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Acronyms and Abbreviations List

BRT:	Bus Rapid Transit
DFID	Department for International Development
GDRT:	Gauteng Department of Roads and Transport
GHG:	Greenhouse gas
GITMC:	Gauteng Integrated Transport Modelling Centre
GPG:	Gauteng Provincial Government
GTFS:	General Transit Feed Specification
IPCC:	Intergovernmental Panel on Climate Change
ITMP25:	25-year Integrated Transport Master Plan
ITP	Integrated Transport Plans
MaaS:	Mobility-as-a-Service
RDP:	Reconstruction and Development Programme
PRASA:	Passenger Rail Agency of South Africa
SANRAL:	South African National Roads Agency
T-TRIID:	Transport-Technology Research Innovation for International Development

Document Control Sheet

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Executive Summary

According to the Intergovernmental Panel on Climate Change (IPCC)'s Special Report on Global Warming of 1.5^{o} (2018), emissions from transport have grown significantly faster than other contributing sectors over the past 50 years. To address this issue, the Applied Research High-Volume Transport Programme, run by the UK Department for International Development (DFID), launched the Transport-Technology Research Innovation for International Development (T-TRIID) funding programme.

Transport technology, in terms of this document, is the use of electronic data through new technology, in order to enhance travel experiences, for both people and goods, and to utilise vehicles in a more efficient manner. One application of this is Mobility-as-a-Service (MaaS). This report sets out the feasibility project which sought to apply a MaaS product, Moses, a taxi-share technology, in South Africa to improve transport availability and reduce carbon emissions. The project was delivered in partnership with GoMetro, a transport technology planning application company based in South Africa, with the support of Snap Out, a user and market research consultancy. This project is called Project Balega and looks to explore the application of the product, Moses, in South Africa.

South Africa is the world's 14th largest emitter of greenhouse gases, with transport being one of the main contributing factors. The Project took a case study approach, with a focus on Gauteng, in South Africa to explore the feasibility of applying Moses to existing transport systems. Gauteng has had a number of transport developments, including the introduction of Gautrain and Bus Rapid Transit (BRT) systems. Data on minibus taxis is being generated and enabling routes to be mapped out in the Gauteng area. Moses helps rail passengers with their onward journey through the use of shared taxis, potentially in the case of South Africa, to aggregate minibus taxis to enhance end-to-end journey options. At the outset of the Project, a literature review was conducted to 'map-out' travel behaviour, transport systems, women's safety, accessibility and carbon emissions. This identified gaps in knowledge that needed to be explored by primary research.

To explore how Moses could operate in Gauteng, South Africa, a mixed method approach was taken. Quantitative data was collected through GoMetro, through a survey approach, using their app to map out minibus taxi routes, specific to the needs of the Project. This data was analysed to calculate carbon emissions and to identify the potential extent to which Moses could impact on these, taking into account vehicle quality and route optimisation. It was found that if routes were optimised and vehicles were upgraded, carbon emissions would change significantly, from a current fleet omitting approximately 60,000 gCO2e compared to an optimised fleet of new vehicles omitting approximately 40,000 gCO2e, a potential 40% gCO2e saving. However, the practical implementation of this would require significant support from Government both in terms of governance and finance to provide incentives for minibus taxis to adopt new routes and upgrade their vehicles. In addition to this, an online survey was conducted by Snap Out, and it was found that for public transport, the key concerns were safety, convenience, reliability and availability.

A qualitative approach was also taken, the aim of this was to understand existing travel behaviour in more detail. To this end, interviews, observations and stakeholder meetings took place, more information about these are in the appendices. There were interviews with low-income and middle-to-high-income communities to explore the way in which they use and choose to use local transport requirements. Value proposition prototypes were discussed to understand what operational model would be of interest and could benefit the Gauteng population. It was found that there was a divide in transport use, particularly for two particular types of transport users: 1) those that owned cars and those that did not; and 2) those that had bank accounts and a bank card and those that did not, which impacts on how people use and pay for transport. Observations identified the utilisation of BRT buses and Gautrain in an area with multiple transport options, to see how people were trip-chaining between Gautrain and taxis or minibus taxis. It was observed the many transport modes were under-utilised and digital tools were limited in providing information to plan transport routes. The interaction between rail passengers and the ways in which onward transport modes were selected was also observed. For minibus taxis in particular, it was found that transport decisions were made based in-person, with minibus drivers using hand-signals and person-to-person discussions to define their routes.

Overall, there were opportunities found for transport technology companies, particularly those in the MaaS sector, which specialises in providing end-to-end, or first-and-last mile journey options. For example, people are already accustomed to sharing vehicles, aside from buses and trains and there is an emerging market for transport using technology such as e-hailing. More data is becoming available that could be used by transport technology companies to provide optimised and personalised transport services. Turning smartphone data on to seek travel information and book e-hailing services is already happening in South Africa, meaning that citizens with smartphones could access MaaS services online.

There are many opportunities to improve the effectiveness and adoption of shared mobility in South Africa and the wider Africa continent. We recommend that the insights and opportunities uncovered in this research project are used as the basis of a larger demonstrator project to prove the benefits in a real-world deployment. There is an opportunity to deliver impact in collaboration with interested local and national transport operators.

1. Introduction

The Intergovernmental Panel on Climate Change's (IPCC) Special Report on Global Warming of 1.5°C (2018) found that emissions from the transport sector have grown at a rate faster than any other sectors over the past half century[1].

To tackle the issue of rising greenhouse gas emissions in developing countries, under the Applied Research High-Volume Transport Programme, the UK Department for International Development (DFID) launched the Transport-Technology Research Innovation for International Development (T-TRIID).

Transport technology, in terms of this document, is the use of electronic data through new technology to enhance travel experiences, for both people and goods, and to utilise vehicles in a more efficient manner. One area of transport technology which is growing is Mobility-as-a-Service (MaaS). MaaS puts users at the centre of transport and offers mobility solutions based on individual needs. MaaS products tend to use electronic data and technology to improve personal mobility to enhance end-to-end journeys, such as e-bike share schemes where users rent bikes and pay for the time using an app. MaaS is a growing area in Europe and can have applications for developing countries. The benefits of MaaS are the use of shared resources, harnessing data and improving access to transport.

Moses, a taxi-share technology company, was awarded funding from the T-TRIID programme, to explore the feasibility for real-time onward journey ride-matching technology for an improved 'end-to-end' rail journey for passengers while reducing carbon emissions in South Africa.

South Africa is the world's 14th largest emitter of greenhouse gases. In 2015, emissions per capita in South Africa were 9.5 metric tonnes, compared to the world average of 6.6. South Africa is part of the UN Paris Agreement and has pledged to reduce emissions by 2025[2]. The case study for this report is Gauteng as it is the most populated province, having had significant investment in its transport system, has a Bus Rapid Transit (BRT) system and Gautrain services.

'Project Balega' was a six-month research project from October 2018 to March 2019. The project was led by Moses with the South African partner GoMetro, a transport app for improved journey planning, and supported by Snap Out, a user and market research consultancy. The project involved an extensive literature review across travel behaviour, accessibility and women's safety, transport survey, interviews, observations and data analysis to explore carbon emissions and how Moses could apply to South Africa.

The aim of the Project consisted of the following:

- Understand travel behaviour and the transport infrastructure and systems in Gauteng, with a focus on shared mobility.
- Identify the needs of people from differing income groups in their travel behaviour in terms of their access to the rapid transit systems in Gauteng and Cape Town and their use of the current transport systems to get to and from the rapid transit stations.

[1] IPCC: https://www.ipcc.ch/sr15/
[2] Carbon Brief (2018) South Africa: https://www.carbonbrief.org/the-carbon-brief-profile-south-africa

- Uncover and understand the key stakeholders and their motivations and views towards Moses.
- Explore barriers to the adoption of rapid transit systems and shared mobility and provide initiatives to address them.
- Gain insight into women's safety (as this is a key issue on transport), social inclusion and exclusion as well as accessibility for disabled people on South Africa's transport systems with a focus on Gauteng.
- Identify metrics to measure the impact that Moses could have on reducing the carbon footprint through offering shared mobility.

This Project Report provides an overview of the findings and the implications of these for Moses operating in South Africa and transport technology for reducing carbon emissions.

2. Methodology

To explore and demonstrate how shared mobility could impact carbon emissions in Gauteng, secondary research and primary research were conducted. A literature review on travel behaviour, travel needs, women's safety, accessibility and carbon emissions in South Africa were conducted to map out the 'knowns' from the 'unknowns' which need to be identified to inform the primary research.

A mixed-method approach was taken for the primary research. Quantitative data was collected by GoMetro to survey transport and its current usage, this data was analysed to identify whether Moses could potentially improve on the current transport model and optimise existing transport systems to reduce carbon emissions. In addition, an online survey was conducted to explore transport challenges and to indicate what challenges exist for Gauteng residents that impact their travel decisions.

Further information was needed to understand travel behaviour in Gauteng as little desk research was available that met the aims of the present project, particularly for minibus taxis, Gautrain and BRT systems. To explore these in more depth, a qualitative approach was taken through observations, interviews and stakeholder meetings.

These will each be reported in the subsequent sections in further detail with findings and analyses.

3. Literature Review

The literature review spanned across transport systems and infrastructure, travel behaviour, women's safety, accessibility and carbon emissions. The literature review was carried out using Google and Google Scholar to access industry reports, academic reports and news articles. A wide range of keywords were used, such as 'South Africa minibus taxis' and 'Gauteng transport'. There were a total of 130 sources consulted with priority given to the most recent information over the past five years.

3.1 Gauteng's Transport Infrastructure

South Africa has nine provinces that are governed on a national, provincial and local level (see Figure 1).

[3]

Figure 1: Map of Provinces of South Africa

The South African population primarily resides in Gauteng and KwaZulu-Natal. Gauteng was the case study for the research project.

Gauteng has the largest population with many migrants moving into the area. Between 2011 and 2016, there were close to one million people that moved to Gauteng.

[3] The nine provinces of South Africa: https://southafrica-info.com/land/nine-provinces-south-africa/

In the 2000's, Gauteng saw a range of new transit planning and public transport infrastructure developments[4]. One was the Gautrain Rapid Rail Link, led by the Gauteng Provincial Government (GPG), which cost around 25bn Rand (£1.36bn) and is one of South Africa's largest transport infrastructure investments. There is 80 km of track, 15 km is underground and there are 10 stations. The first link was between the O.R. Tambo International Airport to Sandton. There are planned expansions which may see new stations being built in Randburg, Roodepoort, Little Falls, Soweto and Lanseria[5].

Various BRT systems that are planned and implemented in Gauteng municipalities (e.g. Ekurhuleni, Johannesburg and Tshwane) are funded by local and national government. The City of Johannesburg implemented Rea Vaya Bus Rapid Transit in 2007. The Tshwane system, A Re Yeng, was built seven years later in 2014.

The Passenger Rail Agency of South Africa (PRASA) overhauled the commuter rail systems in Gauteng. The modernisation programme focused on the key Mabopane-Pretoria-Germiston-Johannesburg-Soweto corridor with new rolling stock, upgraded track and signalling infrastructure and station redevelopment. PRASA will be renewing the rolling stock fleet by acquiring over 3600 coaches over a 10-year period from 2015 to 2025[6]. Seventy-three stations in Gauteng will now be upgraded.

The South African National Roads Agency (SANRAL) led the Gauteng Freeway Improvement Project to upgrade Gauteng's freeways. Initiated in 2007, it involved widening the highways and redeveloping interchanges with the aim to reduce traffic congestion on the highway network. However, the introduction of e-tolls to repay for the project has been controversial. However, recently in 2018, the Electronic Toll Collection (ETC) company reported that road users can spend 3-4 hours on average between their workplace and home with the majority of the time spent in traffic with more highways needed in the future as a continuation of the Gauteng Freeway Improvement Project[7].

Municipal Integrated Transport Plans (ITPs) are local and national plans that are being updated based on the National Household Travel Survey. Finally, there is the long-term integrated transport planning initiative, a 25-year Integrated Transport Master Plan (ITMP25), which started in 2013. This aims to provide a framework to assist government to deliver a sustainable transport system that prioritises public transport - there are eight long-term interventions.

The ITMP25 proposes the Gauteng Transport Commission to advise on transport issues. Integrated transport modelling, which was based on a report on modelling urban spatial change, showed the current fragmented approach to transport modelling in Gauteng. The Gauteng Department of Roads and Transport (GDRT) released the terms of reference for the Gauteng Integrated Transport Modelling Centre (GITMC) to create an operational modelling centre to provide planning and modelling skills for support services. The centre will build on data and models generated by CSIR UrbanSim and MATSim software urban simulation project.

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[4] Wray, C. & Gotz, G. (eds) (2014) Mobility in the Gauteng City-Region, Gauteng City-Region Observatory: http://www.gcro.ac.za/media/reports/mobility_report_july_28_2014_medium_res_2.pdf
[5] The Citizen (2018) New proposed Gautrain expansion to reach Roodepoort, Little Falls, Lanseria and Soweto, 24 October 2018. https://citizen.co.za/news/south-africa/2027143/new-proposed-gautrain-expansion-to-reach-roodepoort-little-falls-lanseria-and-soweto/
[6] Khuzwayo, W. (2015) New Prasa train design unveiled: https://www.iol.co.za/business-report/economy/new-prasa-train-design-unveiled-1803647
[7] Bizcommunity (2018) ETC predicts road congestion to be at an all-time high by 2037 (5 November 2018) https://www.bizcommunity.com/Article/196/582/183896.html

The major form of paratransit is minibus taxis which use cash payment systems. In Gauteng, approximately 70% of all transit trips are made using paratransit. Paratransit is a valuable service offering a flexible mode of transport between formal transit and a private car and collectively includes: dial-a-ride, shared taxis, community transit and subscription buses[8]. The taxi industry has political and economic influence in South Africa. However, taxis are considered unsafe, chaotic and a reason for some of the traffic congestion and air pollution in cities. Informal taxi systems are effective as they lie outside of the rules, taxis leave when full, do not run to a schedule, there are lots of them, competition is fierce, and they can respond quickly to demand. The mapping of the informal networks can go towards recognising informal systems as legitimate forms of public transport with their own systems and ability to self-regulate[9]. Kumar and Barrett (2008) investigated urban transport systems in Sub-Saharan Africa to explore self-regulation of public transport through operator's associations and found that this was "as an industry response to the vacuum left by the failure of government to regulate the sector" (p.17)[10].

Taxi drivers have limited formal training and employment protection. Salary structures and agreements differ between owners but there are two main models: (1) The most common model is the where the owner specifies the daily check-in amount based on the vehicle's specific operating licence route. The driver is then paid 30% of their total weekly check-in earnings. Whatever income the driver makes in excess of this agreement, after fuel expenses are deducted, are given to the driver. (2) The second model, is where the owner will price the check-in rate higher, closer to total turnover and then state a weekly contract price. The driver will spend the first part of the week trying to accumulate the week's contract price without having any claim to money taken until they reach the weekly contract price any money taken after this point is then given to the driver as their income. Financial survival, routes travelled, time, passenger capacity and numbers are more important than safety (brakes and tyres being the main cause for concern[11] and superstition is sometimes seen as the cause of accidents by taxi drivers)[12] and the law. To communicate between drivers and potential passengers, hand signals are in use and are unique to the local area. The cash check-in amount required by owners is a significant factor in the unacceptable driving behaviour of minibus taxi drivers.

Because the taxi industry holds economic and political power and is self-regulated, there is a lack of government intervention in guiding and regulating public transport provision, which has led to less influence in the management and planning of mobility plans in cities. Typically, in African cities there is an underdeveloped infrastructure and few resources to transform them. Each city varies in how it deals with growing mobility needs. There is the need to create an informed mobility strategy, to develop a political vision with urban mobility objectives that align with city socio-economic goals to change the mobility culture. However, the taxi industry, although it is seen as a homogenous group, it is dynamic and heterogeneous, making discussions between the industry and the government complex. The taxi industry should be regulated and governed as it is currently unsafe and is the reason for a number of road crashes.

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[8] A look at paratransit in South Africa: https://www.up.ac.za/media/shared/404/ZP_Files/Innovate%2009/Articles/a-look-at-paratransit-in-south-africa_woolf-and-joubert-web.zp40153.pdf

[9] Clacherty, J. (2017) Can mapping informal taxi networks help legitimize them? UrbanAfrica.net: https://www.urbanafrica.net/urban-voices/can-mapping-informal-taxi-networks-help-legitimize/

[10] Kumar, A. & Barrett, F. (2008): Stuck in traffic: Urban transport in Africa. The World Bank

[11] Van Schoor, O., van Niekerk, J.L. & Grobbelaar, B. (2001) Mechanical failures as a contributing cause to motor vehicle accidents - South Africa, Accident Analysis and Prevention, 33 (713-721)

[12] Peltzer, K. & Renner, W. (2003) Superstition, risk-taking and risk perception of accidents among South African taxi drivers, Accident Analysis and Prevention, 35 (619-623)

Current transport services operate in closed and fragmented environments and reduce the possibility for innovation to respond to mobility challenges. Transport technology start-ups in new mobility services are leading the way, particularly in harnessing data that provides insights into travel behaviour to develop integrated transport plans and reduce car ownership. A Mobility-as-a-Service (MaaS) platform can help manage and provide mobility services, which puts the user at the core of transport services offering personalised suggestions. Innovation for problem-solving needs to be based on the people, the city and the environment. Digital platforms can help bring transport stakeholders together (Zhuwaki, 2018)[13]. In the case of Moses, minibus taxis are unsafe and it would not be viable to aggregate such services. Working with stakeholders such as the national and local government to regulate minibus taxis, taxi operators and public transport operators would be key for Moses, in developing a solution for integrating taxi services with rail and bus services.

