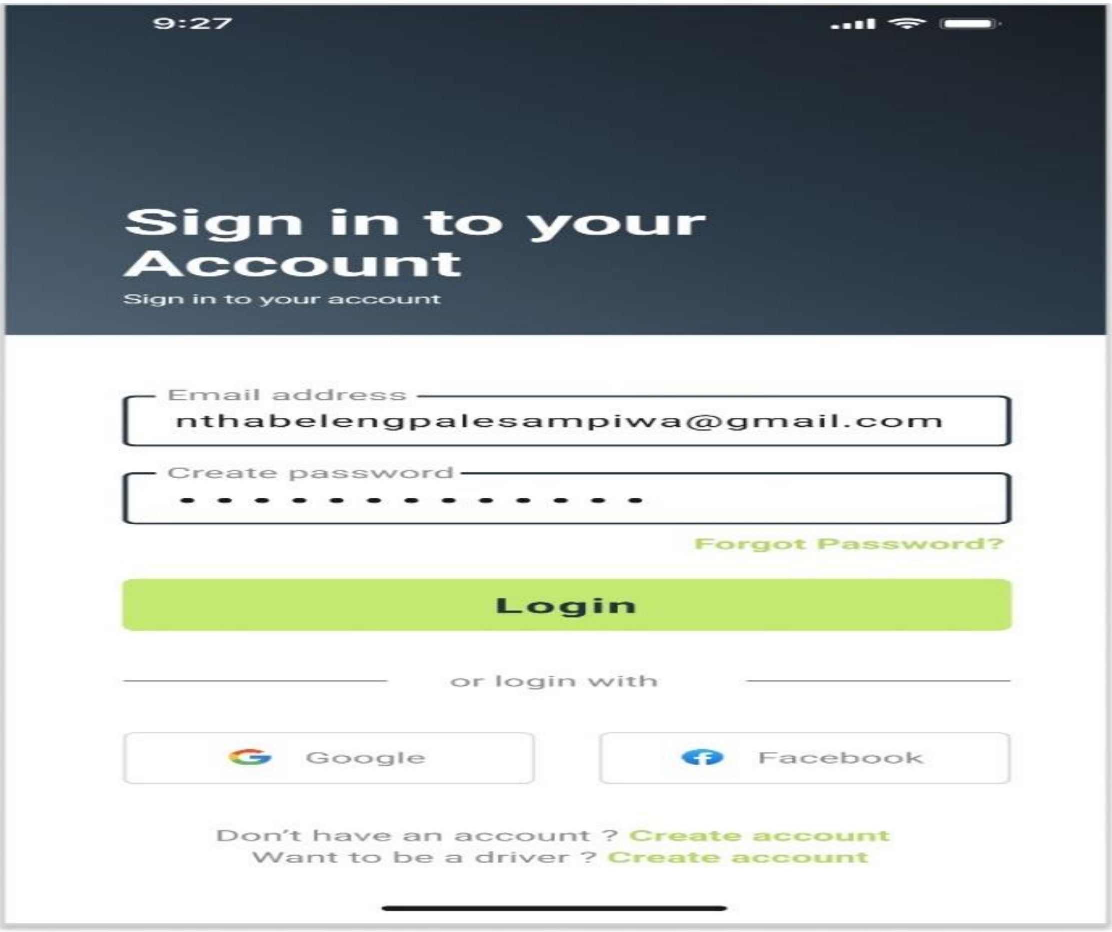

Figure 4.2: Registering as a user screen.

Phase 3: App Ready for Booking

Congratulations! As a registered user now, you can start planning for multiple trips with multiple service providers, with different modes of transport according to your desire and affordability, by simply checking the availability of those modes for your anticipated travel time and at a competitive rate and discounts per service provider.

As a user, it is very important to ensure that, if you are booking multiple trips at a go, between one mode of transport and another, give yourself at least 45-minute intervals between modes.

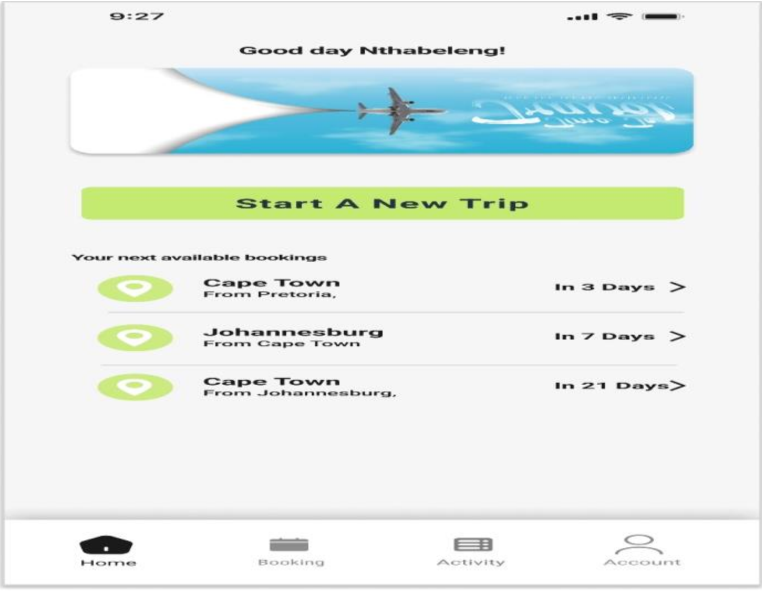

Figure 4.3: User App ready booking screen

Phase 4: Planning, Booking and Paying

Once all the modes of transport to be used for the entire trip have been added to the chart, based on the anticipated desirable time of use of each mode of transport, using real-time and choosing a location pin for each trip, an automatic payment will go through on the primary card that was registered on the app at phase 1. If not, the user has the option to add a new card, but prior to the money deduction from your card, an authenticity verification code SMS from your bank will be sent for your confirmation; then trips will be paid, and e-tickets will be emailed to your email address.

Figure 4.4: User Planning, Booking and Paying Screen

Phase 5: On Transit

The application works in real-time to ensure an approximate forecasted travel time. Between each trip, as a user, it is your responsibility to ensure that you have a free period of 30-45 min available for unforeseen circumstances during the travel, also for moving from one mode to another, e.g., from the Uber to the Gautrain, from the Gautrain to an OR Tambo International Airport flight, from an OR Tambo International Airport flight to Cape Town International Airport shuttle services to the Marriot Hotel Cape Town.

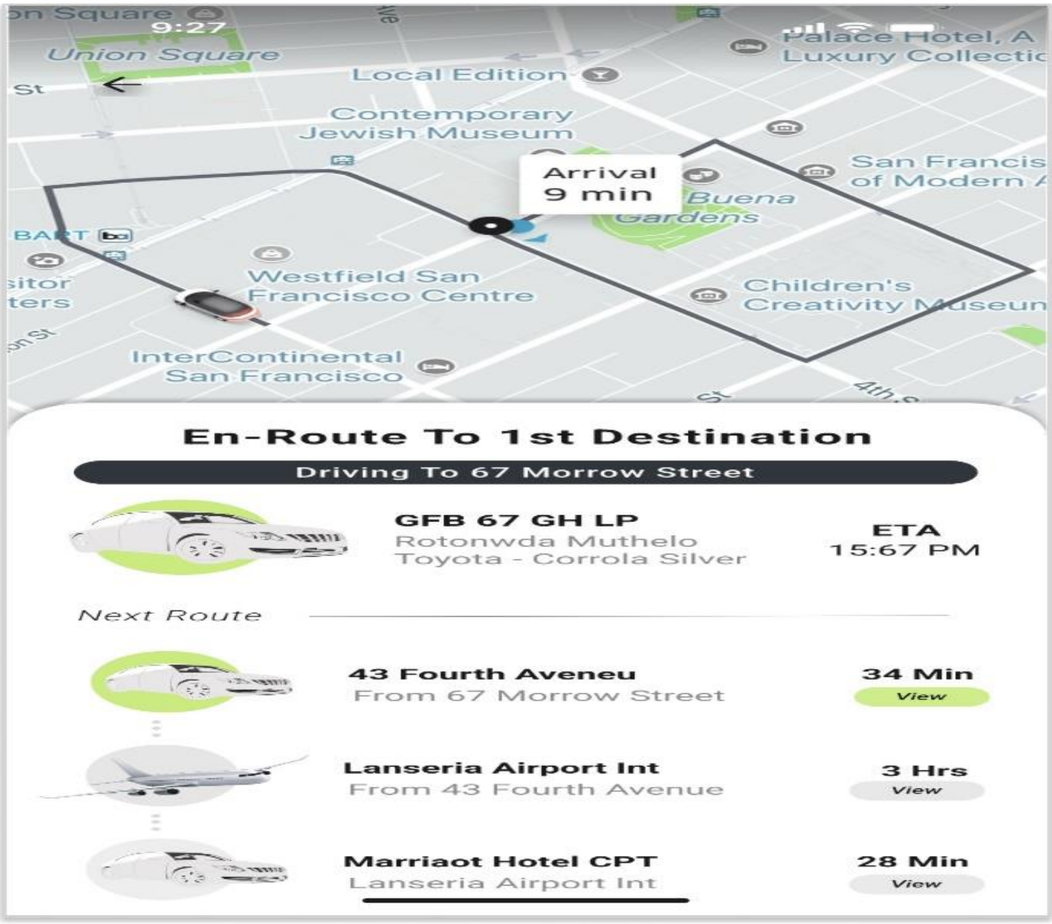

Figure 4.5: User on transit screen

Driver Phases Exported from the Figma Project Simulation/Demo

Phase 1: Downloading the App

Downloading the MaaS application on the smartphone's application store that is available for your smartphone (the driver needs to ensure he or she has all the necessary certified documentation to be uploaded while registering, such as ID/passport, driver's licence, police clearance, ID photos, proof physical address, automobile papers and automobile valid insurance papers).

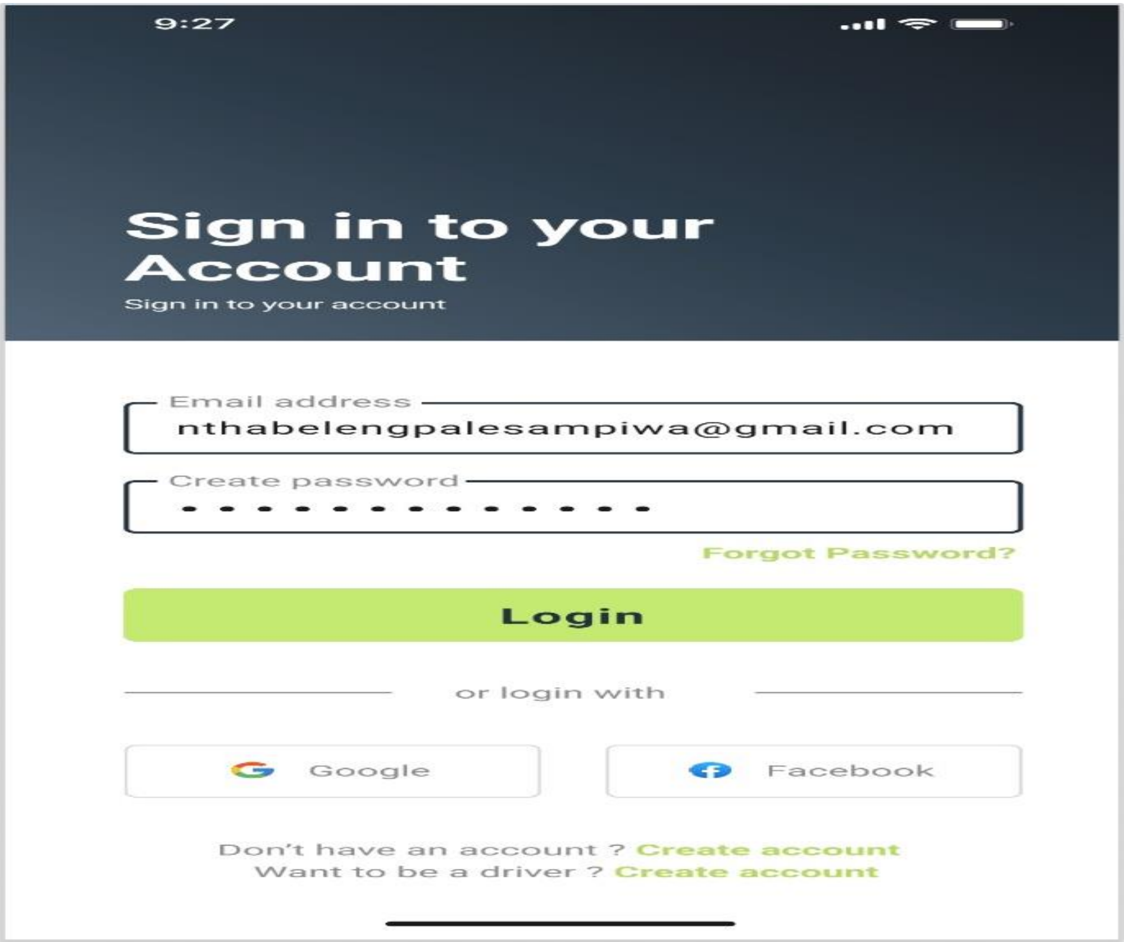

Figure 4.6: Driver Downloading App Screen

Phase 2: Registering as a Driver

If you are a new driver, you will follow through the step of registering and uploading all valid and most recent proof of documentation of the following items:

1. Personal information
    a. ID/passport
    b. Driver's licence
    c. Police clearance
    d. ID photos
2. Primary physical address
3. Automobile
    a. Pictures
    b. VN number

c. Proof of ownership
d. Insurance letter

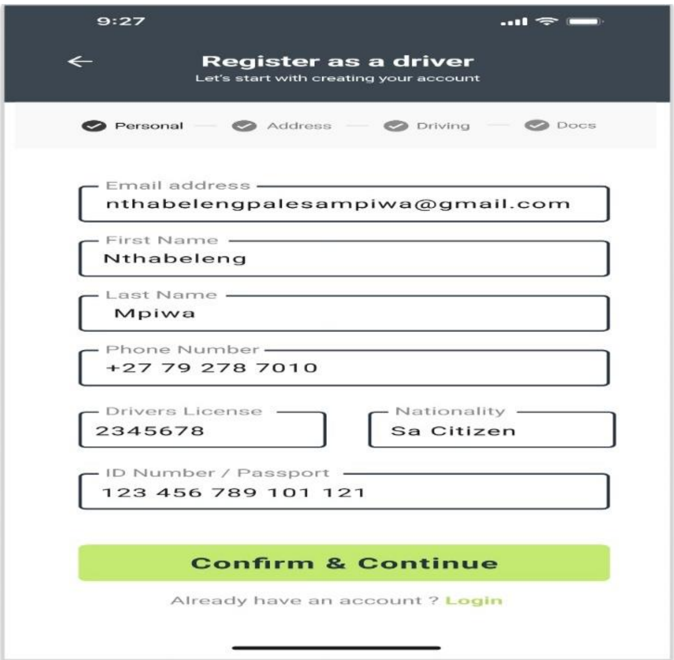

Figure 4.7: Registering as a Driver Screen

Phase 3: Completing the Registration:

After uploading all the required documents, the registration process will be complete. For authenticity, security and background checks on the driver will be conducted while the driver waits three to seven working days before approval or rejection, based on the uploaded documents.