There are a number of transport issues in Gauteng including:

- Modal shifts to less sustainable modes of transport - particularly minibus taxis due to the deterioration of the quality and reliability of commuter rail and bus services. Gautrain and BRT aim to address this shift.
- Ongoing sprawl and relatively low-density development. The transport modes people choose depends on the services offered, cost and the ability of the service to take them to their required destination. The 2013 National Household Travel Survey shows a trend of longer walking times to any form of transport, although public transport is being improved and its accessibility is reducing. Spatial distortions in settlement patterns have been reflected by the Reconstruction and Development Programme (RDP). Public transport has not been provided in these new areas and has led to inaccessible and poor mobility townships.
- Affordability of transport. Commuting is expensive in Africa with 21% of monthly income spent on transport (OECD, 2011[14]). In 2014, public transport costs were 26% of monthly household expenditures for around half of Gauteng households[15].
- Inadequate resources for transport infrastructure.
- Poor intergovernmental coordination.

3.2 Travel Behaviour and the Need for Shared Mobility Systems

Although Gauteng is the focus of the report, there was little literature on travel behaviour on Gauteng's transport services. Instead, travel and transport behaviour in South Africa was used to provide the context for the primary research.

There is a divide in travel behaviour in South African cities based on income. One part of the population relies heavily on private transport and the other predominantly uses public transport. Transport policy, in a post-apartheid era, has led to a need to prioritise public transport modes but in practice this is challenging. Rail services are in decline due to poor uptake and unscheduled paratransit is increasing, taking market share from rail and formal bus companies. Some passengers are choosing BRT services, but the most significant change is from scheduled large

[13] Zhuwaki, N. (2018) Exploring Mobility as a Service - MaaS in emerging markets: https://www.linkedin.com/pulse/exploring-mobility-service-maas-emerging-markets-nigel-zhuwaki-1/
[14] OECD (2011) OECD Territorial Reviews: The Gauteng City-Region, South Africa, OECD
[15] Gauteng City-Region Observatory (2014) Mobility in the Gauteng City-Region: http://www.gcro.ac.za/media/reports/mobility_report_july_28_2014_medium_res_2.pdf

bus and rail travel to the use of unscheduled minibus taxis. Car use has also grown as the middle class has expanded in large metropolitan areas[16].

Population settlement and travel choices have been impacted by the past governmental policies of segregated development. In a National Travel Survey (2013)[17], the Department of Transport found that since the previous survey in 2003, there has been an increase from 59% to 69% in the use of taxis but the use of public transport has not changed significantly since 2003[18]. Minibus taxis were used by half of the South African households for shopping and financial services.

Zhuwaki[19](2017), a GoMetro transportation engineer who builds sustainable urban mobility platforms, describes Africa's rapid urbanisation as an issue of inefficient mobility. The mobility challenge is because of "almost no deliberate policy around public transport systems in most cities across the continent" which leads to negative perceptions toward public transportation. In many African cities, urban commuters do not appreciate the local public transport systems that are available, plus owning a car is seen as a status symbol that shows freedom from public transport.

Zhuwaki (2018)[20], believes that there is mistrust towards public transportation systems. Traffic congested cities and little regulation over transportation providers means that buses and trains are over-crowded with the sole aim to make a profit with prices rising in peak hours or in poor weather conditions. Informal transport modes such as privately-run minibus taxis are commonly used. For those who own a car, they would rather sit in traffic than use public transport. He argues that BRT still has hope and can be a success using a different approach: "There is a will to integrate paratransit services with mainstream BRT", paratransit being services that link into mobility-related exclusion[21] by providing people struggling to use primary transport due to financial and spatial barriers. He believes that, "technology has been playing a crucial role in developing an understanding of urban paratransit with activities such as mapping and digitising public transport information, as witnessed in cities like Cape Town with GoMetro." For Moses, this suggests that there is a need for the integration of minibus services with mainstream BRT to improve transport poverty and data is growing for services such as MaaS to operate.

GoMetro, launched in 2012, is one of the first on-demand MaaS providers in South Africa, which aims to tackle mobility barriers in the country's metro system with technology. GoMetro generates, collects and analyses transport data across South Africa, with insights viewed as a 'flexible transportation platform'. GoMetro provides citizens' transport options and updates on a smartphone app, on the phone or via text. Recently, it has introduced an Accessibility Score tool to capture data on available transport routes and barriers. Over 200,000 people in Cape Town use GoMetro. Zhuwaki believes that collecting data on public transport has led to a shift in thinking about how urban mobility challenges can be solved as more data becomes available for minibus taxis, the most common transport mode for urban south Africans, a ride-sharing service. The digital platform is not yet ready for fully functional MaaS service due to lack of data, but the rest of the pieces of the puzzle are already in place. MaaS providers can build on the data currently available

[16] The challenge of changing travel behaviours: https://www.urbanet.info/changing-travel-behaviours/
[17] National Household Travel Survey (2013) https://www.arrivealive.co.za/documents/P03202013.pdf
[18] Public transport: https://www.arrivealive.mobi/public-transport
[19] Zhuwaki, N. (2016) Africa and the emerging mobility landscape: https://www.linkedin.com/pulse/africa-emerging-mobility-landscape-nigel-zhuwaki/
[20] Zhuwaki, N. (2018) Exploring Mobility as a Service - MaaS in emerging markets: https://www.linkedin.com/pulse/exploring-mobility-service-maas-emerging-markets-nigel-zhuwaki-1/
[21] Making the connections between transport disadvantage and the social exclusion of low income populations in the Tshwane Region of South Africa: https://www.sciencedirect.com/science/article/abs/pii/S0966692311000196

and create ways to capture their own data for digital platforms to inform ride-sharing services that are reliable, affordable, convenient, safe and accessible.

'WhereIsMyTransport' is a platform that connects, digitalises and maps transport networks for information to be available to users. In 2017, it mapped Cape Town's informal minibus taxi system. It has tracked around 1,500 stops, 657 routes over 5,500 miles in Cape Town and has made the data publicly available through its Application Programming Interface (API) platform for apps to integrate minibuses with the public transit network[22]. It has since added Gauteng province.

Zhuwaki (2017) believes that sustainable solutions are needed that are built around the needs of the people, where cities rethink their urban mobility systems using systems and structures that enhance mobility for both formal and informal public transport. One way may be for formal and paratransit services to complement one another within a feed-truck distribution model. Ferro and Behrens (2015)[23] suggested this is a possibility, which could lead to sustainable and equitable public transport systems. Schalekamp (2017)[24] examined how informal transport could be partnered with public transport and found a positive improvement in business practices and attitudes of paratransit operators towards government-led reform programmes as a result of a capacity building programme. This provided stakeholders with the skills to run and manage scheduled vehicle operating companies. Capacity building programmes could contribute toward a level playing field and open communication channels between operators and government.

South Africa has a car-centric culture. Two trends for commuters are shared mobility and driverless vehicles. Research has shown that South Africans spend less time in their cars but more money on them and have a strong emotional attachment to their vehicle and may not like the idea of ride-sharing[25]. In spite of this, shared mobility solutions are growing in South Africa. The country has one small car-sharing service, Locomute and there is now an emerging market of people who are questioning the need for car ownership. Locomute is based in Cape Town and Johannesburg and was launched in 2015. Due to the disconnected public transport network and limited infrastructure, Locomute focused on corporate clients which was a barrier to its adoption[26]. 'flx' on the other hand provide private shuttle services for home-to-work journeys. There are also car-pooling companies such as uGoMyWay (now ceasing operations - we can learn here from their case), FindaLift, RideVu and Jumpin Rides that connect drivers and commuters going in the same direction. They enable users to log their trip and calculate the cost of contributing to the ride. Alongside Uber, there are ride-hailing apps such as Taxify, Zebra Cabs, Africa Ride and Orange Cabs and this market is set to grow[27]. The regulatory barriers and controls for these companies are not clear in the desk research, but future primary research could explore these further.

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22 Mapping Cape Town's informal minibus taxi network: https://www.citylab.com/transportation/2017/02/mapping-cape-towns-informal-minibus-taxi-network-public-transit/516300/

23 Ferro, P.S. & Behrens, R. (2015) From direct to trunk-and-feeder public transport services in the Urban South Territorial Implications, The Journal of Transport and Land Use, 8 (1), 123-136

24 Schalekamp, H. (2017) Lessons from building paratransit operators' capacity to be partners in Cape Town's public transport reform process, Transportation Research Part A, 104, 58-66

25 Unexpected ups and downs of two major mobility trends: http://www.getgometro.com/unexpected-mobility-trends/

26 SA in slow lane as shared wheels sweep the world: https://www.businesslive.co.za/bt/business-and-economy/2017-08-19-sa-in-slow-lane-as--shared-wheels-sweep-world/

27 Ride Hailing South Africa: https://www.statista.com/outlook/368/112/ride-hailing/south-africa

3.3 Women’s Safety on South African Transport Systems

The United Nations set goals for South Africa for its millennium development, and gender equality is one that is still to be achieved. One key reason for not reaching this goal is gender-based violence according to the Commission for Gender Equality[28]. Educational goals have been achieved whereby there is equal enrolment of male and female pupils in primary, secondary and tertiary education. Black women suffer triple marginalisation based on the intersection of race, social class and sexism[29]. Apartheid policies separated people based on gender as well as race. Even now 20 years into independence and the White Paper (1997) from the Department of Education, the education system still embodies gender inequality and disparities. In 2019, South Africa will have its national election. Women, particularly young women, are on the outskirts of economic and political power[30]. Gender equality has a number of laws to protect women but they face difficulties, particularly in the workplace when competing with their male counterparts. Economic empowerment is a crucial factor in gender equality; however, women are still more likely to be unemployed compared to men. The Institute for Security Studies conducted qualitative research in six Gauteng communities viewed as protest hotspots. Gender issues are at the core of young people's’ concerns. There are gender dynamics affecting their daily lives.

The Safe Cities for Women Campaign and the international commemoration of Global Safe Cities Day on 20 May took to Noord and Bree Taxi Ranks to demand safe public transport for women in 2016[31]. As mentioned previously, women face gender violence, and this is reflected in public transport were personal safety and harassment on public transport are concerns for women. When using taxis, they commonly face harassment, stalking, sexual assault or rape. Alongside the problems of public transport most people also face long commuting times, high cost, poor quality and unsafe transport services, bus stops and taxi ranks. Safe transport is needed as the normalisation of violence against women, which the taxi industry contributes, has to stop but it is used because it is cheap and convenient. The taxi industry is huge, with 15 million commuters using minibus taxis daily, the majority are either low income earners or the unemployed. The industry is worth 40bn rand and is the largest black owned sector. There are 250,000 vehicles on the road, employing 600,000 people. Taxi owners have influence over rank marshals and drivers, who are mainly men. The City of Johannesburg supports the Safe Cities for Women Campaign.

People are looking for safe taxi ranks, drivers who are trusted, confirmed routes and the use of a taxi without risk of assault, rape or murder. In March 2017, there were a number of attacks and taxi rapes around Gauteng, the Soul City Institute for Social Justice reviewed how to create a safe public transport system for women and highlight the challenges. They wanted to hear women’s experiences of public transport. They reached out to over half a million black women from low-income communities across every province in South Africa. They developed the National Safe Taxi Charter used to lobby the taxi industry as well as governmental agencies. Access to or lack of, public transport, contributes to whether women can be economically active to give them the

[28] Oliphant, P. (2015) South Africa falling short in gender equality standards, Mail & Guardian, 04 May 2015: https://mg.co.za/article/2015-05-04-south-africa-falling-short-in-gender-equality-standards

[29] Akala, B.A. (2018) Challenging gender equality in South African transformational policies - A case of the White Paper: A programme for the transformation of higher education, South African Journal of Higher Education, 32 (3), 226-248

[30] Tracy-Temba, L. & Roberts, M. (2018) SA’s elections are a chance to advance gender equality, Daily Maverick, 6 July 2018: Tracy-Temba, L. & Roberts, M. (2018) SA’s elections are a chance to advance gender equality, Daily Maverick, 6 July 2018: https://www.dailymaverick.co.za/article/2018-07-06-sas-elections-are-a-chance-to-advance-gender-equality/

[31] Actionaid (2016) Demanding safe public transport for women, 19 May 2016

freedom to stand up to violence. Women need to be able to use taxis with reassurance, in a regulated taxi with:

- Easily identifiable vehicles controlled by the authorities;
- Drivers registered with police clearance IDs that can be scanned who have been vetted by the Department of Transport;
- The use of monitored routes;
- A free hotline to report drivers;
- Taxi ranks as gun-free spaces with police presence and technology surveying ranks and taxis; and
- Employers providing safe transport for people working late at night, female taxi drivers feeling welcomed and taxi drivers to be sensitive and knowledgeable about gender violence[32].

Unfortunately, fear of gender violence also affects young people. Girls travelling to school are also in danger when walking. Walking dominates both genders in South Africa in rural areas that have dedicated bus services. There is a fear of rape on their journey to and from school which is highest in remote rural areas (Porter et al. 2011)[33].

WIReDSpace (2015)[34] explored gender inclusive spaces around the Rea Vaya transit (BRT) and concluded that currently women cannot participate equally in the city. A qualitative approach was taken, it was found that high levels of actual and perceived safety were found when walking in the area and using the BRT at night. Women using the area were found to have needs in ensuring their safety and comfort in the space. It is currently a neglected issue and needs the attention of city planners. If city planners are more aware of women's safety, there could be more measures put in place to improve their personal security.

3.4 Accessibility and Disabled Travellers on Transport Systems

The Census 2011 provides statistics on disability in South Africa, disability is viewed as the level/degree of difficulty in a specific functional domain and the disability index. The national rate is 7.5% and is more prevalent among females than males[35].

There is a lack of research for people in South Africa with 'triple vulnerabilities' i.e. poverty, disability and rurality. A study by Vergunst et al. (2017)[36] found people with disabilities have a range of unmet health needs and face more barriers accessing health care. This is not unusual as globally, people with disabilities are marginalised and excluded from actively participating in society and are faced with discrimination in relation to access to health, employment and education. Work conducted by the South African Human Rights Commission (SAHRC) found that the process in

[32] Makutoane, M. (2017) Women deserve safe transport, The Star Late Edition: https://www.pressreader.com/south-africa/the-star-early-edition/20170831/281728384656259
[33] Porter et al. (2011) Perspectives on young people's daily mobility, transport and services access in Sub-Saharan Africa. In Mobilities: New perspectives on transport and society, M. Grieco & J. Urry (eds). Abingdon: Routledge
[34] Conco, Z. (2015) Making gender inclusive spaces around Rea Vaya transit areas: The case of Commissioner Street, WIReDSpace: http://wiredspace.wits.ac.za/handle/10539/20972
[35] Stats SA (2014) STATs SA profiles persons with disabilities: http://www.statssa.gov.za/?p=3180
[36] Vergunst et al. (2017) Access to health care for persons with disabilities in rural South Africa, BMC Health Services Research, 17, 741

matters concerning disability and implementing the Convention on the Rights of Persons with Disabilities is slow[37].

BRT systems have been built in Cape Town as well as Gauteng and past literature shows the challenges that Cape Town has had with making their new transport systems accessible to those with physical disabilities. Edwards (2018)[38] argues that Cape Town city is 'failing its mandate' to provide transport for disabled people. The Cape Town Association for the Physically Disabled peacefully protested against Dial-a-Ride operations at the Civic Centre. It is believed that the service leaves disabled passengers behind, is limited by transporting two or three disabled people at a time, inconvenient as it passengers must book rides a week in advance and services do not arrive on time. Without transport, disabled people are missing opportunities to contribute towards society and the economy.

People using wheelchairs can find areas around stations difficult to use, in particular Nyanga Junction, where individuals pay people to help them reach the station platform but then must wait for a space before being able to board a train. Taxis are relied on but these involve long waiting times because of them being in a wheelchair and taxi drivers not stopping to pick up disabled passengers. When using minibus taxis, it is expensive however, for many individuals it is the only way to get to the shops to buy provisions. Transport issues create a real barrier for the disabled in either entering employment or enrolling in learnerships[39].

In 2018, it was announced that there would be free bus transport for pensioners and people with disabilities during off-peak hours in Johannesburg. This is now due to be rolled out sometime between 2019-2020[40]. UberASSIST launched in Cape Town in 2017, aims to help older people and passengers with disabilities by providing trained drivers to help accommodate service animals and folding wheelchairs[41].

Poverty and Social Exclusion

South Africa is characterised by the extremes of wealth and inequality. Poverty is rising in South Africa[42], in 2015, more than half of all South Africans were poor. These figures were calculated based on the upper-bound poverty line of R992 per person per month, in 2015 there were over 30.4 million South Africans living in poverty. Although this is less than a decade earlier, the South African economy has experienced low or weak economic growth, high unemployment rates, low commodity prices, high consumer prices, low investment levels, a dependence on household credit and policy uncertainty.

In the 2003 South African National Household Travel Survey, the majority of the poorer households had little access to private vehicles and public transport services where 26% of the lowest income quintile households had access to a car, more than 75% had no access to a train station and nearly 40% did not have access to a bus service. The majority of the white population (83%) held a

[37] South African Human Rights Commission (2017) Research brief on disability and equality in South Africa: https://www.sahrc.org.za/home/21/files/RESEARCH%20BRIEF%20ON%20DISABILITY%20AND%20EQUALITY%20IN%20SOUTH%20AFRICA%202013%20to%202017.pdf
[38] Edwards, M. (2018) City's transport service for disabled people 'failing its mandate', IOL, 20 September 2018
[39] Ntongana, T. (2016) Public transport is a nightmare for the disabled, GroundUp, 14 Oct 2016
[40] SABC News (2018) Free bus transport for pensioners and people with disabilities, SABC News Online, 30 April 2018
[41] Uber (2017) UberASSIST: Making Cape Town more accessible, 03 April 2017
[42] Stats South Africa (2017) Poverty on the rise in South Africa: http://www.statssa.gov.za/?p=10334

driving licence while only 10% of the black population, 21% of the coloured population and 56% of the Asian population. Since this research Lucas (2012)[43] reflects on the progress of transport and social exclusion, she suggested there had been (1) improved conceptualisation of transport-related exclusion as a social phenomenon; (2) improved identification and measurement of social disadvantage and how it interacts with transport provision and (3) greater policy recognition of these issues.

Lionjanga and Venter (2017)[44] explored the evolution of accessibility for the poor to public transport reliant households in the City of Johannesburg by calculating their accessibility to employment between 2009-2013. Time-series analysis showed that their accessibility to employment had improved and after 2011, when Rea Vaya BRT (Phase 1A) was fully in operation, employment accessibility from Soweto had made a notable improvement by 2013. The limited catchment area relative to existing services reduces its effects on accessibility - opening up routes to BRT could help the service reach more people.