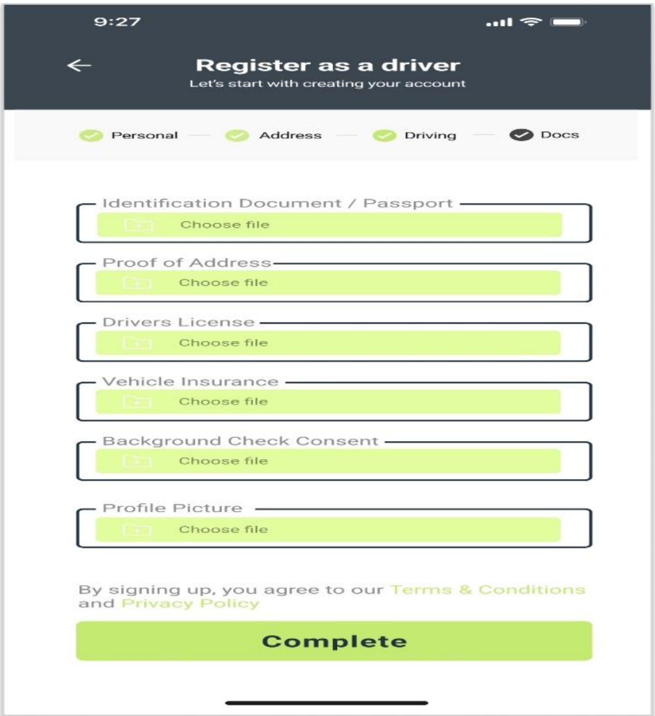

Figure 4.8: Driver Registration Completion Screen

4.3. Data Interpretation

Various South African transportation applications, their features, and the worldwide perspective gained from reading other writers' future predictions on MaaS were all seen, reviewed, and taken into consideration throughout this research.

The MaaS framework simulation in this study will be outlined/put together as ecommerce, as an approach towards supplying services to users from multiple providers of services with different modes of transport in one digital application, based on the knowledge comprehended on the concepts of MaaS, and looking at how the majority of leading, innovative ecommerce retailers in South Africa operate, for instance, Takealot to be precise, but which is presently based on transportation resources but not retail.

A comparison network flow between the currently used transport applications in South Africa and possible mobility being provided as a service on one platform was created following extensive research on the potential mobility transport system.

Chapter 4 Diagram 1: A practical illustration of a current transportation application in South Africa:

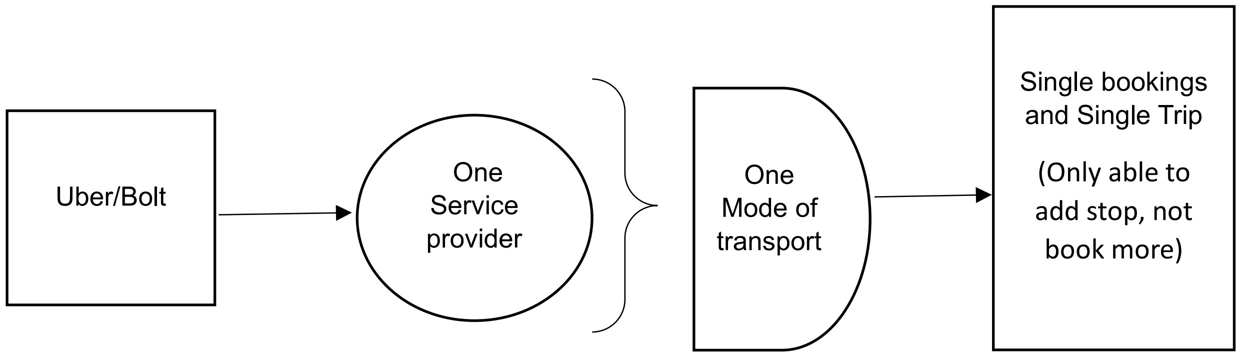

Diagram 4.1: Current South Africa Transportation Apps Illustration

A Practical Illustration of the MaaS Transportation Application Concept

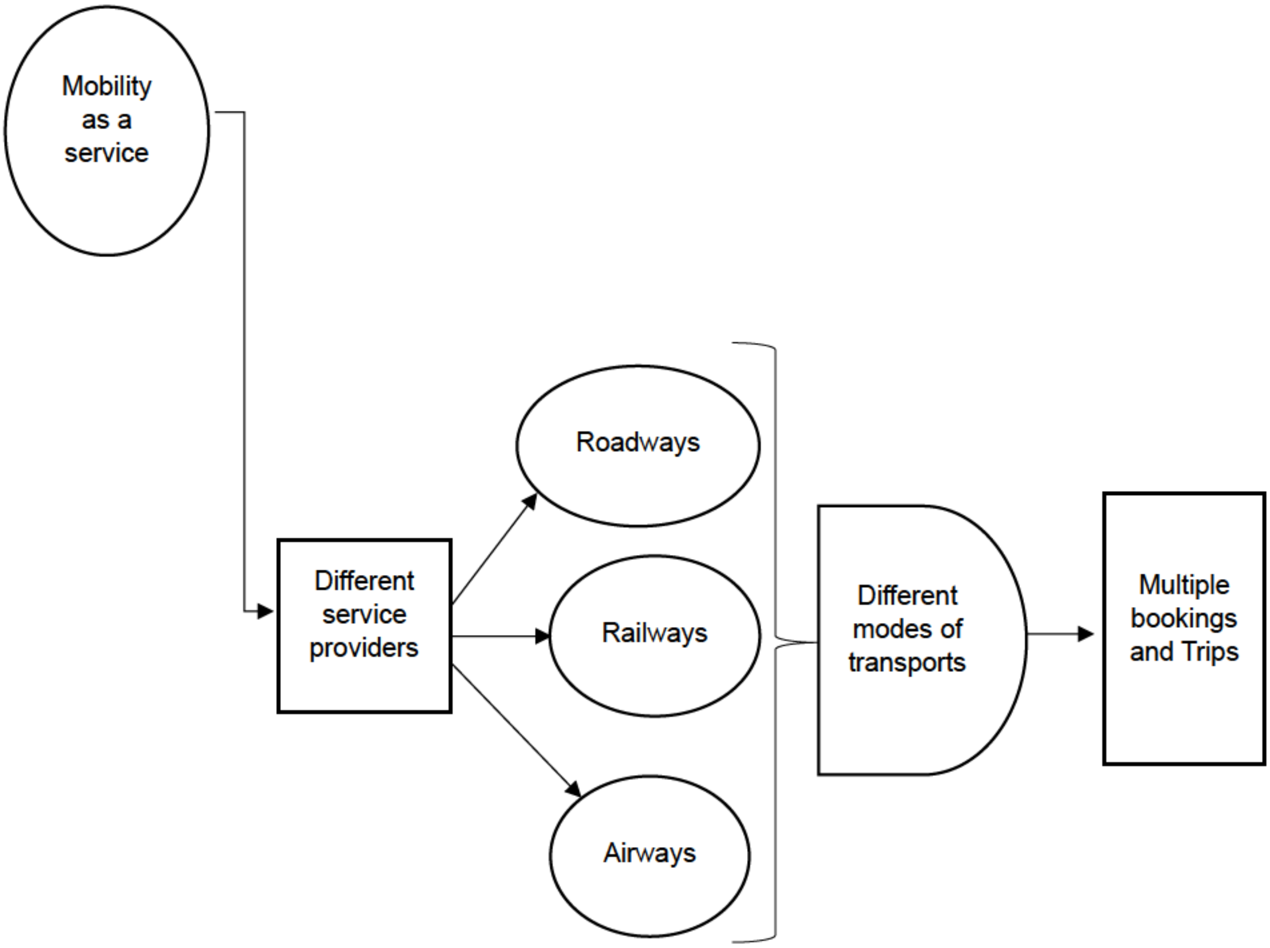

Diagram 4.2: MaaS Concept illustration

4.3.1. Selection of the Simulation Tool

Figma Software was selected as the simulation tool for the study since it was considered pertinent to this investigation's goal of developing the MaaS architecture.

4.3.1.1. What is Figma Software

To design, collaborate on, and iterate designs for websites, mobile apps, user interfaces (UI), and user experiences (UX), designers, developers, and teams use the well-liked cloud-based design and prototyping tool Figma. It was created by Figma Inc and made available in 2016.

4.3.1.2. Why Figma Software

As it speeds the design process and improves team communication in a web-based environment, Figma is a favourite among design teams and individuals, due to its simplicity of use, real-time collaboration, and responsive design capabilities.

Figma’s salient attributes include:

1. Cloud-based: Figma is fully cloud-based, so there is no download or set-up software. Users can access their design projects through a web browser, enabling seamless collaboration and real-time modifications.

2. Real-Time Collaboration: The real-time collaboration function of Figma is by far its most important advantage. In order to facilitate team collaboration, feedback exchange, and design iteration, many users can concurrently work on the same design file.

3. Figma is cross-platform compatible, meaning that designers using various devices can access it. It works with both Mac and Windows operating systems.

4. Figma excels at producing designs that adjust to various screen sizes and devices in terms of responsive design. Designers may produce responsive designs for desktop, tablet, and mobile displays within a single file.

5. Figma makes interaction and prototyping possible thanks to its integrated prototyping capabilities, which let designers make interactive mock-ups and prototypes. These prototypes facilitate the user-experience-design process by enabling the presentation of user flows and interactions.

6. Design Systems and Components: Figma enables designers to produce reusable design components arranged into design systems. This method encourages efficiency and uniformity in design workflows.

7. Version History: Figma records design versions automatically so designers can readily retrieve information or return to earlier iterations.

8. Plugins and Integrations: To increase its functionality, Figma has a growing ecosystem of plugins and integrations. These plugins can interface with other

design and development tools, automate processes, and improve design functionality.

9. Figma is popular among design teams and individuals because of its simplicity, real-time collaboration, and responsive design capabilities. It speeds up the design process and improves team communication in a web-based environment.

4.3.2. Development of the Simulation Model of the MaaS Framework

4.3.2.1. Modelling of the mobility services

Without writing any code, you can simulate an experience for a user by turning sketches into a network of connected screens using Figma's prototyping tools. The Figma Software simulation and PDFs displaying visual life scenarios were used to simulate the prototype in the order described below. These simulation results are included in this study's findings.