The City of Tshwane Metropolitan Municipality is the local government of the northern Gauteng Province. The Metropolitan area is centred on the city of Pretoria. The City of Tshwane is in Gauteng, with a population of 3,275,152[45] the median age is 28, the main language is Sepedi (22%) followed by Setswana (20%) and Africaans (15%). There are 1,136,876 households with 16.4% of these households classified as informal dwellings. The average income is R57,300 per year. Approximately 45% of households have access to a car available to them. Internet access comes from cell phones for 54% of these households and another 23% from other mobile services.

Tshwane experiences transport disadvantage and social exclusion of low-income populations (Lucas, 2011)[46]. The area relies on informal minibus taxis which are expensive relative to incomes but lack of regulation means that the taxis are poorly maintained, driver practices are driven by a need to make a living wage which makes for erratic and dangerous driving practices and transport poverty leads to social exclusion which is a public policy issue.

The BRT reaches Mamelodi, Atteridgeville and Soshanguve and aims to reach Hammanskraal commuters in the future through a compensation agreement with the taxi industry. Tshwane had a new bus depot in 2017, the Belle Ombre Depot, for 114 bus fleet[47]. However, recently the Mamelodi arm of BRT has been withdrawn by A Re Yeng after taxi operators demanded Tshwane Rapid Transit raised its fares to be the same as taxi fares, which increased on 1 December 2018. The buses are grounded at Belle Ombre as a safeguarding measure[48]. Alongside these issues with

[43] Lucas, K. (2012) Transport and social exclusion: Where are we now? Transport Policy, 20, 105-113
[44] Lionjanga, N. & Venter, C. (2017) Time-series analysis of accessibility in the city of Johannesburg, 36th Southern African Transport Conference (SATC 2017), Pretoria, SA, 10-13 July 2017
[45] Wazimap (2016) City of Tshwane: https://wazimap.co.za/profiles/municipality-TSH-city-of-tshwane/
[46] Lucas, K. (2011) Making the connections between transport disadvantage and the social exclusion of low income populations in the Tshwane Region of South Africa, Journal of Transport Geography, 19 (6), 1320-1334
[47] Maromo, J. (2017) Tshwane extends A Re Yeng bus service across townships, IOL, 2 October 2017: https://www.iol.co.za/news/south-africa/gauteng/tshwane-extends-a-re-yeng-bus-service-across-townships-11461045
[48] Mahlangu, I. (2018) A Re Yeng not going anywhere near Mamelodi, Sowetan Live, 13 December 2018: https://www.sowetanlive.co.za/news/south-africa/2018-12-13-a-re-yeng-not-going-anywhere-near-mamelodi/

the taxi industry, A Re Yeng and Gautrain have had strikes over wages[49],[50] and commuters facing bus fare rises[51]. One of the taxi associations in Pretoria is Menlyn Taxi Association, has recently been involved in a taxi war conflict with Mamelodi Amalgamated taxi association[52]. Both associations have now signed a pledge with the City of Tshwane to stop violence over disputes about routes.[53,54].

3.5 Summary

The literature review shows the complexities of South Africa's economic, political and social context, which intertwines with the transport systems and how they are used. There are divisions between low-income communities and middle-to-high income communities, which is reflected in car ownership, public transport usage and accessibility to the internet. The digital divide also impacts on the ability of low-income communities to use cashless payments.

The transport systems are nuanced with formal (BRT and Gautrain) and informal (paratransit) transport and governmental regulation with minibus taxis continuing to have political and economic power, leading to poorer vehicle maintenance and unsafe driving practices. Gauteng has heavily invested in public transport however, the literature suggests that this may not be widely accessible to all communities and minibus taxis are continuing to serve low-income communities, who cannot benefit from the BRT or Gautrain.

The literature on women's personal safety on public transport suggest that women have poor experiences travelling and feel unsafe on public transport and in minibus taxis. Research shows recommendations for improving transport, which Moses should address by improving customer experience and personal safety. Past research on accessibility demonstrates a lack of transport for the chronically poor or disabled, impacting on their economic and social opportunities and increasing their social exclusion.

Overall, the literature review highlighted gaps in the availability of detailed data on minibus taxi routes, shared mobility and multi-modal transport travel behaviour.

[49] Ndlazi, S. (2018) National bus strike deadlock, IOL, 19 April 2018: https://www.iol.co.za/pretoria-news/national-bus-strike-deadlock-14530393

[50] Niselow, T. & Evans, J. (2018) Gautrain strike to continue, Fin24, 06 August 2018: https://www.fin24.com/Economy/Labour/News/gautrain-strike-to-continue-cape-town-taxi-strike-is-over-20180806

[51] Ndlazi, S. (2018) Commuters angry as bus fares increase again, IOL, 21 June 2018: https://www.iol.co.za/pretoria-news/commuters-angry-as-bus-fares-increase-again-15584242

[52] Kgosana, R. (2018) Pretoria shoot-out street was off limits for both taxi bodies, The Citizen, 7 July 2018: https://citizen.co.za/news/south-africa/1972587/pretoria-shoot-out-street-was-off-limits-for-both-taxi-bodies/

[53] Mabena, S. (2018) Five Pretoria taxi drivers hospitalised after shooting linked to routes dispute, Sowetan Live, 05 July 2018: https://www.sowetanlive.co.za/news/south-africa/2018-07-05-five-pretoria-taxi-drivers-hospitalised-after-shooting-linked-to-routes-dispute/

[54] Ngqakamba, S. (2018) Taxi associations sign pledge with City of Tshwane to stop violence, News24, 11 July 2018: https://www.news24.com/SouthAfrica/News/p3-taxi-associations-sign-pledge-with-city-of-tshwane-to-stop-violence-20180711

4. Travel Behaviour Survey

The transport survey was carried out in Gauteng in February 2019 in the following areas in Pretoria:

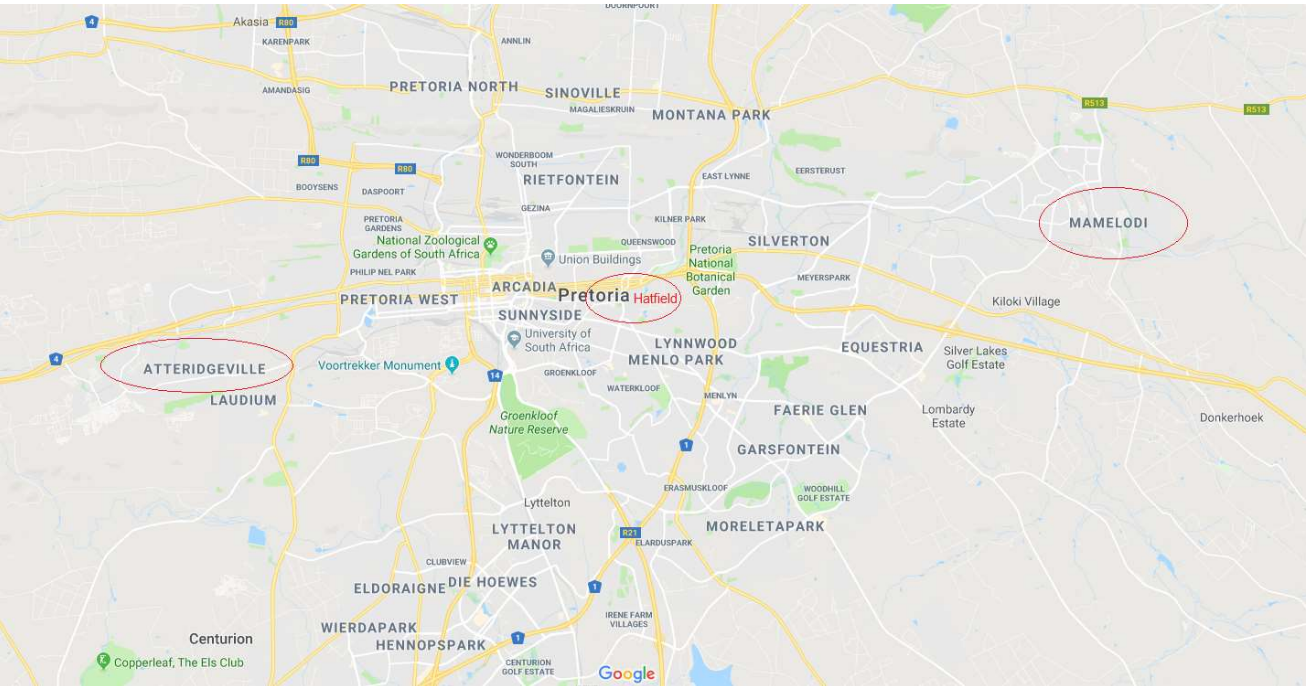

Figure 2: Map of Pretoria

The technologies used for the travel behaviour survey, have been highly-focused crowdsourcing, using GoMetro’s mobile platform. This has resulted in the generation of various General Transit Feed Specification (GTFS) datasets, to map relevant minibus taxi routes in Johannesburg. The routes were:

- 7 km radius to rail stations to look at the first-and-last mile journeys.
- From Gautrain and Prasa stations: Hatfield and Mamelodi stations.
- From Bus Rapid Transit stations - A Re Yeng.

In addition to the information collected on route mapping will be measuring: route popularity, passenger capacity and fares. The aim of collecting this data was as follows:

- Design and deliver a data collection project for informal transport analysis;
- Identify popular destinations for different user groups to and from each A Re Yeng transit station (The station chosen for this study is Hatfield Station);
- Identify popular destinations for different user groups to and from each Gautrain transit station in Tshwane region (Hatfield Station for the sake of this study);
- Obtain pricing information for informal transport to popular destination from A Re Yeng stations (Within a 7 km radius of specified station);
- Obtain pricing information for informal transport to popular destination from Gautrain stations in Tshwane region (Within 7 km of specified station);
- Obtain capacity information (how much capacity in use in vehicles) at different times of the journey;
- Provide feedback of a proposed systematic approach for informal transport;

- Assist with identifying factors that will make ride sharing more attractive for different users and to highlight barriers to its adoption.

The feasibility study was focused on parts of the Tshwane Municipality in the Gauteng province. This transport survey was specifically performed in Hatfield and Mamelodi within the greater Tshwane municipality. The survey aimed to observe and understand first-and-last mile travel behaviour around train stations or multimodal public transport hubs, namely the travel behaviour in the vicinity of the Gautrain, A Re Yeng, PRASA Station (Passenger Rail Agency of South Africa) and the integration of minibus taxis with these stations. The data collection and feasibility study were focused on these modes of transport and service providers.

4.1 Methodology

In order to assess the first-and-last mile common destinations around transport hubs within a 7 km radius, data collection was carried out using on-board mapping. The on-board surveys were performed on minibus taxis, the Gautrain bus shuttle, the A Re Yeng buses in Hatfield and on the minibus taxis in Mamelodi.

Data collection was conducted using the smartphone application GoMetro Pro. The on-board surveys were conducted during the morning and afternoon peaks as well as off peak times throughout the day. The methodology was hinged on two interfaces, the mobile mapping platform, and the data management platform. The GoMetro Pro app is a smartphone application, which allowed our enumerator to collect public transport taxi operational data on the minibus taxis, Gautrain Bus and the A Re Yeng buses.

The data collected on the mobile smartphone was stored and managed on the GoMetro Pro platform. Figure 1 below shows the main characteristics of the GoMetro Pro app, which collected the public transport data.

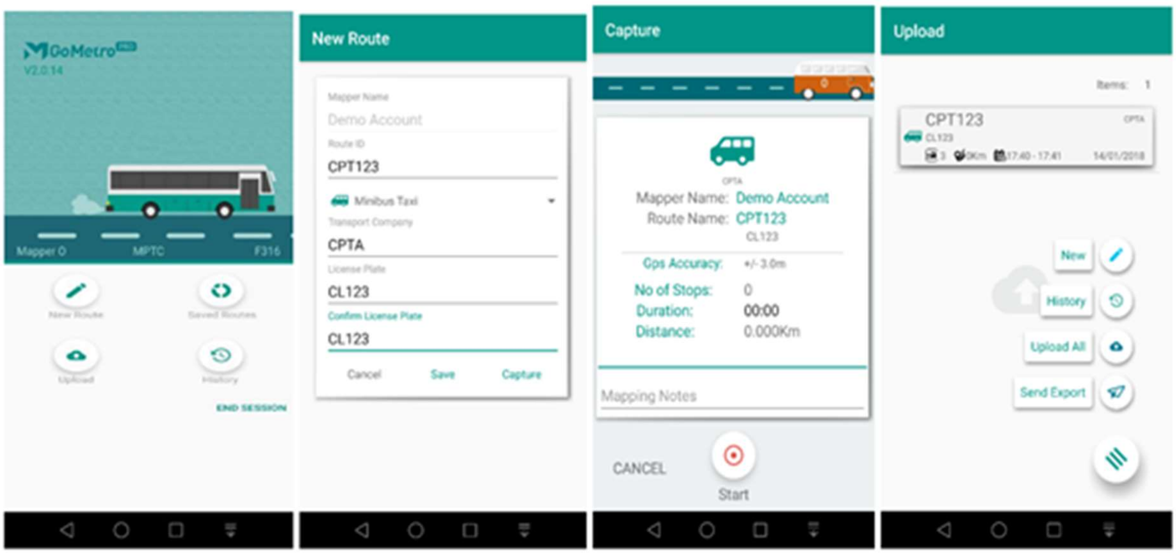

Figure 3: Mobile application showing simple login and data collection interface.

The GoMetro Pro data manager platform compiles, processes and analyses all surveyed data collected using the GoMetro Pro app. The data management system includes three layers: (1) geographic layer; (2) transport data layer; and (3) the data collection quality layer. These three layers are built on a stable and compact cloud-based architecture to improve the robustness of the custom management platform. A project management tool is a new addition to the GoMetro Pro mapping software and has been specifically developed for data management of large-scale field survey work.

GoMetro conducted desk research on the areas in Gauteng, South Africa to help decide the areas and stations that would be included in the primary research to provide an overview of travel behaviour of both low-income communities and middle-to-high income communities.

4.2 Results

From all the surveys that were performed, the following data was captured:

- Vehicle Registration Number, Vehicle Type and Seating Capacity
- Route Details – the standard Origin-Destination, i.e. stop or rank names for those that were known when departing on first trip and standard destination rank or suburb
- Applicable fare for each of the main defined route / trip
- The number of passengers on-board when departing on the first trip
- All passengers boarding and alighting along the route at each stop
- All passengers still on-board at the end destination (any listed rank)
- At each stop where passengers get on or off, the dwell time and GPS coordinates will be recorded and registered on the device and uploaded to the server
- The fare amount paid per passenger boarding at each stop location.

Times are defined as:

- AM Period: 6.00am - 11.00am
- Noon Period: 11am - 13.00pm
- PM Period: 13.00pm - 18.00pm

“Young”, “Middle” and “Old” age groups were defined as:

- Young: 0-10 years
- Middle: 10-35 years
- Old: 35 years and older

These categorisations of age are a limitation on the quality of data collected as it is not clear from the data collected who are children, adults and pensioners. These age groups were not agreed on by the UK Moses team but were categories that GoMetro used.

4.2.1 Hatfield

Tshawe is where the South African government and numerous government national offices are situated. Hatfield, in the City of Tshwane, is a busy transport hub. It can be described as a suburb, where middle-to-high income communities live and work in office blocks and retail businesses. The University of Pretoria is situated here too, making it a place where a high number of students reside. The Hatfield hub has Gautrain Hatfield station, a major station for Gautrain in Tshwane. Less than 100 metres away is the General M. Siyakhula station, a major station on the trunk route for A Re Yeng BRT system. The informal minibus taxis operate in the area, these taxis pick up and drop off a small percentage of passengers who use Gautrain and A Re Yeng.

Table 1 below shows when Hatfield station was observed.

	2 February			4 February			5 February			7 February			8 February			11 February		
	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM
TAXI			✓			✓									✓			✓
GAUTRAIN					✓		✓			✓								
A RE YENG				✓				✓	✓			✓						

Table 1: Hatfield station observation times

Table 2 shows the transport modes observed in Hatfield.

MODE	INDICES (average per trip)					
	DISTANCE (km)	TRAVEL TIME (min)	REVENUE (Rand)	NUMBER OF STOPS	PASSENGER NUMBERS	FARE (Rand)
Min Bus Taxi	5.3	15.7	205	7	14	14.5
A Re Yeng	11.1	36.44	441.22	12	62	7
Gautrain Bus	14.91	39.9	170.29	8	11	16

Table 2: Hatfield station findings

Overall, the average distance per trip and average travel time per trip, were higher for Gautrain, followed by A Re Yeng and finally minibus taxis. The average revenue (Rand) per trip was highest for A Re Yeng, then minibus taxi with Gautrain following. The average passengers carried per trip was highest for A Re Yeng, followed by minibus and finally Gautrain. The average fare was highest for Gautrain, followed by minibus taxi and finally A Re Yeng. See Appendix 1 for graphs to illustrate more information and Appendix 2 for the maps.

Table 3 presents the demographics of the Hatfield observations.

DEMOGRAPHICS								
GENDER					AGE GROUPS			
	FEMALES	MALES	TOTAL		OLD	MIDDLE	YOUNG	TOTAL
TAXI	61	22	83		31	48	4	83
GAUTRAIN BUS	37	38	75		3	72	0	75
A RE YENG	309	271	580		23	515	42	580

Table 3: Hatfield observations of the demographics of the passengers

4.2.2 Mamelodi

Mamelodi predominantly uses the PRASA Metrorail services. Popular stations were observed by GoMetro: Greenview Prasa Station, Mamelodi Gardens Prasa Station, Eerste Fabrieke Prasa Station and Denneboom Prasa Station.

Table 4 shows the observations times at Mamelodi station.

	11 February 2019			12 February 2019		
	AM	NOON	PM	AM	NOON	PM
MINIBUS TAXI		✓		✓	✓	✓

Table 4: Mamelodi station observation times

Table 5 presents the demographics of minibus taxi passengers observed.