MaaS Figma Simulation Network Diagram for Users

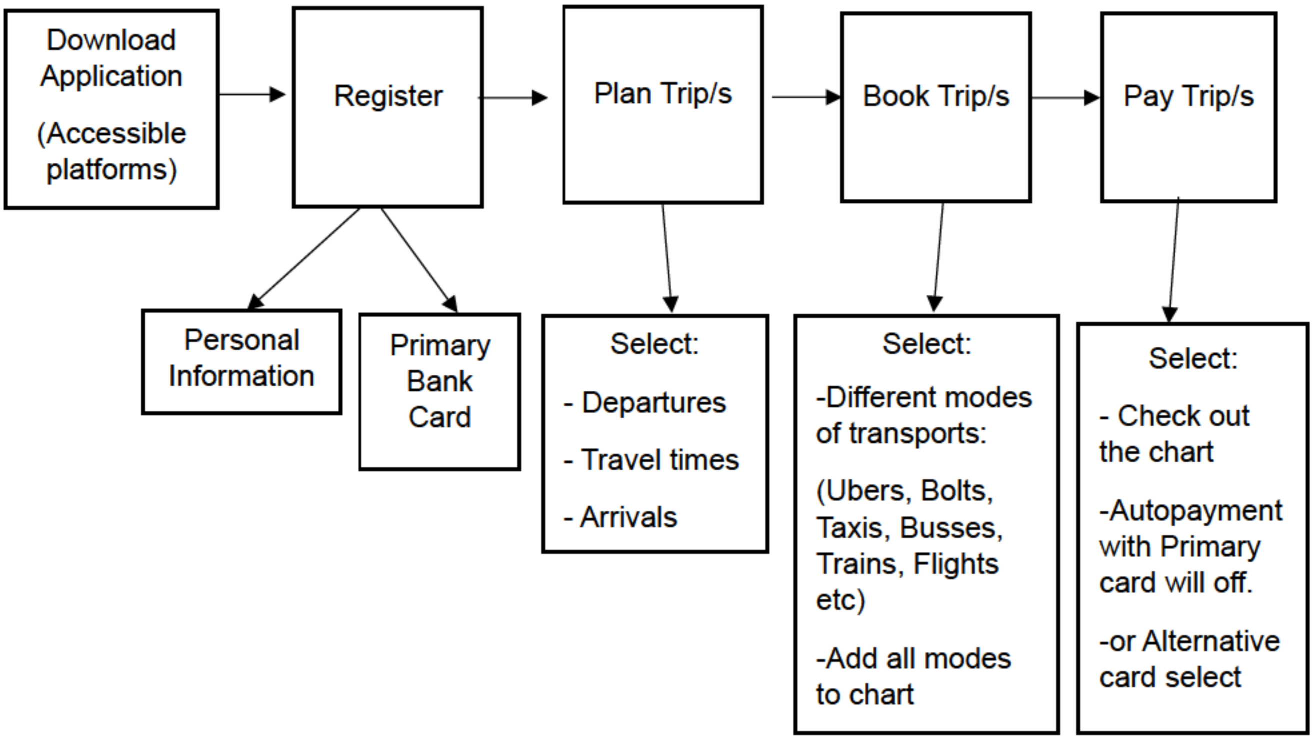

Diagram 4.3: Figma MaaS Network For users

MaaS Figma Simulation Network Diagram for Drivers

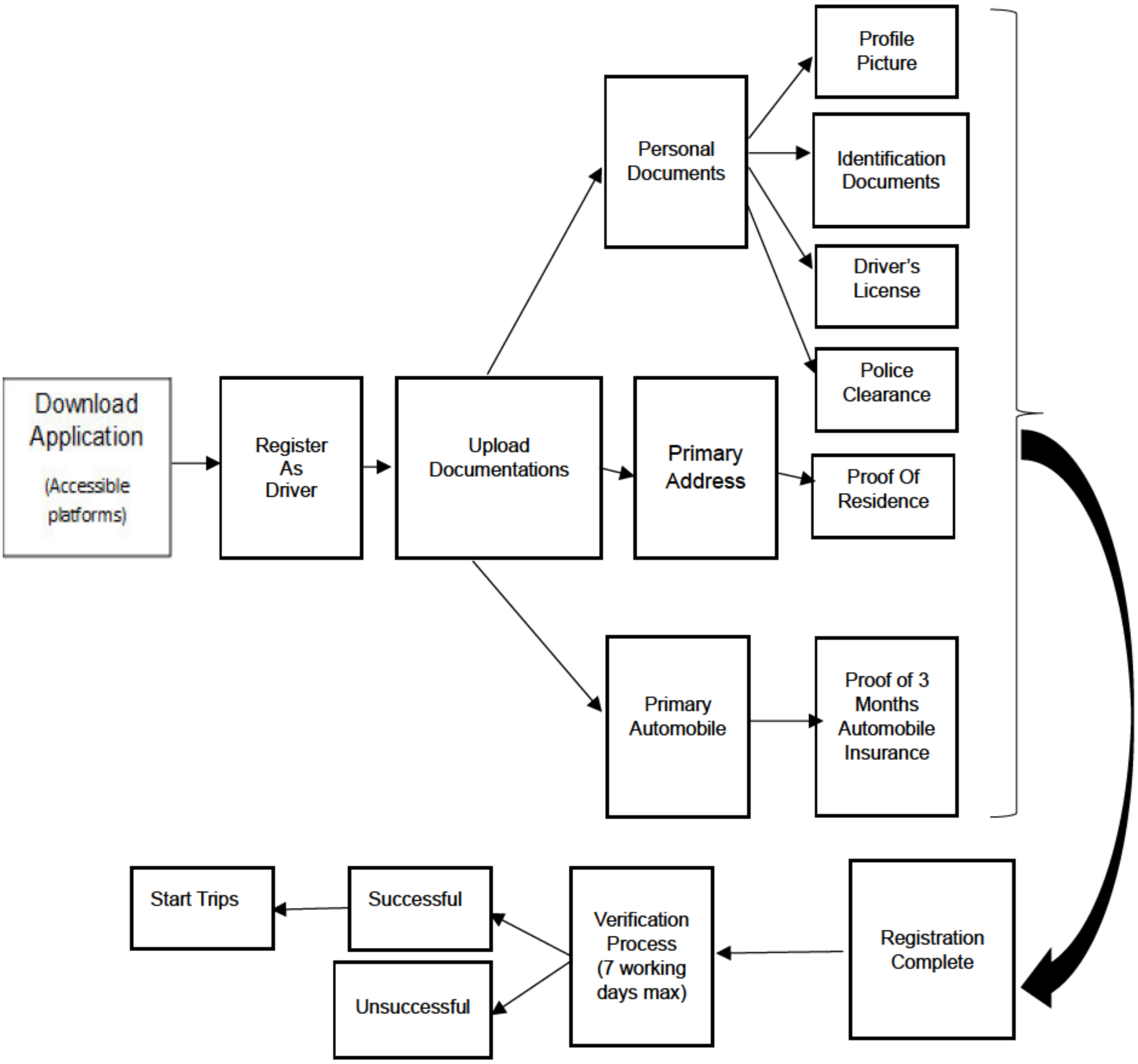

Diagram 4.4: Figma MaaS Network for Drivers

This study's simulation prototype and PDF illustrations include the following user and driver network diagram.

Incorporating flights and train services into the app as APIs (application programming interface) instead of having them register individually. This integration method can streamline the process, enhance the user experience, and provide a seamless, all-in-one solution for users. The app becomes a centralised platform for transportation services by integrating flights and train services via APIs. Users can access and book various transportation options within a single application, making it convenient and efficient.

- **Collaboration as Service Providers**

Partnering with aviation and rail-service providers to gain access to their APIs can result in advantageous relationships for both parties. Users can negotiate deals advantageous to both sides, like revenue-sharing plans or marketing alliances.

- **Real-Time Data**

The software can obtain real-time data from train and flight service providers thanks to APIs. Users can make informed decisions due to access to the most recent information on schedules, availability, pricing, and any last-minute adjustments.

4.3.2.2. Modelling of the multimodal transportation services

Urban mobility is being revolutionised by technological advancements that provide smarter, more effective, and environmentally friendly transportation options. Modern technology is being used in numerous cities across the globe to address age-old issues like traffic, ineffective public transportation, and high emissions (Djahel *et al.*, 2014). Many future forms will be considered soon to create a MaaS paradigm for transportation.

The following overview of various transportation technologies has been discussed in detail throughout this study:

- Smart Traffic Systems
    - Enhancing the smart traffic system will help with safe transportation, while intelligent transport systems will help reduce traffic congestion.
- Artificial Intelligence (AI) in Transportation
    - In order to forecast the demand for transportation in various areas of a city, AI can be used to evaluate data on population trends, job patterns, and other aspects.

- Autonomous Vehicles (AVs)
    - In order to navigate a vehicle from its starting point to its destination while avoiding obstacles on the road and adapting to traffic conditions, AVs use technology to replace the human driver partially or completely.

The user of this app can reserve several journeys through a variety of service providers, with rates that are comparable and acceptable for selection by the user, based on cost and comfort.

4.3.2.3. Modelling of the sharing system (car sharing, bicycle sharing, fleet and ride-sharing, car rental, etc)

Djahel *et al.* (2014) claim that incorporating drones into traffic management systems for smart cities can improve traffic monitoring emergency response and possibly even construct air-based public-transit systems in the future. Platforms for shared mobility are a new development in the restructuring of urban transportation. These systems, which range from bike-sharing to ridesharing, respond to the growing demand for adaptive and environmentally responsible mobility solutions.

4.4. Conclusion

This chapter included broad conclusions regarding the literature that applied suggestions for the MaaS framework simulation prototype in South African metropolitan cities.

5. CHAPTER 5 – Findings, Conclusions and Recommendations

5.1. Findings

Metro towns can receive assistance addressing issues brought on by inadequate transportation infrastructure by employing the MaaS model, which was used to infer the conclusions in Chapter 4 of this section. Urban travel could be revolutionised by the idea of MaaS, which combines several modes of transportation onto a single digital platform. The adoption of MaaS, however, has to confront several challenges, such as infrastructural constraints and worries about public acceptance.

It was determined during the prototype simulation that MaaS is digitally based and is a novel way for the transportation industry; thus, it may take some time for commuters and public-transit operators to embrace it initially.