DEMOGRAPHICS								
GENDER					AGE GROUPS			
	FEMALES	MALES	TOTAL		OLD	MIDDLE	YOUNG	TOTAL
TAXI	70	66	136		0	130	6	136
%	51	41	100		0	96	4	100

Table 5: Mamelodi observations of the demographics of the passengers

See Appendix 2 for the routes for minibus taxis.

4.2.3 Atteridgeville

Atteridgeville predominantly uses the PRASA Metrorail services. Popular stations were observed by GoMetro: Atteridgeville Prasa Station, Kalafong Prasa Station and Saulsville Prasa Station. The area is supplemented by minibus taxi routes. The observations took place on the following days and times:

	18 February 2019			19 February 2019		
	AM	NOON	PM	AM	NOON	PM
MINIBUS TAXIS		✓	✓			✓

Table 6: Atteridgeville station observation times

The demographics of those taking minibus taxis were as follows:

DEMOGRAPHICS								
GENDER					AGE GROUPS			
	FEMALES	MALES	TOTAL		OLD	MIDDLE	YOUNG	TOTAL
TAXI	27	52	79		2	74	3	79
%	34	66	100		3	94	4	100

Table 7: Atteridgeville observations of the demographics of the passengers

Please see Appendix 2 for Atteridgeville minibus taxi routes.

4.3 Analysis

The survey found that in Hatfield, the Gautrain bus service has the highest average fares and distances per trip. A Re Yeng buses have the highest average passengers per trip, number of stops, revenue and travel time per trip. The minibus taxis have the highest dwell time at stops followed by A Re Yeng and the Gautrain Bus had the lowest dwell time.

The A Re Yeng bus service had the highest number of passengers across male and female. Older people i.e. over 35, were the main demographic group to use minibus taxis. There may be errors for A Re Yeng buses due to full buses with only one observer. The Gautrain Bus and minibus taxis were smaller in size and therefore errors are likely to be lower.

In Mamelodi, surveys were done on minibus taxis as this is the main mode of transport in the area. For the trips surveyed, females were the majority users and the middle age group i.e. 11 to 35 were the highest among all age groups. Average dwell times at stops was high at Hatfield and Atteridgeville for minibus taxi operations. Atteridgeville had more male riders than females, the middle age group i.e. 11 to 35, were the highest for minibus taxis and dwell time at stops for minibus taxis was high and similar to Mamelodi.

The limitations of the transport survey were the categorisation of young, middle and old as it is unclear from the data as to who are children, adults and pensioners, particular for ‘middle’ age group.

5. Online Survey

The online survey was distributed in Gauteng, to complement the data collected as shown in the previous section. This section shows the findings of the survey. There were 22 respondents in total. The survey was distributed between the 18th and 22nd February 2019. See Appendix 3 for further results.

Respondents came from Gauteng: Pretoria (12), Sandton CBD (1), Johannesburg CBD (6), Olympus (1) Melville (1) and Mpumalanga (1). Their employment status were: full-time employee (9), unemployed (2), student (7), self-employed (5). Job titles varied and included: Junior Finance Officer, Civil Engineer, Technician, Accountant, HR Practitioner and Private Tutor.

When asked their reasons for their choice of transport and why they selected the above challenges, the respondents said it was convenient, faster and cheaper and they liked privacy as well as the following.

> *"More convenient. Difficult to get a public transport between my workplace and my domicile. I think the distance is too short, but I spend R90/day on average to go to and from work. That's a lot."*
>
> *"Public transport such as taxis could be convenient if the system for it was better developed and monitored. There are too many owned cars on the road because of poor public transport causing lots of traffic"*
>
> *"Taxis are easily accessible but not so convenient when it comes to personal safety"*
>
> *"Uber or taxify.. Safe and reliable"*
>
> *"I prefer driving my own vehicle for convenience. There is traffic on my way to JHB, but using my car is quicker than public transport"*

When asked what tools/strategies they use to plan their travel, the majority said they used apps on their phone (17) and mentioned Google, Waze and TravelStart or they did not plan their trips at all (3).

The changes the respondents would like to be targeted in the public transport space were: safety (6), petrol prices (1), cheaper public transport (1), availability and reliability of public transport (3), improvement to traffic laws (1), to make it easier to choose the taxi to take for a certain route (1), use more new technology (1), dedicated travel lanes for taxis (1) and for people to use public transport more frequently for commuting (1).

5.1 Analysis

The online survey gives a better view of middle-to-high income communities as opposed to low-income communities, which is its main limitation. However, it may be assumed that some of the issues with public transport may be shared with low-income communities and this indicates what these may be. The sample size was small, at 22 respondents, this survey provides an indication of the issues that young people (16-35 year olds), in middle-to-high income groups have in Gauteng, but this needs further research with a larger sample.

Interestingly, safety is a key issue that particularly shone through the last question and was mentioned less frequently earlier in the survey. This illustrates that there is a need for better safety, either personal or vehicle safety, for public transport.

As was seen in GoMetro's data collection in section 11, dwell times and lack of convenience is a second key issue. For minibus taxis, dwell times are long as taxis must be filled to a minimum capacity before they depart on their routes. Plus, there is a lot of congestion on the roads, which impact taxis but also car owners and increases the time taken to complete the trips. In addition, convenience is highlighted by the respondents as an issue as public transport is not always available and reliable and minibus taxis can have long waiting times, increasing travel times.

Also, it was highlighted that public transport is not affordable for this group. The GoMetro data shows that PRASA Metrolines are more available for low-income communities as opposed to Gautrain and A Re Yeng. In the Mamelodi area, minibus taxis are the main form of transport and it may be that it is more available and convenient compared to its public transport counterparts.

6. Observations

In Gauteng, South Africa, the UK Moses team conducted observations of transport and travel behaviour between different modes of transport. These observations were performed at different times to when GoMetro attended the stations. The purpose of the observations was different to GoMetro's. GoMetro noted frequency, dwelling time and demographics of those using transport.

The UK Moses team identified user behaviours at these stations. The aim of the observations was to look at current travel behaviour and how people continue their final journey home from bus and train stations.

1. Gautrain
2. Bus Rapid Transit
3. Minibus Taxi

The questions explored in the observations at Hatfield station were:

- What are the users' problems?
- How are they solving it?
- What workarounds are they making?
- What are their pain points? (What are they getting frustrated with?)
- What is working for them?
- What process/tool is or isn't working for them?
- What do they need to solve their problem?

Please see Appendix 4 for the findings.

6.1 Analysis

The observations complement GoMetro's work and give more context to the desk research undertaken by GoMetro as well as the user interviews. The findings that were of interest from the observations is that in Hatfield, a middle-to-high income area were:

- The A Re Yeng and Gautrain buses were underutilised, users relied on e-hailing services such as Uber and Taxify for journeys, although passengers couldn't use these services outside the train station, they had to meet passengers in a separate meeting place.
- Gautrain is oriented towards middle-to-high income communities based on the passengers that were observed;
- Onward journey waiting times for Gautrain passengers varied;
- Most passengers observed were assumed to be students;
- Mobile phone data usage was limited. It was observed that mobile phone data is expensive meaning that data was turned on when required, to for e-hailing or looking at travel information such as Google maps.
- Metered-taxis outside the station are not regulated so there are no safeguards on who might be getting in the car with. People may feel safer in minibus taxis as they are shared and personal safety was felt at risk as they did not know who the driver is, comparing this to UK Uber services for example, where the driver's identity and ratings are clear to the passenger.
- Taxis can wait outside the station for up to an hour and e-hailing providers being used more, which may be increasing taxi waiting times.

7. Interviews and Contextual Inquiry

Interviews were carried out with two user groups: low-income and middle-to-high income communities. The interview guide is in Appendix 5.

The aim of the interviews was to explore the following issues:

- How people travel
- What their current problem when travelling from the station to their place of work/home is
- What tools are used as solutions to solve their problem
- What their pain points are
- What could help them solve their problem that current tools aren't doing
- What their views are toward the value propositions that will help guide Moses in the design of their solution for South Africa.

An interview is a guided discussion with the objective of collecting relevant information for research. A contextual inquiry is a semi-structured interview within the context of use where observations also take place.

7.1 Low-income Community Interviews

The interviews were carried out by the UK Moses team in English (there are many languages spoken in Gauteng: IsiZulu (19.8%), English (13.3%), Afrikaans (12.4%) and Sesotho (11.6%)). Interviews occurred the week of 25th February 2019 in Pretoria. Participants were given an incentive of ZAR100 (£5.30), this is the equivalent of half a day's salary for low-income communities. There were three interviewees (first names are pseudonyms): two males (Chidi and Neo) and one female (Ndidi).

Mode of Transport

The participants interviewed travelled to work on minibus taxi (2) and bus. The mode of transport was chosen because they did not own a car, it was the cheapest option, there were no other alternatives available, the minibus taxi is reliable and on demand, or the train was not reliable.

Pain Points
The pain points for taxis and buses are listed below.

Taxi

- The drivers were generally not friendly and the wait at the taxi rank can sometimes be as much as 45 minutes, meaning people arrived late to work because the minibus taxi was trying to pick up more people. The participants had to leave for work early to reduce the risk of being late or choose a bigger taxi as it is more comfortable.
- It was found that safety can be an issue as minibus taxi drivers will go through red lights to get to a customer first,
- People have to wait at the taxi ranks for long periods of time,
- Taxis can go and pick up passengers and extend the length of the journey,
- Taxis can go above the speed limit,
- Taxi drivers' driving behaviours can be dangerous,
- There are cultural and language issues and it can be difficult to communicate,

- Taxis are not direct to work and it can take a long time to get to work.

Bus

- The bus did not always turn up and it could take hours for a replacement to arrive,
- The bus is not comfortable,
- Buses were old,
- Buses or taxis are the only option from home,
- The buses do not have good availability,
- The buses are cheap and late,

Tools for Planning Travel

The participants did not use tools for planning travel, there are no apps for minibus taxis, one of the participants (Chidi) arrives at the minibus taxi dispatch area to meet scheduled minibus taxis. Neo plans his travel against his work rota on a monthly basis so he knows what transport he will need to use according to his shifts. Leaving times are planned when doing early or late shifts at work, Ndidi currently has a ten-minute walk to her minibus taxi.

Transport Improvements

When transport improvements were discussed with participants, having the bus and train available would help them and if minibus taxis could be closer to Taxify, this would suit participants better. Having Uber equivalents available that were convenient, cheaper and reliable, particularly cheaper as long-distance travel is costly, this would be ideal for Neo.

Value Propositions

Low-fidelity prototypes in the form of sketched visualisations of value propositions were discussed with participants.

Value Proposition 1: Employer-Employee Model

The participants said if dispatch time was guaranteed, it is a good model. It would need to get people to work on time, the employer would need not be satisfied with transport being an excuse for being late, it would need to arrive 15 minutes before a shift starts. Less waiting time would be good, preventing late or no-show transport.

> *"It is perfect."*
> *"The employer would like it."*
> *This is "what they [employers] need"*
> *"Companies would pay for it"*

Value Proposition 2: Verified People Only

The participants believed that people would pay more to use it. It was not of much benefit to one of the participants and the extra cost was not worth it.

> *"Good idea"*
> *"I can use this"*

Value Proposition 3: Digitised Current System

The participants suggested that if it showed spaces left in a minibus taxi, the individual would select the one with low numbers so the taxi would leave sooner. Using data on the smartphone was not an issue, a cashless model is not an issue as Uber is used in the area and an Uber-style app that is quick, easy and instant is appealing. One participant said they would pay more for a seat in a vehicle that has seats left and would leave earlier. If there were problems with the phone, an option to pay by card in the car would suit the participant. This value proposition was seen to be good for safety and may have fewer delays.

> *"Good idea"*

Value Proposition 4: Efficient Route Utilisation

Changing the Place of Interest (POI) for pick-up would be a problem for one participant as they would need to check every morning and planning would be difficult for travelling to work daily. The same spot to build a routine would be helpful, 10-minute to the POI would be suitable, however walking to the POI in a non-safe area is an issue such as a good area with sufficient lighting.

7.2 Middle-to-High Income Community Contextual Inquiry

For the middle-to-high-income communities, the people involved were recruited through GoMetro's professional network. The UK Moses team were able to spend time with four male participants (names are pseudonyms) (Jacques, William, Richard and Amos) within this community, contextual inquiry was used, where the UK Moses Team observed how they travelled and ask questions about travel behaviour, similar to the interview guide in Appendix 5. However, the value propositions were not discussed directly due to time restraints but discussions around solutions indicated which of the value propositions would be needed by this community.

Mode of Transport

The people within this community own cars or hire cars to drive in Johannesburg or Cape Town or use e-hailing services. Cars were an option for these participants due to their affordability and convenience and were preferred compared to formal public transport. Minibus taxis could be delayed for 20-30 minutes and total journey times are unknown. The challenges participants experienced were predominantly traffic and congestion.

Journey Plans

With regards to planning travel, this community did not plan this on a daily basis and generally learned about the best ways to travel from other people. Google Maps had little information about transport, except for the Bus Rapid Transit, transport options and information were not readily available. There are also different sign languages that a traveller must learn to signal where they want to travel too. Typically, drivers are shouting and talking to potential customers who are on the side of the road. Transport systems are less digital and more 'in-person'.

Participants would drive to the Gautrain station and park at the station, but parking availability was a challenge. It was observed that multimodal transport was less common as direct travel on one mode of transport was more common. Hatfield was observed because there are multiple transport modes available. Bus services were observed to be branded as part of the Gautrain system and ran based on train arrival times, with midi-buses, smaller shuttle services, to serve certain routes.

Value Propositions

When discussing Moses, it was suggested by a participant that the employee-employer model would be popular as housekeeping services and nanny services require staff to be on time. They suggested people would be willing to pay extra for guaranteed, punctual staff.

7.3 Analysis

The low-income community interviewees suggested they preferred to take the cheapest option of transport, which was a minibus taxi or bus. They felt frustrated with unreliable trains and buses and preferred to use minibus taxis as they were reliable and on-demand however, they could increase their likelihood of being late to work due to high dwell times when picking up passengers. They suggested Uber equivalents were available and if taxis could provide a similar service to Taxify this also help the low-income community. Trains were unaffordable for these participants and minibus taxis and buses were affordable alternatives.

The high-income community interviewees typically relied on private or hire vehicles. They hired cars when visiting new areas. When using Gautrain, parking was a challenge. The participants did not generally plan their travel and learned about the best way to take their journeys by word-of-mouth. There was little digital information available to them to plan their journeys, in spite of a high rate of smartphone ownership. This is due to the informal nature of minibus taxis although companies such as GoMetro and WhereIsMyTransport are mapping this information for the purposes of digital consumption. There appeared to be a lack of systems that integrate services into one multimodal travel planner.

The limitations for the people interviewed was the lack of a personal and professional network in South Africa. External research agencies had been contacted to see if they could assist the project with the research, however their costs were high and outside what was feasible. For future research, having a South African research agency to support the project could be useful when reaching out to recruit participants. In addition, in Gauteng, 13.3% of the population speak English. The interviews were conducted in English and may have limited the communities included in the project. In future research, an interpreter could be present for non-English speaking participants and the project could then extended to participants from non-English speaking communities. In addition, there needs to be a better gender balance in the research to understand the specific issues relating to women and transport. There is also the limitation of bias, as the participants may be giving answers that they believe are what the interviewers wanted to hear.

8. Stakeholder Analysis and Meetings

8.1 Stakeholder Analysis

The stakeholder analysis identified key people with an interest or that could benefit from Moses. The stakeholder analysis identified their needs with an example and is in Appendix 6. GoMetro introduced the UK Moses team to key stakeholders in Johannesburg to explore both local government and transport provider needs in more detail.

- Technical Director POAD Consulting (formerly Acting Director at City of Tshwane) - A consultant to the A Re Yeng rapid transit system
- City of Tshwane
- Gautrain
- City of Cape Town

It was logistically and practically challenging to put a stakeholder workshop together, with individual or small group stakeholder meetings a more viable option.

8.2 Stakeholder Meetings Analysis

The findings from these meetings are documented in Appendix 6. The stakeholder meetings highlighted key points:

- Cash is a preferred way for people to pay for transport, the government is trying to change this by using Capitec instead - Capitec provides simplified banking services at a low cost. It makes its services accessible to all customers including low-income demographics. In reality, a third of the local population is living ‘hand-to-mouth’ and a bank card may not be a feasible option for them;
- Low-income groups rely on cash to pay for transport services and services such as minibus taxis are cash-based. E-hailing providers typically use a bank transaction model which is not accessible to these users. E-hailing providers such as Uber and Taxify are typically lower cost compared to meter taxis.
- There are over 1,000 minibus taxis in the Gauteng area contributing to carbon emissions.
- The minibus taxis do not depart until a minimum number of passengers has been met which can result in a high dwell time. The high dwell time is a barrier to some users who cannot wait.
- Minibus taxis have political and economic power, due to their importance to communities that rely on them to get to work. There is little regulation of the minibus taxi industry.
- Many minibus taxis operate illegally without correct insurance and licensing in place.'
- Taxi providers were paid to cease their operations so A Re Yeng can run at peak capacity. An agreement was made between A Re Yeng and taxi providers for the area that A Re Yeng is in operation to compensate drivers for lack of income and to help drive demand for the BRT system.
- Minibus taxis are underutilised for the last mile of travel.
- They are currently targeting national and international targets for carbon emissions. More research can explore this in further detail in the future.
- There are specific target audiences that would immediately benefit from Moses, such as hospital users that need more accessible direct forms of travel and workers that are commuting on a daily basis and currently use unreliable forms of transport

- Accessibility is a key issue as there are very limited options currently. This may explain why Dial-A-Ride services have a list of over one month long - this is an insight that also was highlighted in the literature review.
- Digitising systems could work but there would be big challenges to overcome

9. Transport Modelling for Carbon Emission

9.1 Measuring Carbon Emissions

There are six common models that are used to measure vehicle emissions for road freight transportation which could be extrapolated and apply to shared mobility based on fuel consumption[55]. Alongside these models, there is research on personal travel in the UK, which looks at distribution across income, economic activity, age, household structure in terms of car availability and their influence on emissions[56], as well as research to evaluate ridesharing and its impact on carbon emissions that can be replicated[57,58, 59]. The models and research were reviewed for the best approach to take to measure Moses's potential impact on carbon emissions.