Since the idea is still in its early stages, for launching the app, they would need to also integrate significant international modes like flights and train services as APIs (application programming interfaces) rather than requiring them to register separately. This integration technique can improve the user experience, speed up the procedure, and give users a smooth, all-in-one solution. The app transforms into a centralised platform for transportation services by combining flight and train services via APIs. It is practical and effective because users can access and reserve various transportation options through a single application. Partnering with aviation and rail-service providers to gain access to their APIs can result in advantageous relationships for both parties and negotiating deals advantageous to both sides, like revenue-sharing plans or marketing alliances.

5.2. Conclusions

This chapter discusses all conclusions drawn from the objectives developed to show whether the research study was successful. Future researchers will have a platform to examine conclusive findings critically.

Urban mobility is no exception to the inexorable march of technological advancements that profoundly impact numerous industries. The impact of technology on urban transportation has been substantial, transforming everything from how we plan our trips to the kinds of transportation we choose. In this study, we have outlined several compelling arguments for why South African metropolitan areas should join the MaaS trend. These include not only the fact that it is a convenient way to travel but also important considerations like our welfare, the problem of traffic congestion, the difficulty of predicting travel times, and the problems with greenhouse emissions that it gets rid of in our metros, which relieves the climate-action backlog we have been experiencing as one of the developing nations. As a result of the extensive literature review, this study created detailed network diagrams on the user and driver experience of MaaS, which were then turned into a prototype using Figma Software as one of the study's outcomes.

5.2.1. The Goals Review and Validation

The objective below is completed, and the aims are referred to as the research's final conduct outcome, as follows:

1. To analyse the historical background of urban mobility in South Africa and technology's role in transforming it.

    - The literature review in Chapter 2 offers in-depth knowledge of the historical backdrop of urban mobility in South Africa and how technology has shaped and transformed urban mobility.

2. Consider the main variables affecting South Africa's poor transportation networks that affect the country's economy, environment, and society.

    - The study has gone into depth, expressing how traffic congestion costs the economy billions of rands in wasted fuel, lost productivity, and delayed delivery every year. Due to the inefficiency of service-delivery processes, cities like Johannesburg feel these economic repercussions directly. Furthermore, the effects on the ecosystem are obvious. Slower speeds and more idle time lead to higher emissions and a bigger carbon footprint, which worsens the environment. Congestion lowers the quality of life in society. Longer commutes rob people of their free time, tax their mental health, and may even discourage tourists, adversely affecting the local economy.

3. To examine the benefits, drawbacks, and many authors' perspectives on MaaS, with studies as an object of guidance, to better comprehend the potential that MaaS holds for the future.

    - The effectiveness of MaaS is one of its most alluring features. Heikkilä (2014) asserts that incorporating numerous modes of transportation, such as buses, taxis, bicycles, and e-scooters, into a unified platform enables users to effectively plan, reserve, and conduct financial transactions for their travels. This condensed strategy improves customer satisfaction and best uses already available transportation resources, minimising inefficiencies caused by underutilised capacity. MaaS installations may substantially impact metropolitan regions that struggle with traffic congestion and the resulting financial difficulties.

4. Create an interactive prototype to show how mobility is provided as a service in South African metros by integrating various service providers with various types of transportation.

    - Utilising Figma Software, which designers, developers, and teams use to create, collaborate on, and iterate designs for websites, mobile apps, UI, and user experiences (UX), a simulation MaaS transportation application with various service providers with various modes of transport was created for demonstration within the South African metropolises showing how to alleviate the problems those cities experience because of poor transportation systems.

5.3. Recommendations

5.3.1. It is Possible to Draw the Following Conclusions from a Successful Study

MaaS is still largely an idea that is being tested all around the world. A trial run of the MaaS simulation prototype must be conducted with a small sample of transport consumers and a small community of service providers using various modes of transportation. The developer will then be able to see how the programme works and the extent of its limits in order to improve it for upcoming releases. MaaS should be integrated into future smart transportation systems to ensure positive global transportation prospects.

5.3.2. The Procedures Listed Below are Advised before Running the Proposed Simulation

- Since the simulation demonstration is still a mock-up of the application, it must be approved.
- A breakdown of what is listed in the simulation must be done as part of the mock-up (simulation) analysis, which guarantees that the necessary features or fields are there.
- The project's design stage will begin as the simulation is a component of the application's development.
- During the implementation stage, the developer begins coding the entire application.
- The application's testing and integration follow.
- Following the application's launch, it will be available for future maintenance, where users can use it and report any complaints about it.
- The application will essentially be launched online, and improvements will be made based on feedback from the small sample of users chosen to test the program's functionality.
- Everything will revolve around maintenance and improvement, and the programme will carry out the necessary functionality.

Future work might involve considering MaaS in conjunction with the tourism sectors rather than just providing day-to-day transportation services from one location to another.

5.3.3. Potential Strategies for the Technology's Future Distribution Across the Continent

The deployment of advanced technology over a continent is a difficult project that necessitates thorough planning, multiparty collaboration, and consideration of local regulations and legislation. The following actions can be performed in future to make it easier for mobility being offered as a service technology to be implemented across the continent:

- The initial step is to comprehend the unique potential and challenges in each of the continent’s areas, starting with a thorough needs assessment.
- Provide a precise structure for regulations that tackles concerns about security, privacy of data, and morality. A legal and regulatory framework that supports the use of mobility as a service technology should be established (regulatory structure).
- Make investments in data centres and high-speed internet access, among other crucial technological infrastructure developments. Make certain that it is accessible even in rural places (infrastructure development).
- To provide the workforce with the skills necessary to operate cutting-edge technology, set up educational programmes and training efforts. For professionals, this involves training in data science, machine learning, and AI (education and training).
- Encourage research and development in the fields of artificial intelligence and related fields. Encourage the development of creative solutions by research institutions, both public and commercial.
- To promote technological innovation and adoption, public-private partnerships should be established between governmental bodies, the commercial sector, and academic institutions. Large-scale project implementation and financing can be facilitated via public-private partnerships.
- Establish local technology clusters or innovation hubs where entrepreneurs and startups can collaborate on AI and ML projects. These centres can act as launch pads for fresh concepts and ventures.
- Provide grants, financial resources, and investment options for start-ups and established technological businesses. Promote angel and venture capital investments to aid in the expansion of the tech industry (finance and investment).

- Make sure that, in accordance with privacy and security laws, data is available for research and development. Data sharing agreements and open data efforts are two ways to accomplish this (data accessibility).
- To gain access to resources, knowledge, and best practices, cooperate with global organisations, governments, and technology firms. Funding and assistance may also be obtained through international alliances.
- Educate the public about digital literacy and capacity-building programmes. Make sure everyone understands the advantages of technology and how to use it efficiently (capacity building).
- Solutions that are scalable and adaptable to many communities and locations should be considered while adopting technology. To meet regional needs, customisation must be feasible.
- Establishing systems to track and assess the results of technological initiatives is necessary for monitoring and evaluation. Conducting routine evaluations can aid in improving tactics and guaranteeing efficient utilisation of resources.
- Make plans for how technological efforts will be sustained over the long run. This entails making certain that revenue models exist and that technology can be updated and maintained as required (sustainability).
- Building trust and raising public awareness of technological initiatives requires active engagement with the public and local communities. Respond to worries and promote involvement.

Since every continent presents unique opportunities and challenges, the approaches and tactics will also vary. It is also essential to adapt the rollout over time to evolving legal and technological frameworks to ensure that it remains effective and applicable. To successfully implement technology across the continent, collaboration, adaptability, and a focus on satisfying local needs are necessary.