The aim of Moses is to reduce traffic congestion. Past research on ridesharing in China found that Uber can reduce traffic[60]. Ultimately, the model needs to show the difference between the use of older cars with too many passengers on routes that are inefficient and potentially have a higher fuel use against the use of newer cars (taking into account the GHGs to produce these) with passengers travelling more safely.

There is debate as to how to evaluate CO_2 emissions with such approaches as the 'atmospheric inverse' approach, or modelling strategies such as forward, large scale or bottom-up terrestrial ecosystem models[61]. Moses could use a life cycle assessment method as this is widely applied to areas such as business decision-making[62] and has been used to evaluate the comparison of ridesharing services[63]. The MATSim model[64] can simulate daily plans of individuals and allow emission calculations on a detailed level which may be a useful model for measuring emissions for Moses.

Diana, et al. (2007)[65] looked at the emissions of demand responsive services. They apply an emissions mode, Computer Programme for estimating Emissions from Road Transport (COPERT) to find the least polluting transit system. COPERT4, is the most commonly used model in the European Union to estimate road transport emissions. They found that atmospheric pollution for

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55 http://www.pbmc.coppe.ufrj.br/en/component/docman/doc_view/188-2001-demir-et-al

56 Taming of the few - The unequal distribution of greenhouse gas emissions from personal travel in the UK: https://www.sciencedirect.com/science/article/pii/S0301421507003527

57 Investigating the potential of ridesharing to reduce vehicle emissions: https://www.researchgate.net/publication/320377527_Investigating_the_Potential_of_Ridesharing_to_Reduce_Vehicle_Emissions

58 Analysing the effects of car sharing services on the reduction of greenhouse gas (GHG emissions: https://webcache.googleusercontent.com/search?q=cache:y2BoplRAq-4J:https://www.mdpi.com/2071-1050/10/2/539/pdf+&cd=4&hl=en&ct=clnk&gl=uk&client=firefox-b-ab

59 Estimating the environmental benefits of ridesharing: A case of Dublin: http://www.tara.tcd.ie/bitstream/handle/2262/68116/TRD-D-09-00031.pdf;jsessionid=74280BF2D3F53807CC9F8815A8508361?sequence=1

60 An empirical analysis of on-demand ride-sharing and traffic congestion: https://scholarspace.manoa.hawaii.edu/bitstream/10125/41152/1/paper0003.pdf

61 Regional Carbon Cycle Assessment and Processes: http://www.globalcarbonproject.org/reccap/protocol.htm

62 https://dspace.lboro.ac.uk/dspace-jspui/bitstream/2134/12143/3/Thesis-2012-Itoya.pdf

63 https://www.ioes.ucla.edu/wp-content/uploads/uber-vs-car-ownership.pdf

64 Kickhofer, B. & Nagel, K. (2011) Mapping emissions to individuals: new insights with multi-agent transport simulations

65 Diana, M., Quadrifoglio, L. & Pronello, C. (2007) Emissions of demand responsive services as an alternative to conventional transit systems, 12, 183-188

demand responsive transport showed the most promise. Tongwane et al. (2015)[66] explored GHG emissions from road transport in South Africa. They found that minibus taxis were the most efficient transport mode.

The potential for mitigating GHGs through expanding public transport services is explored by Bubeck et al. (2014) in Gauteng[67]. South Africa is the largest economy in Africa and experienced strong economic growth since the end of the apartheid in 1994 and this has led to an increase in greenhouse gas (GHG) emissions. Gauteng Province is the centre of South Africa contributing one third of the national GDP. The Province has realised its importance for South Africa and wants to play a leading role for the country's climate protection strategy. The transport sector is a good starting area. The expansion of the public transport system is one option to mitigate GHG emissions, but the costs of suitable measures have not been evaluated. The public transport system of Gauteng is mainly built on minibus taxis and on a few scheduled bus and train services. Important expansions were the BRT in Johannesburg (Rea Vaya) in 2009 and the rapid rail system for Gauteng (Gautrain) in 2010. Evaluations show that both projects have not achieved passenger numbers, one factor may be its lack of affordability for low-income communities.

Nakamura and Hayashi (2013)[68] give an overview of strategies and instruments for low-carbon solutions in urban transport and find that the effectiveness of different GHG mitigation measures to be highly dependent on the city and urban land-use transport systems. To rank the cost-effectiveness of GHG mitigation measures in the transport sector, GHG mitigation costs could be considered. Numerous methodologies are available to estimate modal split in a city, more complex analysis takes into account the possible decisions of travellers considering their travel needs and socio-economic characteristics. For Gauteng Province, a travel demand model is available that incorporates socio-economic aspects and uses locally available travel surveys but does not take into account Rea Vaya and Gautrain and their future expansions. Future expansions are likely to increase passenger numbers but more needs to be done to increase the attraction of Rea Vaya and the Gautrain. Future transport systems of Gauteng need to integrate the various public transport modes more effectively, including minibus taxis. The minibus taxi systems should be standardised to ensure safety, security, reliability, availability as well as quality standards to make it available to broader parts of society. Existing policy and regulations should be implemented with due cognisance of the role of minibus taxis on GHG mitigation efforts. Possible routes could be defined in a stakeholder process to develop an integrated ticketing system for the whole network. Modal split models take socio-demographic factors into account and are appropriate to use in countries with rapidly changing living conditions.

9.2 Calculating Carbon Emissions for Moses

Key assumptions for the analysis were:

- All vehicles are fuelled with gasoline (95% of minibus taxi vehicles in South Africa use gasoline[69]).
- All people have access to a mobile phone.

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[66] Tongwane, M. et al. (2015) Greenhouse gas emissions from road transport in South Africa and Lesotho between 2000 and 2009, Transportation Research Part D, 37, 1-13

[67] Bubeck, S., Tomaschek, J. & Fahl, U. (2014) Potential for mitigating greenhouse gases through expanding public transport services: A case study for Gauteng Province, South Africa, Transportation Research Part D, 32 (57-69)

[68] Nakamura, K. & Hayashi, Y. (2013) Strategies and instruments for low-carbon urban transport: An international review on trends and effects. Transport Policy, 29 (264-274)

[69] Bruno Merven, Adrian Stone, Alison Hughes and Brett Cohen (2012) Quantifying the energy needs of the transport sector for South Africa: A bottom-up model. Cape Town, South Africa: SANEDI.

- The Moses application offered to passengers can optimise as well as the capacitated vehicle routing problem (CVRP) algorithm used in the analysis.
- The fuel consumption estimates of new and old taxis and minibus taxis (minibus taxis) from Merven et al. (2012)[70] are accurate.

Though COPERT and MATsim were considered for application to the data collected, it was decided that both pieces of software were not applicable for the initial analysis of the data. As indicated on MATsim's website[71] it is suitable for "large-scale agent-based transport simulations". Therefore, to use MATsim, data would need to be gathered on traffic densities and commuting patterns.

From the COPERT[72] website it states that "COPERT is the EU standard vehicle emissions calculator. It uses vehicle population, mileage, speed and other data such as ambient temperature and calculates emissions and energy consumption for a specific country or region." Therefore, to use COPERT in the present data analysis, data would be required for each scenario of interest (i.e. we need knowledge of the vehicle population, mileage and speed for each scenario). Data is available on the mileage of each taxi bus in the study, however there is no data on speed or knowledge of the full population of minibus taxis, making COPERT calculations difficult. There are also some further, secondary, considerations with regards to COPERT. Firstly, the product appears to be only available for Windows and will thus not run on macOS or Linux computers. Secondly, the data available for purchase is very expensive (up to 4000 euros). Thirdly, the data available for purchase is only available for the EU area (a South African data set is not available, necessitating the construction of the full dataset). Under present constraints these limitations make COPERT even more problematic to apply.

As COPERT and MATsim models were deemed as unsuitable for the analysis of CO_2 for the use of Moses in South Africa, the overall approach used involves the comparison of CO_2 emissions based on distance travelled, between the business-as-usual case and the case in which Moses is in operation within the region. The CO_2 emissions for the case in which Moses is in operation are constructed via the creation of distance estimates. The data acquired from GoMetro contains details on when passengers board and alight from each service (single trip) studied. These details may be used to frame the CO_2 reduction challenge as an optimisation problem, specifically a CVRP. We therefore seek to optimise each of the routes recorded such that all the original passengers are served (with Moses in operation) but at a lower total level of GHG emissions.

An authoritative reference on vehicle routing problems is the volume edited by Toth and Vigo.[73] Those interested in further details of CVRP could consult this volume. There are also a number of prominent libraries and tools that provide concrete implementations of a number of algorithms that are described within the literature on the CVRP. All of these algorithms aim to minimise the overall “cost” of serving a number of customers with capacity-limited vehicles. Here we use such algorithms to try and minimise the overall emissions associated with a given set of customers. The minimised emission estimates produced in this way are then interpreted as the emission estimates made possible where Moses to provide services for the given passenger groups. This is a

[70] Bruno Merven, Adrian Stone, Alison Hughes and Brett Cohen (2012) Quantifying the energy needs of the transport sector for South Africa: A bottom-up model. Cape Town, South Africa: SANEDI.
[71] MATsim: https://matsim.org/
[72] COPERT: https://www.emisia.com/utilities/copert/
[73] Paolo Toth and Daniele Vigo (2014) Vehicle routing: Problems, methods and applications. 2nd ed. Philadelphia, PA: MOS-SIAM.

reasonable assumption since the CVRP algorithms are exactly the same kind of algorithm that can be found embedded within ride sharing systems.

Two key papers provide fuel consumption details that can be used in the data analysis[74, 75]. Of these, the paper by Merven et al. provide fuel consumption details for both cars and minibus taxis (MBT) in South Africa in terms of gasoline litres consumed per 100KM:

	Average Vintage	New Vehicle
Minibus	15.1	13.5
Car	9.1	8.3

The CO_2 conversion factor used was obtained from the UK government website which provides CO_2 conversion factors for a large range of fuels.[76] The conversion factor used, for petrol from a mineral source, is 2.30531 kgCO_2e/litre. There is no indication of what Euro standard minibuses are. Merven et al. (2012) do not link minibuses to a Euro standard. The calculations are based on distances, with driving characteristics such as acceleration, deceleration, speed and idling are not being included. Future calculations with the dataset to gain approximate knowledge of driving characteristics based on the coordinates, meaning that the traffic data would be needed to then estimate driving characteristics for optimised routes.

9.4 Results

The steps taken to conduct the carbon emissions calculations are in Appendix 7.

Figure 2 estimates the overall gCO_2e emitted for all journeys that are part of the survey (the "Original Journeys" column). The total gCO_2e emitted as a result of each of the four combinations of fleet vehicles and associated technology (i.e. Moses optimisation algorithms) are then shown. As can be seen, route optimisation with the same kind of vehicle used in the original trips produces a small reduction in total gCO_2e. If new minibus taxis were used and the journeys optimised, a greater reduction in gCO_2e would be possible. Finally, for each of these scenarios, if taxis were used alongside minibus taxis further gCO_2e efficiency gains could be realised.

Each single original journey features one minibus taxi, assumed to have 'average' emissions, for each single journey where each journey features one or two vehicles as well as considering a case where one or two vehicles are 'new'. For the aggregate results this is where the 'new minibus taxi' assumes all minibus taxis are upgraded and 'new minibus taxi and taxi' assumes all vehicles are upgraded rather than assuming the whole fleet is replaced. We are assuming all vehicles are using petrol as fuel, based on Mervin et al. (2012) but could be adjusted in future iterations.

[74] Francisco Posada (June 2017) South Africa's new passenger vehicle CO2 emissions baseline analysis. Final Report. Washington, DC: ICCT.
[75] Bruno Merven, Adrian Stone, Alison Hughes and Brett Cohen (2012) Quantifying the energy needs of the transport sector for South Africa: A bottom-up model. Cape Town, South Africa: SANEDI.
[76] See https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2018

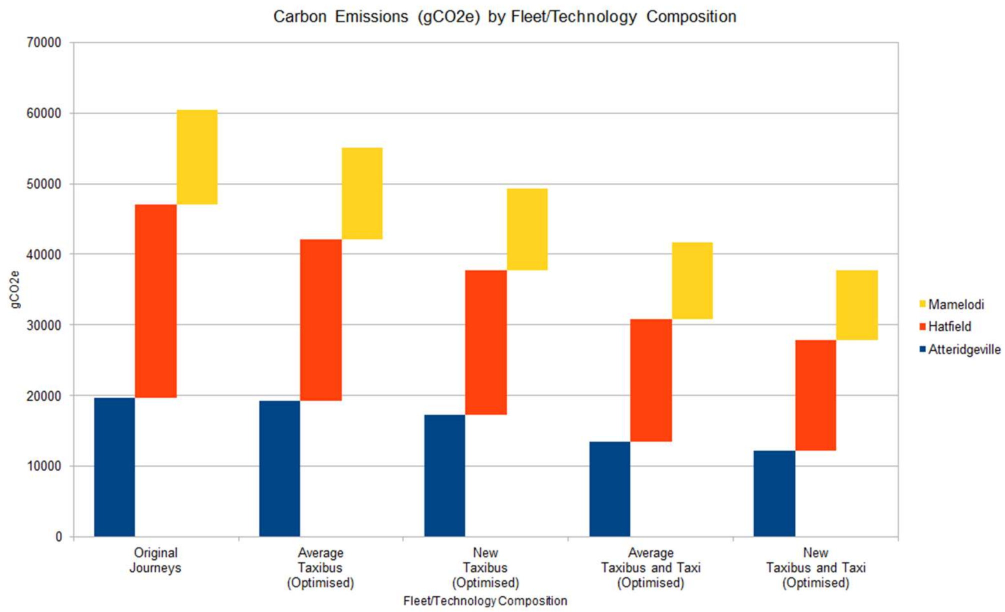


Figure 2: CO_2 Summary of gCO_2e by fleet/technology composition

See Appendix 7 for the breakdown of Hatfield, Mamelodi and Atteridgeville.

9.5 Analysis

The hypotheses were as follows:

1. Sharing rides to similar locations in a direct taxi (avoid indirect scheduled routes to areas with limited demand);
2. Maximise efficient use of capacity in vehicles (don't send a large bus if it is not fully occupied);
3. Improving the quality of vehicles that are used (through incentivised regulation);
4. Promoting multi-modal journeys that make use of more efficient modes of transport such as the train.

The analysis showed that Moses has the potential to reduce CO_2 emissions through modifying routes, vehicle size, vehicle age and the number of vehicles to provide routes. The analysis considered all four factors. It could be assumed that minibuses would be at maximum passenger capacity as it was found in the observations that minibus taxis operated when vehicles were full and this contributed toward longer dwelling times at each stop, however this is not confirmed within the dataset and was not factored into the analysis as accurate passenger capacity was unknown.

The analysis demonstrated that optimising the use of taxis and minibus taxis together has the potential to significantly reduce CO_2 emissions. The analysis suggests that optimising the fleet with having higher quality vehicles improved CO_2 emissions. The analysis did not include the promotion of multi-modal journeys, but it may be assumed that the use of rail reduces carbon emissions and services should be able to support this, through shared transport.

The data analysed, although useful, was gathered in an unbalanced manner (with only five minibus taxis considered at Hatfield, 12 at Atteridgeville and 23 at Mamelodi). Unfortunately, the sample is not representative and therefore the generalisations we can draw are limited. One service item was excluded because the stop points did not fully correspond to the recorded route (as indicated by the list of GPS coordinates).

Taking these limitations into account, it is not possible at this point to say definitively that Moses could reduce CO_2 emissions across the country by a specific percentage or to say that Moses could reduce CO_2 emissions across specific regional areas by a specific percentage. Nevertheless, we have been able to show that the current taxi bus operations are sub-optimal and that optimisations (e.g. as available via a future Moses ride sharing application) and fleet modification could substantially reduce overall CO_2 emissions.

The analysis did not consider full real-world driving emissions; however, additional pollutants could be assumed to reduce if emissions are reduced. Exploring other pollutants such as nitrogen oxide (NOx) (a combination of nitrogen and oxygen), hydrocarbons (HC) and particulate matter (PM), could be explored in future calculations.

10. Key Themes and Discussion

This project has included a wide range of secondary and primary research:

- An extensive literature review,
- GoMetro data on Gauteng's transport systems and passengers,
- Online survey,
- Observations,
- Interviews with users from low and middle-to-high income communities,
- Stakeholder meetings,
- Transport modelling and visualisation.

This section focuses on the thematic analysis of the primary data. The UK Moses team used the KJ Technique, the process is as follows:

- Establish focus questions,
- Talk about each piece of research and everyone take notes,
- Write down key areas of interest on post-it notes,
- Organise the post-it notes into themes and name each theme,
- Vote for the most important groups,
- Rank the most important groups.

See Appendix 8 for the themes. The key themes are discussed below.

10.1 Politics

The political nature of informal and formal public transport and the relationship between them and local and national government is nuanced. Formal public transport has had heavy investment, with incentives for informal public transport (minibus taxis) to reduce operations in areas where BRT delivers services. However, from our research, it was found that BRT can be problematic for passengers due to long payment waiting times, increasing travel time where direct, minibus taxis can deliver this service, as well as prices which are unaffordable for low-income communities, making minibus taxis a viable option.

The taxi industry is economically, socially and politically powerful. If a new operator were to enter the market, it would need to have the support and permission from taxi operators and unions as the alternative may be that it would not be possible to operate and deliver services in specific geographical areas. This would be important if the value proposition for digitising minibus taxi routes and optimising taxi routes were to become a reality. A result of not having their support would be Uber picking up rail passengers, Uber drivers must pick-up and drop-off rail passengers close by the rail station as they are discouraged to go near the station as it results in territorial violence.

10.2 Payment

A 'cash-culture' operates in South Africa with one of the contributing factors being that some of the population are living 'hand-to-mouth'. There is a divide in South African society between the 'banked' and 'unbanked', making cashless payments challenging, but it is also an opportunity. It may be possible to use alternatives such as ‘airtime’ Econet and Google Mobile Money, both of which exist in Kenya as well as ‘Capitec’ to promote a basic bank card.