5.3.4. Proposals for Commercial Approaches to Mobility as a Service

Commercialisation is possible for a number of elements and components within the framework of mobility as a Service (MaaS). Aiming to offer users complete and seamless transportation services, MaaS frequently takes the shape of an app or digital platform. Aspects of MaaS that can be commercialised comprise:

- It is possible to sell the MaaS platform alone. This platform acts as a digital centre that links consumers to a range of transportation choices, including ride-sharing, bike-sharing, car-sharing, and public transportation. Subscription fees, transaction fees, and platform advertising are all possible sources of income.

- Users may be offered subscription-based models by MaaS providers. For access to a variety of transportation services, customers must pay a monthly or yearly charge. This promotes user loyalty and generates consistent revenue.

- MaaS providers can collaborate with other transportation service providers to offer their services via the MaaS platform, including ride-sharing businesses, bike-sharing services, and public-transit systems. To monetise these services, revenue-sharing plans or transaction fees may be employed.

- Massive amounts of data about consumer preferences, travel habits, and transportation usage can be gathered via MaaS platforms. For a variety of uses, including targeted marketing and city planning, this data may be anonymised and sold to outside parties like advertisers, urban planners, or transit providers.

- MaaS platforms can make money by partnering with advertisers and running promotions. Companies can pay for placement or promotion on the site, and they can show adverts to users depending on their travel habits and preferences.

- MaaS providers can create loyalty programmes that give discounts, special offers, or other rewards to regular customers. These programmes can be made profitable by partnering with other companies.

- To optimise infrastructure and services, MaaS platforms can deliver data analytics and insights to urban planners and transportation suppliers.

Subscription models or one-time payments are two ways to monetise these services.

- Certain MaaS applications might charge for extra features or premium services. For instance, consumers may have to pay for services like access to luxury car alternatives, priority seating on public transportation, or real-time traffic information.

- MaaS companies can collaborate with local governments to include their platforms in more comprehensive smart city programmes, including parking structures, traffic control, and urban planning. Contracts and service fees are two ways that these alliances might be made profitable.

- MaaS providers can help cities and businesses wishing to adopt MaaS solutions that are customised to meet their unique needs by providing advice and customisation services.

Depending on the MaaS provider, the regional market, and the regulatory landscape, several commercialisation tactics may be used. A thorough grasp of user needs, effective technology, and strong collaboration with local governments and transportation service providers are frequently necessary for the successful commercialisation of MaaS.

5.3.5. Research Design Disclosure with the Tshwane University of Technology Transfer Office

Please be advised that the content contained within this study has been subject to a formal disclosure request through the Tshwane University of Technology's Technology Transfer Office. This measure has been undertaken to safeguard against potential copyright infringement and unethical practices.

6. REFERENCES

AFRIN, T. & YODO, N. 2020. A survey of road traffic congestion measures towards a sustainable and resilient transportation system. *Journal of Sustainability* (Switzerland), 12(11).

AL-ABABNEH, M.M. 2020. *Linking ontology, epistemology and research methodology*. *Science & Philosophy*, *8*(1), June: 75-91.

ANDERSON, C. 2010. Presenting and Evaluating Qualitative Research. *American Journal of Pharmaceutical Education*, 74(8) Article 141.

ARONS, A., DEAKIN, S., FRICK, E. & TRAPENBERG, K. 2009. Access Magazine Spring 2009. *Journal of Access Magazine*, 1(34).

CHEN, C.F., FU, C. & CHEN, Y.C. 2023. Exploring tourist preference for Mobility-as-a-Service (MaaS) – A latent class choice approach. *Transportation Research Part A: Policy and Practice,* 1742023/08/01/:103750.

CRESWELL,J.W., HANSON,W.E., CLARK,V.L.P. & MORALES,A. 2007. *Qualitative Research Designs: Selection and Implementation.* The counseling psychologist 2007, 35(236). Available from: http://tcp.sagepub.com/cgi/content/abstract/35/2/236

DASGUPTA, S., LALL, S. & WHEELER, D. 2021. Spatiotemporal analysis of traffic congestion, air pollution, and exposure vulnerability in Tanzania. *Science of The Total Environment,* 7782021/07/15/:147114.

DESOTO, E. 2022. *Evaluating the Impacts of Mobility-as-a-Service in Prototypical North American Cities via Agent-based Simulation* (Doctoral dissertation, Massachusetts Institute of Technology).

DJAHEL, S., DOOLAN, R., MUNTEAN, G. & MURPHY, J. 2014. *A communication-oriented perspective on traffic management systems for smart cities: Challenges and innovative approaches*. Manuscript submitted to IEEE Communications surveys & tutorials, 1(18).

DZISI, E., OBENG, D.A., TUFFOUR, Y.A. & ACKAAH, W. 2023. Digitalization of the paratransit (trotro) using mobility as a service: What are the adoption intentions of operators and operator unions in Ghana? *Research in Transportation Business & Management,* 472023/03/01/:100968.

ENOCH, M. & POTTER, S. 2023. MaaS (Mobility as a Service) market futures explored. *Transport Policy,* 1342023/04/01/:31-40.

FATTAH, M.A., MORSHED, S.R. & KAFY, A.A. 2022. Insights into the socioeconomic impacts of traffic congestion in Chittagong city, Bangladesh's port and industrial areas. *Transportation Engineering,* 92022/09/01/:100122.

FLICK, U. 2015. *Introducing research methodology: A beginner's guide to doing a research project*. Sage.

GARCIA,J.R.R., LENZ,G., HAVEMAN,S.P. & BONNEMA,G.M. 2019. *State of the Art of Mobility as a Service (MaaS) Ecosystems and Architectures- An Overview of, and a Definition, Ecosystem and System Architecture for electric Mobility as a Service (MaaS)*. World Electric Vehicle Journal. University of Twente: Netherlands.

GIESECKE, R., SURAKKA, T. & HAKONEN, M. 2016. Conceptualising Mobility as a Service. In: *2016 Eleventh International Conference on Ecological Vehicles and Renewable Energies (EVER)* [Online]. Available from: https://www.researchgate.net/publication/303513413

HASSELWANDER, M., NIELAND, S., DEMATERA-CONTRERAS, K. & GOLETZ, M. 2023. MaaS for the masses: Potential transit accessibility gains and required policies under Mobility-as-a-Service. *Multimodal Transportation,* 2(3), 2023/09/01/:100086.

HEIKKILÄ, S. 2014. *Mobility as a service- A proposal for action for the public administration, case Helsinki*. M.Sc. Thesis, Aalto University school of engineering.

HENAMA,U.S. & SIFOLO, P.P.S. 2017. *Uber: The South Africa Experience*. African Journal of Hospitality, Tourism and Leisure, 6(2), 2017, Pretoria, South Africa [online]. Available from: http//:www.ajhtl.com

HENSHER, D.A., MULLEY, C. & NELSON, J.D. 2023. What is an ideal (Utopian) mobility as a service (MaaS) framework? A communication note. *Transportation Research Part A: Policy and Practice,* 1722023/06/01/:103675.

HERKO, S. 2019. *A blockchain infrastructure for transportation in low-income country cities and beyond*. *The Journal of The British Blockchain Association*, 2(2), Sep: 3.