Continuing the cash system means that there are barriers in exposing the numbers of drivers and operators that do not want to disclose their income for tax purposes or for taxi operators to know how much revenue the driver is generating.

People prefer to pay the driver directly and the driver prefers to receive payments directly. Having a mix of digital and cash payment, which Taxify deliver, would need to be available for a transport technology company, such as Moses.

10.3 Customer Experience: Improving Safety and Efficiency

For Moses to be adopted in South Africa, a high level of customer experience is a key factor. This can be achieved in a number of ways across both low-income and middle-to-high-income communities.

Firstly, to take measures for personal safety on shared transport, when optimising journeys, the drop-off points must be in safe areas. Past research highlighted a number of ways that taxi companies can improve women’s safety on this form of transport such as training drivers to understand more about women’s safety and having confirmed routes. Having digitised routes, where there is information about the drivers and booking onto taxi routes, similar to e-hailing products available in the UK, would benefit South African women.

Secondly, having vehicles available which are accessible would benefit South African citizens. Currently there are few provisions for wheelchair users or people with disabilities, to access transport, pushing them further into poverty and increasing their social exclusion. A challenge here, is the vehicle, as taxi companies would need to be incentivised to have wheelchair friendly vehicles with trained drivers. In addition, drivers would need to be incentivised to have fewer or a limited number of passengers.

Thirdly, vehicle safety and safe driving behaviour is important for customer experience and improving passenger safety. Drivers currently operate without licenses while they are waiting for these to be processed, vehicles are old and uninsured, putting passengers at risk. In addition to the poor state of vehicles is the dangerous driving behaviour by many drivers. This driving behaviour is actually encouraged by the current payment model for drivers which encourages high passenger numbers and the illegal overcrowding of vehicles combined with a need for the driver to get through the routes as quickly as possible and as many times as possible regardless of speed limits or road conditions.

Having efficient, optimised routes which are digitised would benefit customer experience as it would provide them with choices of taxis. Currently, taxis are hailed in-person and it is not always clear which is the best option in terms of journey times. Taxi dwelling times can be long, and this frustrates passengers. Customers are looking for convenient, available and reliable transport and transport technology could potentially deliver many of these needs.

10.4 Advancing Shared Transport Technology

South Africa is car-centric and there is a divide between those that own a car and those that do not. From the research, it has been found that minibuses largely serve low-income communities and making these more accessible through digitising and legitimising minibus taxis could help this community access transport and provide them with choices. Currently, there is little information digitally to assist in transport decision making, Google maps only has data for BRT routes. Transport information is largely communicated either verbally or by driver's hand signals.

Aside from the low-income communities, there are other communities that would benefit from a digitised, aggregated, minibus taxi service such as schools, employers for housekeeping staff or nannies, hospital patients as the Dial-A-Ride has a long waiting list and mothers with new-born babies coming home from hospital.

There are technology companies that exist in South Africa that are mapping out and digitising public transport information, including GoMetro and WhereIsMyTransport. It is feasible and realistic to assume that it is possible to use this information to integrate paratransit services with BRT and the stakeholders showed a willingness to do this, particularly to improve end-to-end journeys for multimodal journeys. Minibuses are being underutilised and integration through digitised systems could optimise the use of this resource.

Optimising journeys can potentially help customers plan their journeys, but the present research highlighted the benefits it could have for the environment. In the small dataset from the travel survey, which should be extrapolated to a wider context with caution, it showed that a reduction of CO_2 emissions would be possible if journeys were optimised with new vehicles and if the most suitable vehicle was used for the journey to reduce the use of underutilised vehicles.

Government support is needed to move transport technology forward, particularly for minibus taxis. Top-down regulation has not been a successful strategy, however partnering with taxi associations and unions and working with them would benefit South Africa in how they are currently utilised. Improving vehicle standards will play a large role in reducing carbon emissions and if these vehicles were used in the most efficient way possible, using intelligent digitised systems, it would reduce carbon emissions further.

The overall research has shown that the environment in South Africa could support future transport technology for shared mobility:

- People are willing to share transport;
- Minibus taxi routes are becoming digitised, providing data for transport technology companies;
- People can and do access data on smartphones to seek travel information by turning it on when it is required;
- There is a willingness to integrate informal and formal transport;
- There could be a carbon emission saving if vehicle engine standards are improved, but government support would be required to ensure this happens in practice;
- Challenges exist but these could be seen as opportunities such as overcoming the cashless payment for the 'unbanked' communities;
- There are markets available that could immediately benefit from having digitised, shared mobility that both do and do not include rail passengers, such as employers paying for a service that ensures employees arrive on-time;
- There is a growing market for the use of apps for transport;
- There are wider benefits to safe, reliable, shared transport such as improved personal safety in booking routes with a known drop-off point;

- Differing ways to incentivise drivers and changing driver payment models such as using set hourly rates;
- A need for affordable, low-cost transport, which is widely available for low-income communities;
- Taxify is a model that was highlighted that the participants from low-income communities would like taxis to move towards which may give transport technology companies a model to use and build on.

11. Further Research

Throughout the research, a number of possibilities of future research arose.

- **Women's Safety and Accessibility:** An important issue for the key stakeholders as well as the UK Department for International Development (DFID). This can be explored further in how Moses can address this in the delivery of their services and have a better representation of women in the primary research to explore women and transport in more detail.

- **Taxi Associations and Taxi Drivers:** Taxi Associations hold large power economically and politically in South Africa and Moses gaining their support will be key. Further research can explore what their needs would be from Moses and how Moses can address these and work collaboratively.

- **Industrial Research:** A small pilot to explore how Moses would apply to existing transport infrastructure and systems and to identify how people would use Moses in a real-world setting.

- **Low-Carbon Research:** We have explored existing travel behaviour and modelled this alongside different options based on improved vehicle specification or optimised routing using carbon emissions models that have been used multiple times in past research. Further research could explore the impact and evaluate Moses's influence on carbon emissions in a real-world setting if it were able to change travel behaviour using an operating model informed by this present research.

  The optimisation conducted in the research could be made more realistic in a number of ways.

  Firstly, a number of simulations could be run where only a subset of people have access to mobile phones, thereby decreasing the ability of the emulated Moses system to optimise. This would be expected to decrease the size of the reduction possible through the use of ridesharing but would not eliminate the improvement. Secondly, we could consider scenarios where the number of vehicles available in the Moses fleet is limited.

  Further work leading on from improvements to the original optimisation-based comparison could include a full scale MATsim simulation (after additional data was gathered and cleaned). If sufficient data were gathered and the correct model obtained, country-wide CO_2 impact assessments could be conducted (these are not yet possible due to the quantity and accuracy of data required for such an assessment).

- **Wider Applicability of Moses:** South Africa is not the only place which has the BRT system. Similar research regarding travel behaviour, travel needs, and transport modelling could be done to see how Moses could be applied to other areas in Africa such as Lagos as well as beyond Africa including Brazil.

12 Conclusion

This research has uncovered interesting and useful insights into shared mobility challenges and opportunities in South Africa, and many of the findings can be generalised to other countries in the African continent.

It is clear that there are numerous benefits from introducing Moses' shared mobility model. This study has outlined ways for these benefits to be realised by identifying current barriers to its adoption and the quantification of its benefits. A deeper understanding of the area helps us to design a compelling and working service for the country.

Moses intends to continue the research and development activities that were carried out during this project and deliver one or more of the value propositions presented in this report. Moses will continue to explore commercial opportunities that have arisen from this project.

There were a number of limitations to the approach, which have been discussed throughout the report. The report took a case study approach in Gauteng, there were limitations to focusing on one geographical area and studying three areas in more depth in the travel survey; Hatfield, Atteridgeville and Mamelodi. These areas were chosen to give an indication of the ways in which low-income and middle-to-high-income communities travel. There were limitations to the data collected on these three areas as the focus was on frequency of routes, passengers, dwell time and fares. There were limitations to the way in which the data was analysed to calculate carbon emissions as the dataset was relatively small. However, in spite of the limitations, the data found differences in travel behaviour between the two communities, and the challenges that low-income communities have with the transport available. In the future, a wider dataset can be collected and analysed that takes into account driving characteristics and traffic data.

The qualitative research was limited in that it focused on a relatively small dataset and was predominantly male. For user research, for one user group the number of participants is five ideally with three to four as acceptable. However, more data needs to be collected on a wider level, with more women represented in the research. The results indicated the issues that low and middle-to-high income communities have, such as unreliable transport or unaffordable public transport. The observations focused on one station, more observations could be done in future research. The observations in this project highlighted under-utilised vehicles and the way in which people choose which mode of transport to use and which vehicle using in-person techniques rather than digital. The stakeholder meetings highlighted challenges for transport providers and local government, and what their aims and wills are for future public transport.

In spite of these limitations, the project indicated a number of challenges and opportunities for Moses and future transport technology to expand into South Africa. We recommend that the insights and opportunities uncovered in this research project are used as the basis of a larger demonstrator project to prove the benefits in a real-world deployment. There is an opportunity to deliver impact in collaboration with interested local and national transport operators.

Appendices

Appendix 1: GoMetro Graphs

Hatfield

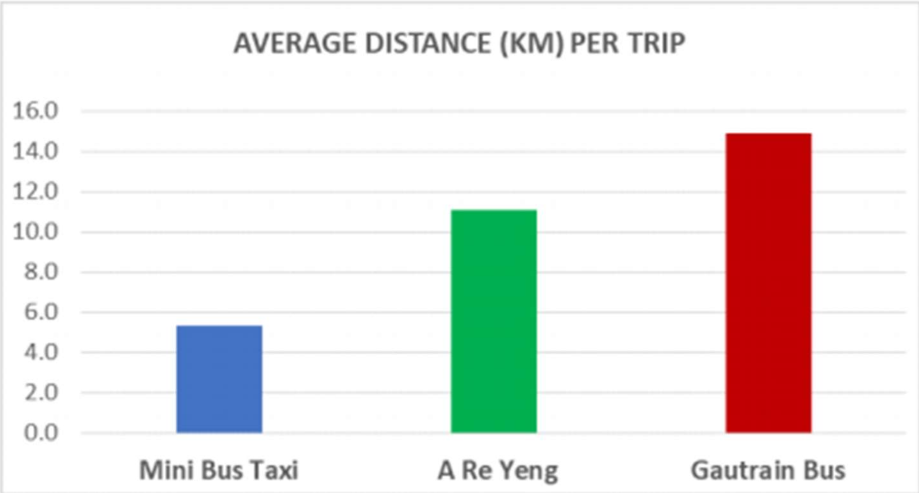
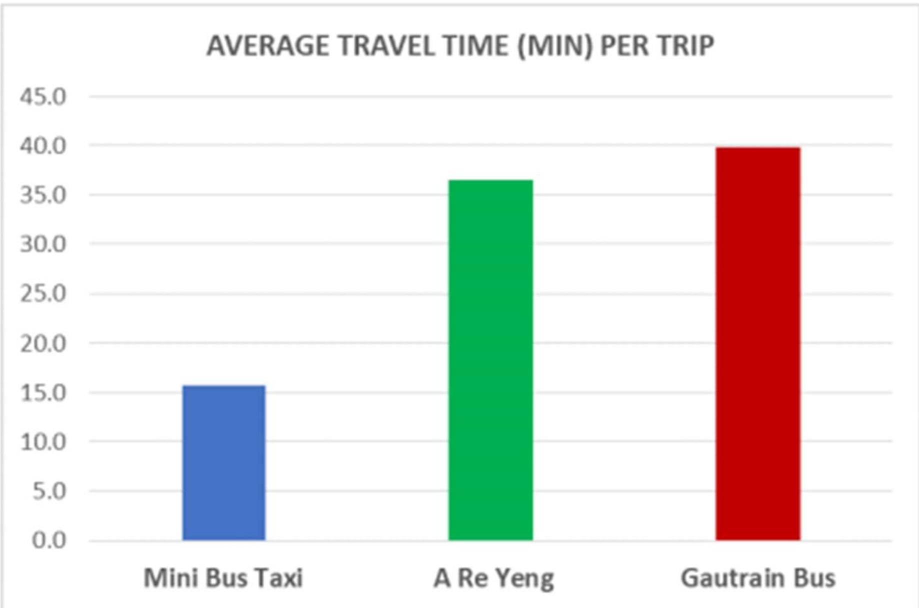
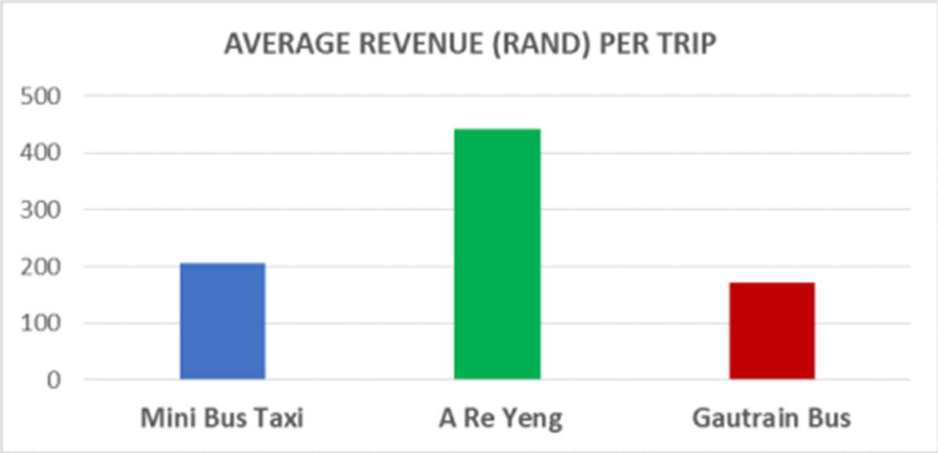
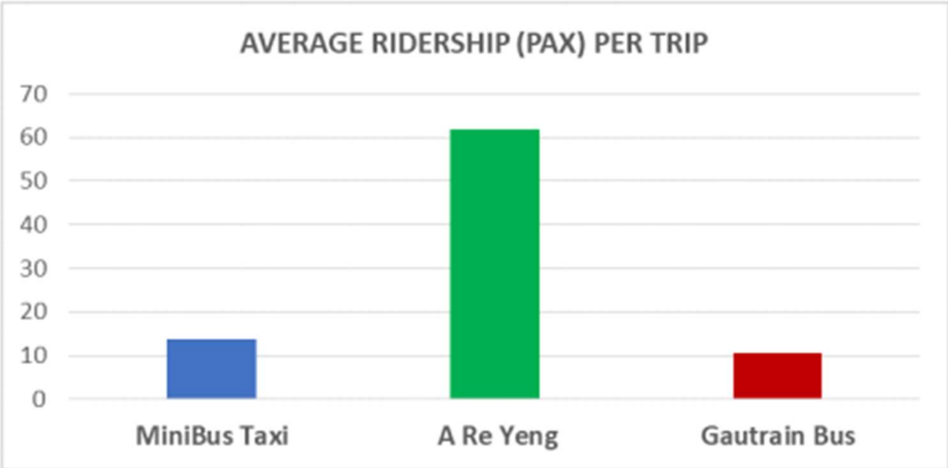
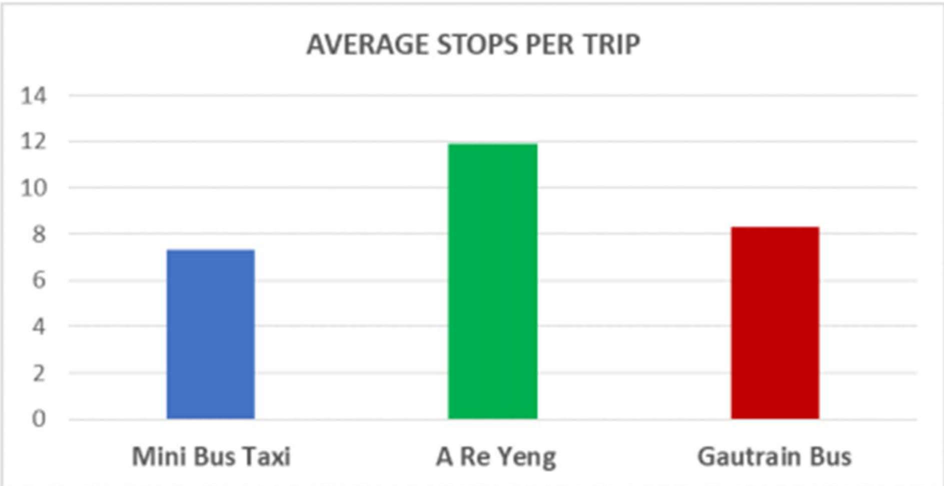


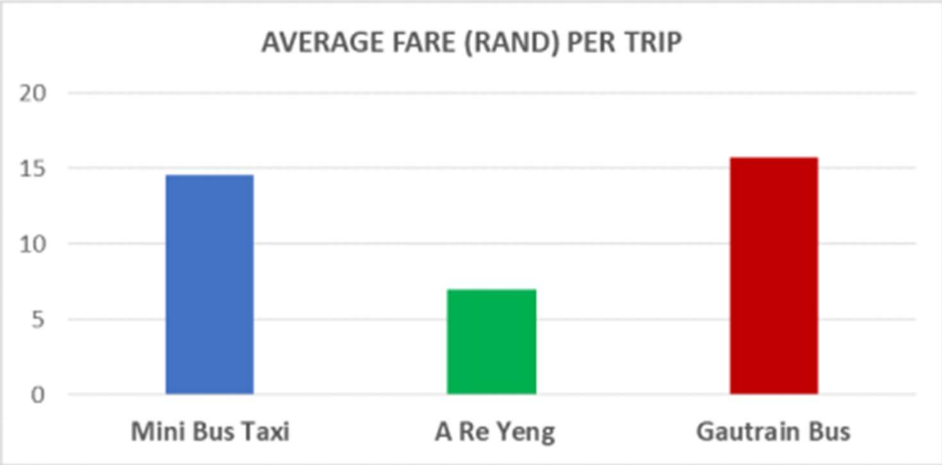
Table 8: Hatfield: Average Distance Per Trip




AVERAGE REVENUE (RAND) PER TRIP
500
400
300
200
100
0
Mini Bus Taxi
A Re Yeng
Gautrain Bus


AVERAGE RIDERSHIP (PAX) PER TRIP
70
60
50
40
30
20
10
0
MiniBus Taxi
A Re Yeng
Gautrain Bus

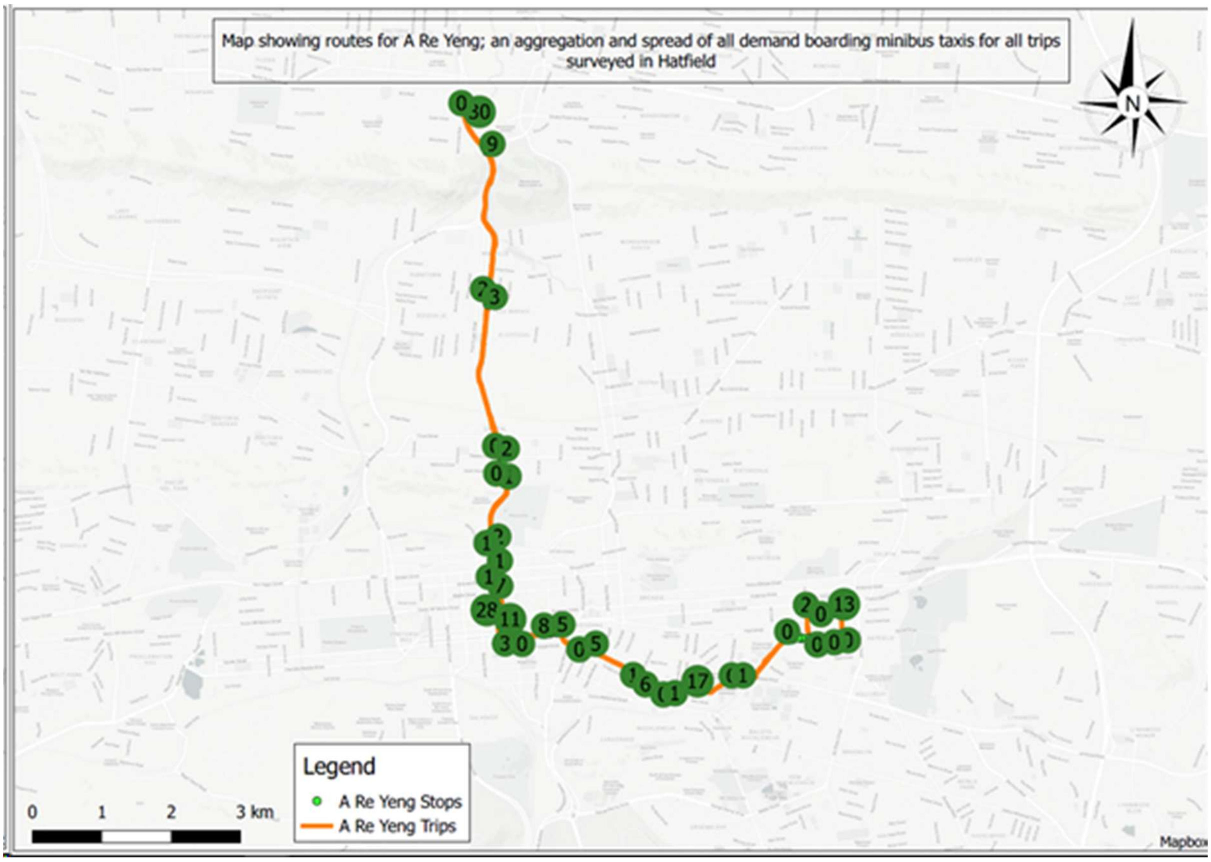

AVERAGE STOPS PER TRIP
14
12
10
8
6
4
2
0
Mini Bus Taxi
A Re Yeng
Gautrain Bus



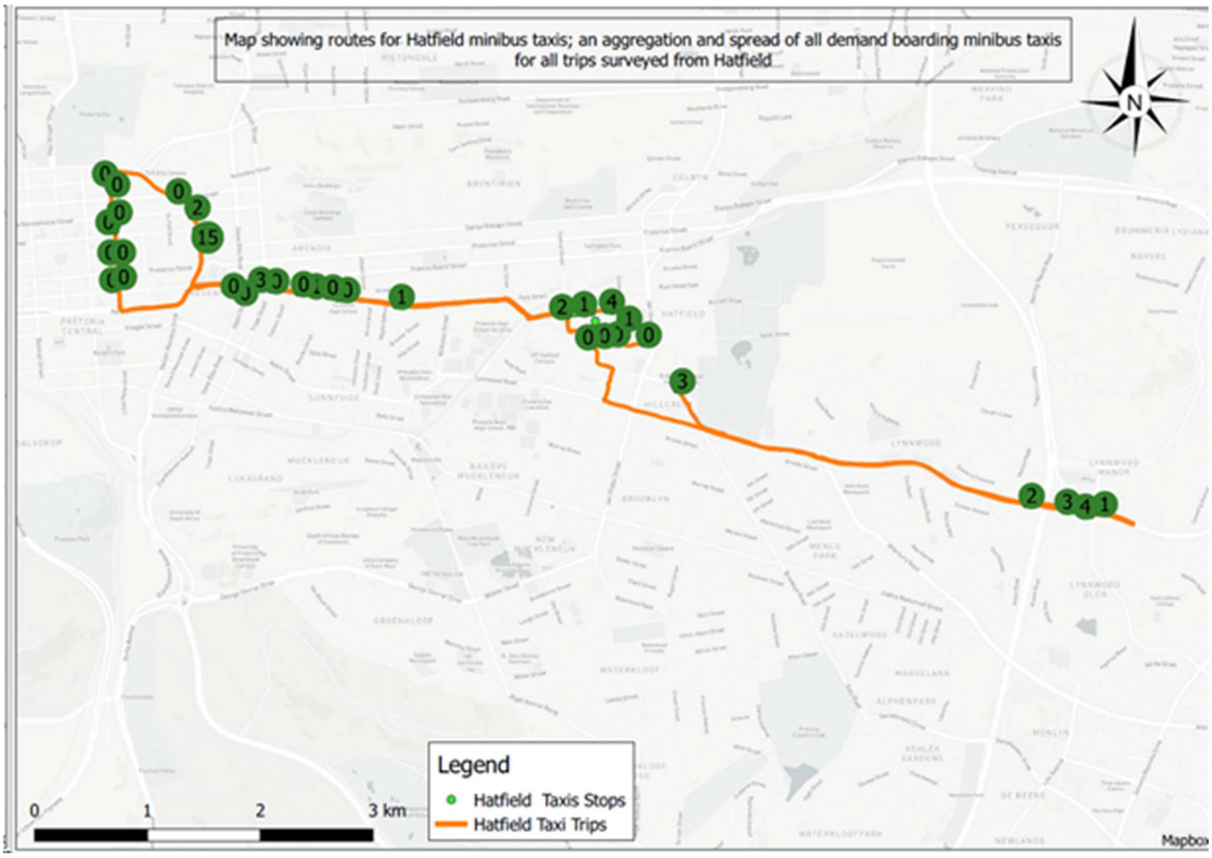
AVERAGE FARE (RAND) PER TRIP
20
15
10
5
0
Mini Bus Taxi
A Re Yeng
Gautrain Bus

Appendix 2: Maps

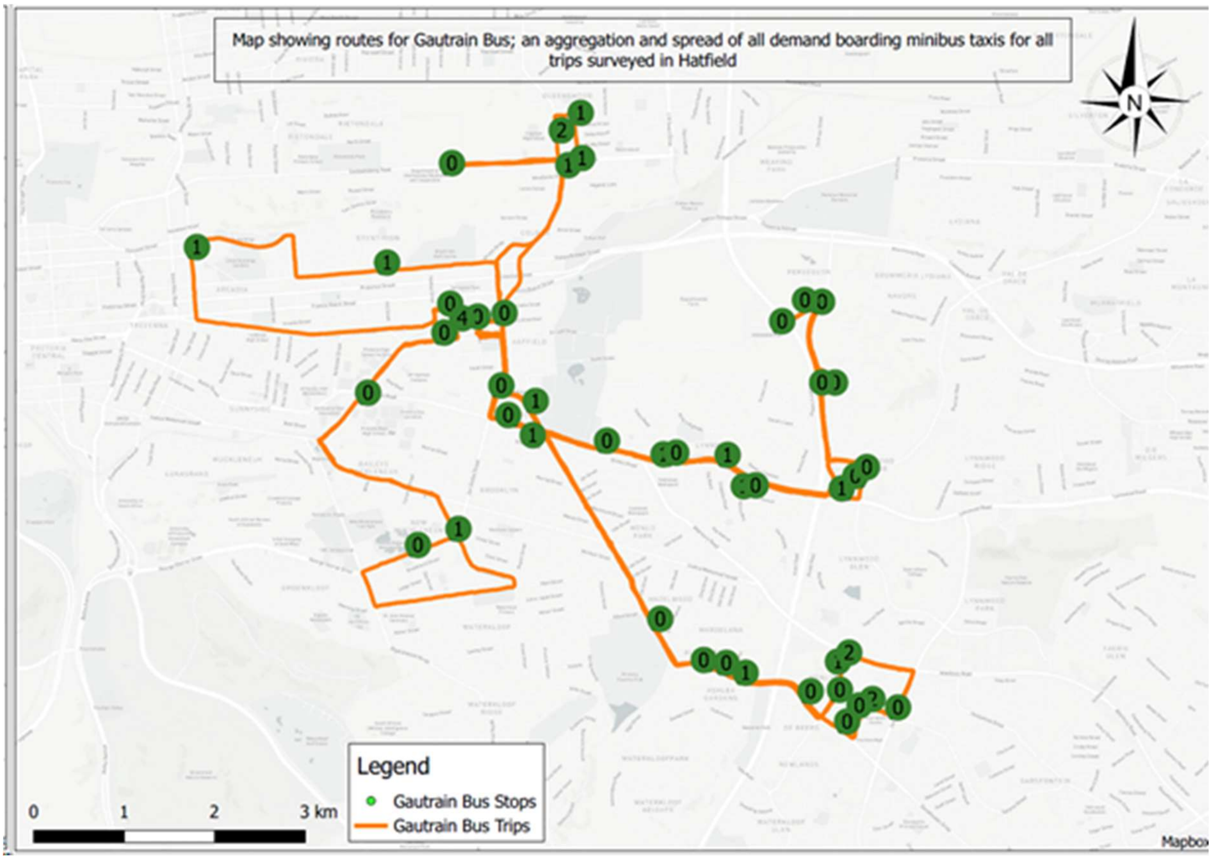
Below is a map showing the routes for A Re Yeng in Hatfield:



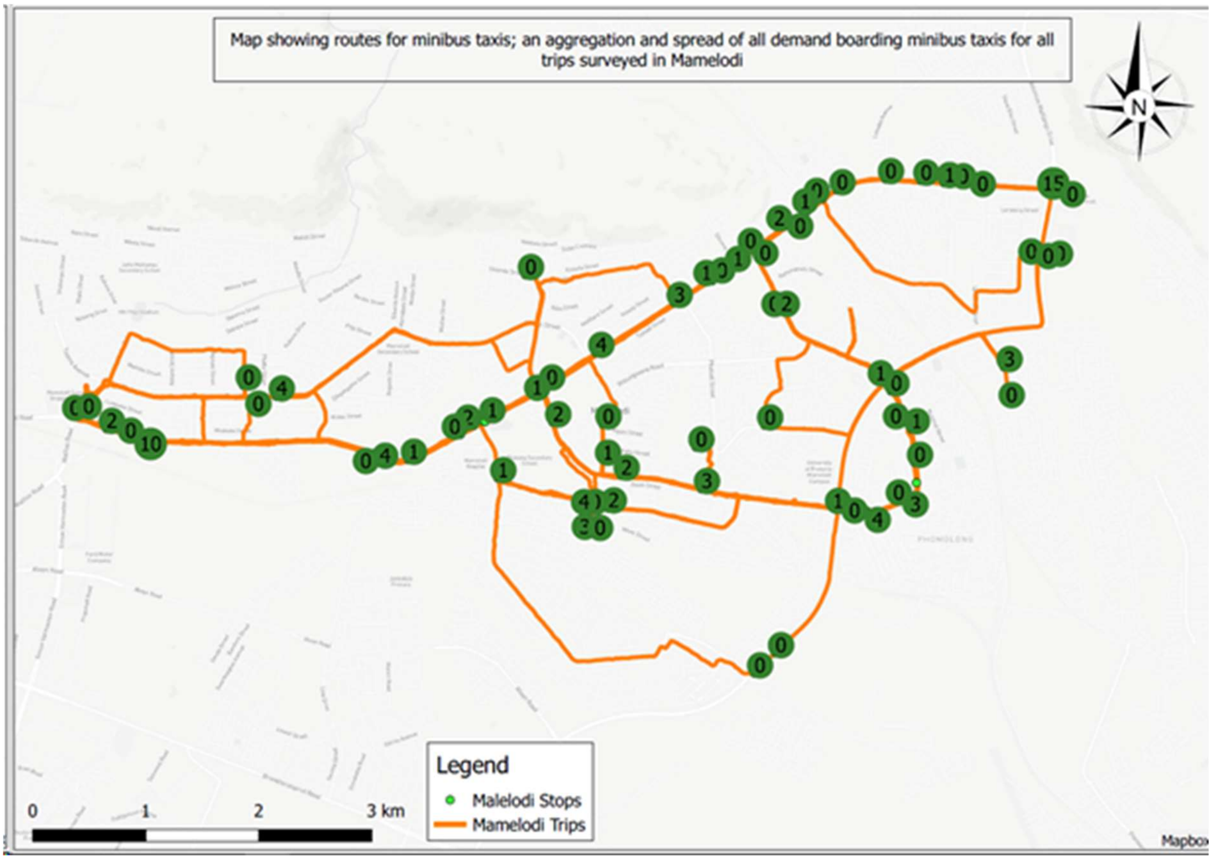
Below is a map showing the routes for minibus taxis in Hatfield:



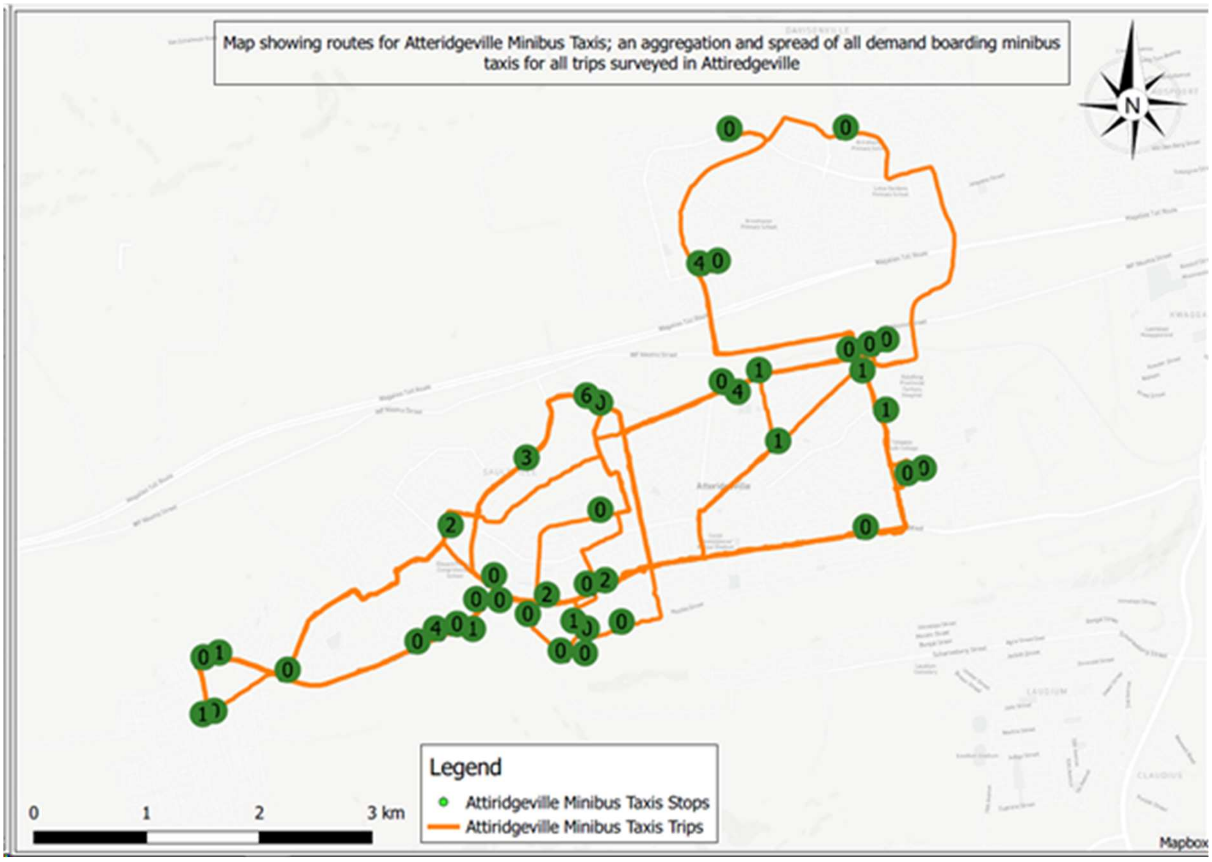
Below is a map showing the routes for Gautrain buses in Hatfield:



Map of the minibus taxis in Mamelodi



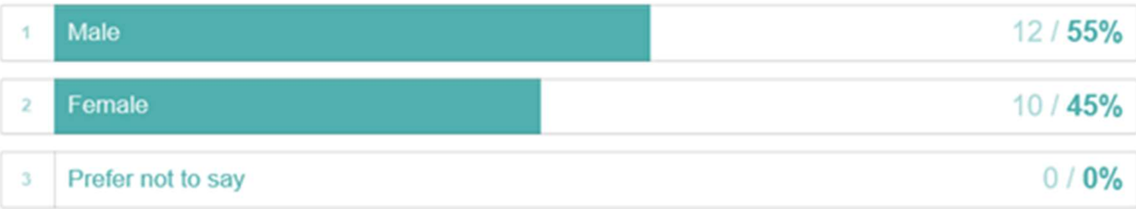
Below is a map showing the routes for minibus taxis in Atteridgeville:



Appendix 3: Online Survey Results

What is your gender?