HOYLE,D. 2015. *ISO 9000 Quality Systems Handbook*. 4th ed. Completely revised in response to ISO 9000: 2000. Jordan: Oxford.

HUANG, Z. & LOO, B.P.Y. 2023. Urban traffic congestion in twelve large metropolitan cities: A thematic analysis of local news contents, 2009–2018. *International Journal of Sustainable Transportation,* 17(6), 2023/01/01/:592-614.

HUNTER, D., MCCALLUM, J. & HOWES, D. 2019. Defining exploratory: Descriptive Qualitative (EDQ) research and considering its application to healthcare. *Journal of Nursing and Health Care*, 4(1).

KADYRALIEV, A., SUPAEVA, G., BAKAS, B., DZHOLDOSHEVA, T., DZHOLDOSHEV, N., BALOVA, S., TYURINA, Y. & KRINICHANSKY, K. 2022. Investments in transport infrastructure as a factor of stimulation of economic development. *Transportation Research Procedia,* 632022/01/01/:1359-1369.

KAMARGIANNI, M., LI, W., MATYAS, M. & SCHÄFER, A. 2016. A critical review of new mobility service for urban transport. Transport Research Procedia, 3294-3303.

KAYIKCI, Y. & KABADURMUS, O. 2022. Barriers to adopting the mobility-as-a-service concept: The case of Istanbul, a large emerging metropolis. *Transport Policy,* 1292022/12/01/:219-236.

KHAN, S. 2014. Qualitative Research Method: Grounded Theory. *International Journal of business and management*, 9(11).

KIBANGOU, A.Y., MOYO, T. & MUSAKWA, W. 2021. Dynamic Linear Model for Urban Essential Traffic Congestion and Emissions. *IFAC-PapersOnLine,* 54(21), 2021/01/01/:151-156.

LOUBSER, J. 2020. *Analyzing the potential demand for Mobility as a Service in a developing country*. University of Johannesburg (South Africa).

LUKE, R. & HEYNS, G.J. 2020. An analysis of the quality of public transport in Johannesburg, South Africa, using an adapted SERVQUAL model. *Transportation Research Procedia,* 482020/01/01/:3562-3576.

MAKHUBU, A. & VYAS-DOORGAPERSAD, S. 2022. Policy frameworks and implementation gaps in poverty alleviation strategies in the City of Ekurhuleni, South Africa. *African Journal of Development Studies*, *12*(3), p. 149.

MASEKO, N. 2018. *The use of alternative service delivery mechanisms within the City of Johannesburg Metropolitan Municipality*. M.Sc. dissertation, University of Johannesburg.

MASUKU, B. & NZEWI, O. 2021. *The South African informal sector's socio-economic exclusion from basic service provisions: A critique of Buffalo City Metropolitan Municipality's approach to the informal sector*. *Journal of Energy in Southern Africa*, 32(2), May: 59-71.

MCMILLAN, J.H. & SCHUMACHER, S. *2010. Education research: Evidence-based inquiry*. 7th ed. Cape Town: Pearson.Mishra, S.B. & Alok, S. 2022. *Handbook of research methodology*.

MUSOLINO, G., RINDONE, C., VITALE, A. & VITETTA, A. 2023. Pilot survey of passengers' preferences in Mobility as a Service (MaaS) scenarios: A case study. *Transportation Research Procedia,* 692023/01/01/:328-335.

NEMOTO, E.H., KORBEE, D., JAROUDI, I., VIERE, T., NADERER, G. & FOURNIER, G. 2023. Integrating automated minibuses into mobility systems – Socio-technical transitions analysis and multi-level perspectives. *Technological Forecasting and Social Change,* 1882023/03/01/:122260.

NEWMAN, M. & GOUGH, D. 2020. *Systematic reviews in educational research: Methodology, perspectives and application*. Systematic reviews in educational research: Methodology, perspectives and application, 3-22.

NOWEK, A. 2023. Transportation in South Africa: trains, buses, and taxis. Expatica Live. Work. Love. [Online], August 22. Available from: https: // www.ecpatica.com/29/living/transportation//public-transportation-in South-Africa-105982/#buses.

OKRASZEWSKA, R., ROMANOWSKA, A., WOLEK, M., OSKARBSKI, J., BIRR, K. & JAMROZ, K. 2018. *Integration of a multilevel transport system model into sustainable urban mobility planning*. Journal of Sustainability (Switzerland), 10(2).

OLAGUNJU, K. 2015. *Evaluating Traffic congestion in developing countries: A case study of Nigeria.*

OLAYODE, I.O., TARTIBU, L.K. & OKWU, M.O. 2021. Prediction and modelling of traffic flow of human-driven vehicles at a signalized road intersection using artificial neural network model: A South African road transportation system scenario. *Transportation Engineering,* 62021/12/01/:100095.

PANDEY, P. & PANDEY, M.M. 2021. *Research methodology tools and techniques*. Bridge Center.

PANDIT, D. & SHARMA, D. 2022. Expected service dimensions and service levels for paratransit considering future mobility needs in emerging countries. *Transportation Research Part A: Policy and Practice,* 1622022/08/01/:1-13.

PAUL,A., CHILAMKURTI,N., DANIEL,A. & RHO,S. 2016. *Intelligent Vehicular Networks and Communications: Fundamentals, Architectures and Solutions*. Elsevier. Amsterdam: Netherlands.

PRITCHARD, J. 2022. MaaS to pull us out of a car-centric orbit: Principles for sustainable Mobility-as-a-Service in the context of unsustainable car dependency. *Case Studies on Transport Policy,* 10(3), 2022/09/01/:1483-1493.

REPUBLIC of South Africa. 1997. *The constitution of the Republic of South Africa was adopted by the constitutional assembly on 1 September 1977 and amended on 15 June 1977*. Cape Town: Government printer.

RULASHE, T. & IJEOMA, E.O. 2022. *An exploration of public accountability and service delivery at the Buffalo City Metropolitan Municipality in the Eastern Cape province, South Africa*. Africa's Public Service Delivery and Performance Review, 10(1), Feb: 535.

SCHALEKAMP, H. & KLOPP, J.M. 2018. Beyond BRT: Innovation in minibus-taxi reform in South African cities.Rongen, T., Tillema, T., Arts, J., Alonso-gonzález, M.J.

& Witte, J.J. 2022. An analysis of the mobility hub concept in the Netherlands: Historical lessons for its implementation. *Journal of Transport Geography,* 1042022/10/01/:103419.

SCHRODER-HINRICHS, J., SONG, D., FONSECA, T. & LAGDAMI, K. 2019. *Transport 2040 Automation technology employment- the future of work*. World Maritime University, United Kingdom: London.

SMITH, G., MULLEY, C., NELSON, J. & ISON, S. 2021. *Mobility as a service and public transport.* The Routledge Handbook of Public Transport, pp.33-45.

ZHANG, Y. & KAMARGIANNI, M. 2023. A review of the factors influencing the adoption of new mobility technologies and services: Autonomous vehicle, drone, micromobility and mobility as a service. *Transport Reviews,* 43(3), 2023/05/01/:407-429.

7. APPENDIX

7.1. MaaS use case manual (attached in the main folder)

7.2. MaaS framework simulation prototype sketch exported from Figma Software (attached in the main folder)

7.3. MaaS Framework Figma Software Simulation prototype video (attached in the main folder)