22 out of 22 people answered this question



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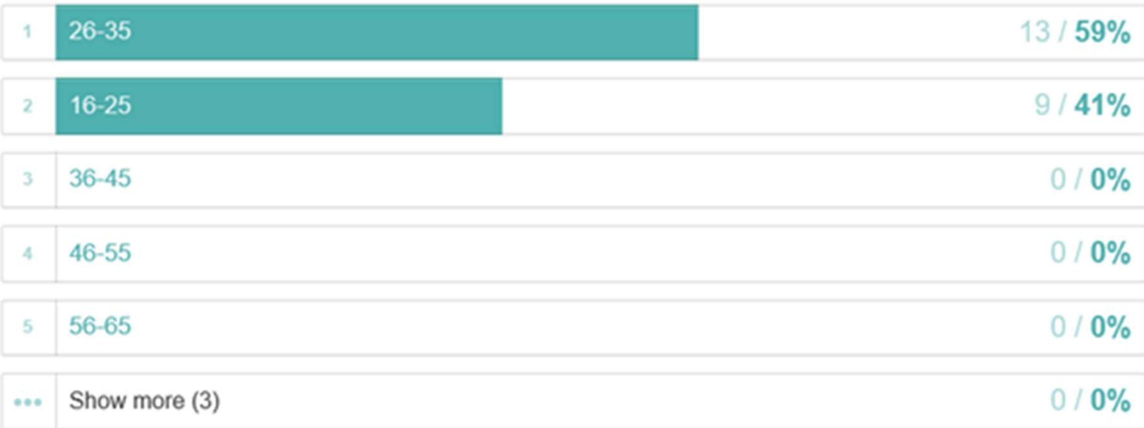
What is your age?

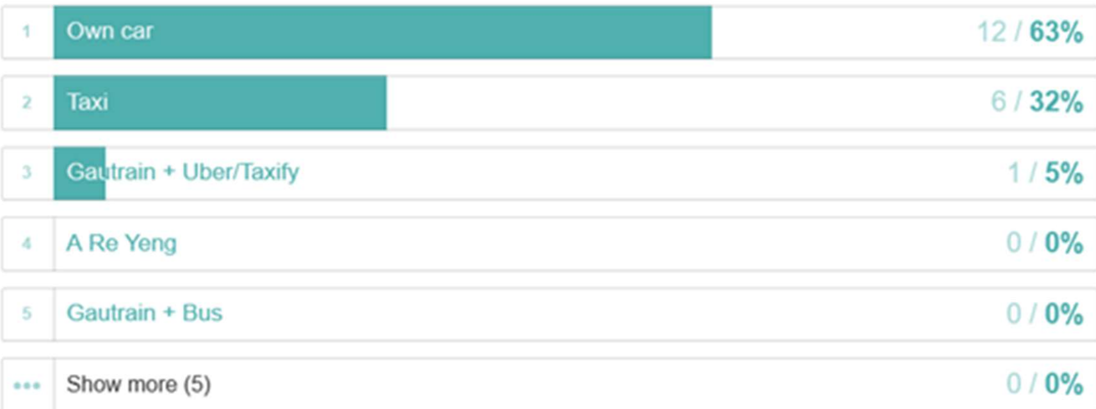
22 out of 22 people answered this question



-

How do you currently travel to work? (Tick as many that apply)

19 out of 22 people answered this question



-

What are your biggest challenges with transport? (Select as many as you like)

22 out of 22 people answered this question

1	Personal safety	6 / **27%**
2	Convenience	4 / **18%**
3	Congestion on the roads	3 / **14%**
4	Cost of transport	3 / **14%**
5	Time taken to travel	2 / **9%**
^	Show less	
6	Comfort	1 / **5%**
7	Lack of choice of routes available	1 / **5%**
8	Other	1 / **5%**
9	Vehicle safety	1 / **5%**
10	Accessibility (i.e. wheelchair friendly)	0 / **0%**
11	Can't use too much data on my phone to find information on travel	0 / **0%**
12	Lack of choice of transport mode	0 / **0%**
13	Lack of frequency of transport services	0 / **0%**
14	Passenger capacity within a vehicle	0 / **0%**

Appendix 4: Observation Findings

Assumptions:

- Minibus taxis will operate close to the station
- The station will be busy
- The bus rapid transit system will be operating close to the station

Venue	Hatfield Gautrain Station, Hatfield, Pretoria, South Africa
Date	26 February 2019
Time	7:00am - 9:00am
Weather conditions	Clear and sunny, 20 degrees Celsius approx.
Observers	Aaron Mason, Terry Yoell, Isaac Mzengereza, Lets

General	● Approximately 150/200 people per train departing at Hatfield ● 50% of people arriving at and 50% departing from Hatfield train station ● Almost 50% of people observed could be classified as students ● Large proportion of people walking to final destination from Hatfield, others were using Gautrain coaches ● No minibus taxis in the area ● Meter taxis by entrance (2/3 vehicles) - no bookings evident throughout observation study ● Car park in frequent use and most spaces occupied. Total utilisation unknown. About 5/10% of visitors to Gautrain station were using it. ● Small number of people getting dropped off at the station by presumably family/friends ● People generally moving around the area with purpose - limited waiting around outside the station - presumably commuters that know the area well ● Limited multi-modal travel, i.e. transition between modes, at this location ● People will use data on smartphone but will try to limit its use if they can. For example, they may search at beginning of journey and then turn off data while in transit.
Gautrain coaches	● Limited utilisation, most coaches had a maximum of ten occupants. Heavily underused. ● People getting off train and waiting for coaches, up to 15 minutes. ● Used by “upper blue collar” or “white collar” groups predominantly ● Large diesel coaches: Mercedes Benz BUSMARK - guessing they are 50-seaters
A Re Yeng Rapid Transit	● Underutilised - majority of buses were empty
Ride hailing	● Most travellers that use ride hailing providers have Uber and Taxify installed on their phone - they use these to compare price/availability

Private shuttles	● On other side of the station, corporate shared shuttles for employees going to businesses
Notes on Minibuses	● For cost-sensitive users. Normally won't depart unless full therefore may have dwell time of up to 20 mins. ● Major upside required to shift the existing culture away from current evolved system

Hatfield Station: Bus Rapid Transit System

Appendix 5: Interview Materials

DFID Research Project on Low-Carbon Transport

Participant Information

What is the research for?

The Department for International Development (DFID) is funding this project to explore low-carbon transport in South Africa. Our company, Moses Mobility, based in the UK, is looking into this in more detail through research, to develop ideas as to how our products could fit and offer ways to help.

Why have I been invited?

We are interested in speaking to people who live in Johannesburg and currently use their own transport, minibus taxis and/or public transport.

What do I need to do?

You have been invited to take part in a short 30-45 minute interview. An interview is a discussion about a certain topic. The interview will be in English and you can bring a translator if you wish. We are offering ZAR100 to express our gratitude for your time participating in the interview.

Confidentiality

You will be asked to sign a consent form, which we will go through together. This shows that you are aware of the purpose of the research, your rights as a participant and confirm whether you are happy for us to audio-record the interview. All of the views shared will be anonymised and any identifiable information will be kept confidential.

What will happen to the research findings?

The research is being carried out by Moses, a transport technology consultancy who will be analysing the data for the DFID report and DFID will see the themes and insights from the research. The findings may be featured in future public presentations or reports through DFID, however, your personal information will be kept confidential and your views will remain anonymous.

Further information
If you have any further questions, please contact [Details deleted]

Interview Guide

PREPARATION

Things to bring:

- ZAR100 per person
- Receipt forms for incentives
- Consent forms
- Mobile phone for recording audio and for photos
- Laptop/notepad for note taking
- Paper and pen for the participant in case they want to visualise their point

THINGS TO KEEP IN MIND WHEN INTERVIEWING:

- Ask open questions
- Don't ask leading questions that can influence someone's answer
- Observe and note their behaviours and workarounds they use
- Observe their environment and the things they use/have around them
- Remain neutral
- Take photos of them, things they show you, things that may be of interest and related to the research (of course ask first)
- Capture key quotes and map journeys
- Ask about recent experiences, ask about actions not opinions and ask why

PRE-INTERVIEW

Introduction
Hello, my name is … from Moses, a shared mobility company. We are doing research for a Department for International Development project. We'd like to learn more about your travel and transport habits. We have a series of questions to ask you, but before we get started, we have a consent form for you to review and sign. This will be a copy for you, and we will take a photo of it.

Explain consent form:
- If you would like we can change your name to maintain anonymity.
- One of us is going to chat with you and the other person is going to take notes. Do you mind if we record your voice as well? It is so we can listen back to anything we miss.
- We also take photos of research participants if they are ok with us doing this. Would you be happy for us to do this? (if they don't want to consent, ask if you could take photos of objects, hands etc) Do you have any questions?

Do you have any questions before we get started?

QUESTIONS

TRAVEL BEHAVIOUR

1. How do you currently travel to work?
2. Why do you use that mode of transport?

PAIN POINTS

1. What are your biggest challenges with transport when travelling to and from work? (prompt: safety, accessibility, choice, comfort)
2. How do you currently overcome these challenges?
3. What tools do you use to plan your travel? (Prompt: Your phone, paper timetables, ask

people) Why?

4. If you had a magic wand, how would you make your transport to and from work as you want it to be?

VALUE PROPOSITIONS

We have some ideas as to how to help make journeys better in South Africa and we'd love to get your views on them.

Moses is a shared taxi company, which brings together taxi companies in one area who give rides to a group of people. The taxis and the passengers are matched using an online system.

We'd like to show you four ideas we have for making this work in South Africa and talk about each one individually.

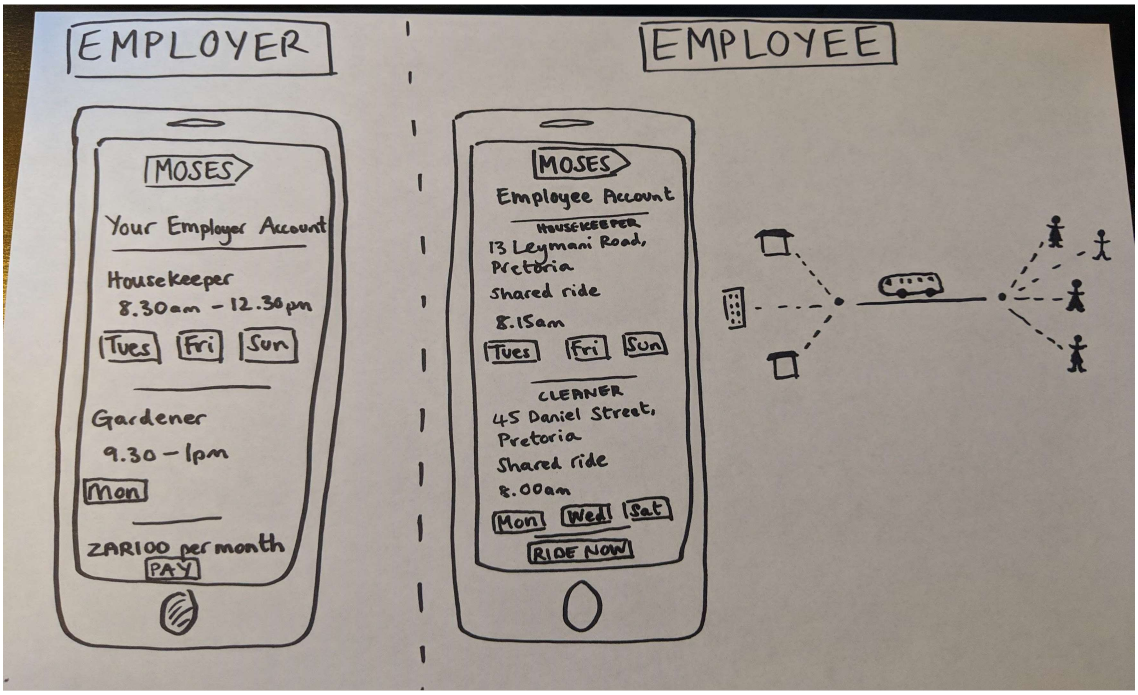
VALUE PROPOSITIONS: QUESTIONS

For each value proposition

1. What are your thoughts on this product?
2. Is it something you would use? Why? Why not?
3. What do you like about it?
4. What do you not like about it?

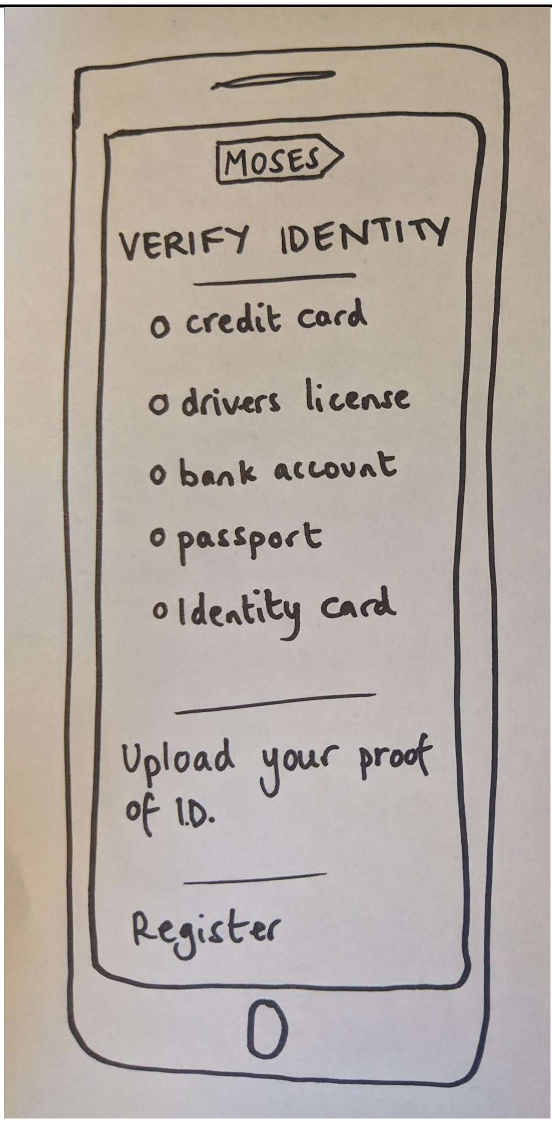
VALUE PROPOSITION 1

EMPLOYER - EMPLOYEE MODEL
Aimed at middle-to-high income community Employer pays for employee to arrive to work on time (aimed at housekeeping staff) ● Up-front price ● Costs and payment are on a drawdown/subscription model ● Fixed routes and times ● Match passengers based on end location ● Employees request ride home that uses little data ● Employers payment data is encrypted and in a separate account



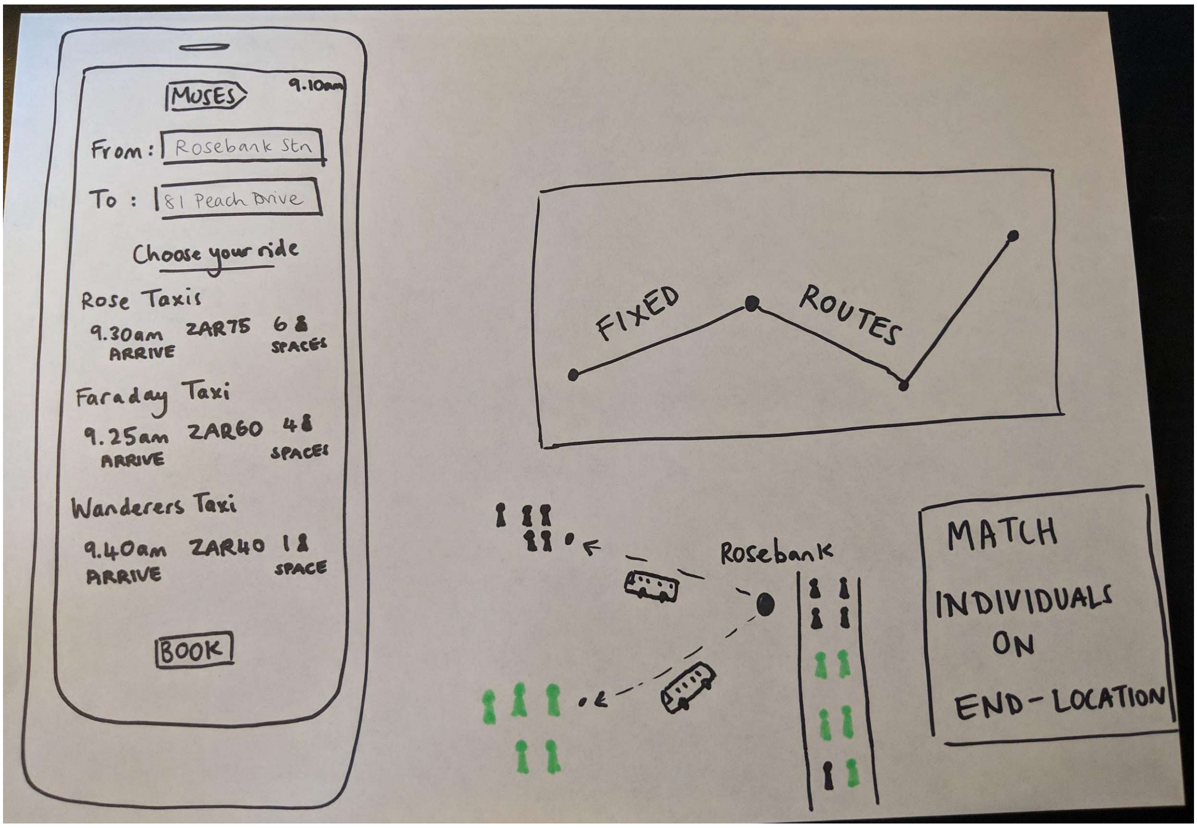
VALUE PROPOSITION 2

VERIFIED PEOPLE ONLY
Aimed at middle-to-high income community Verified people are only able to register onto the system ● Improved safety ● Higher cost ● App-based



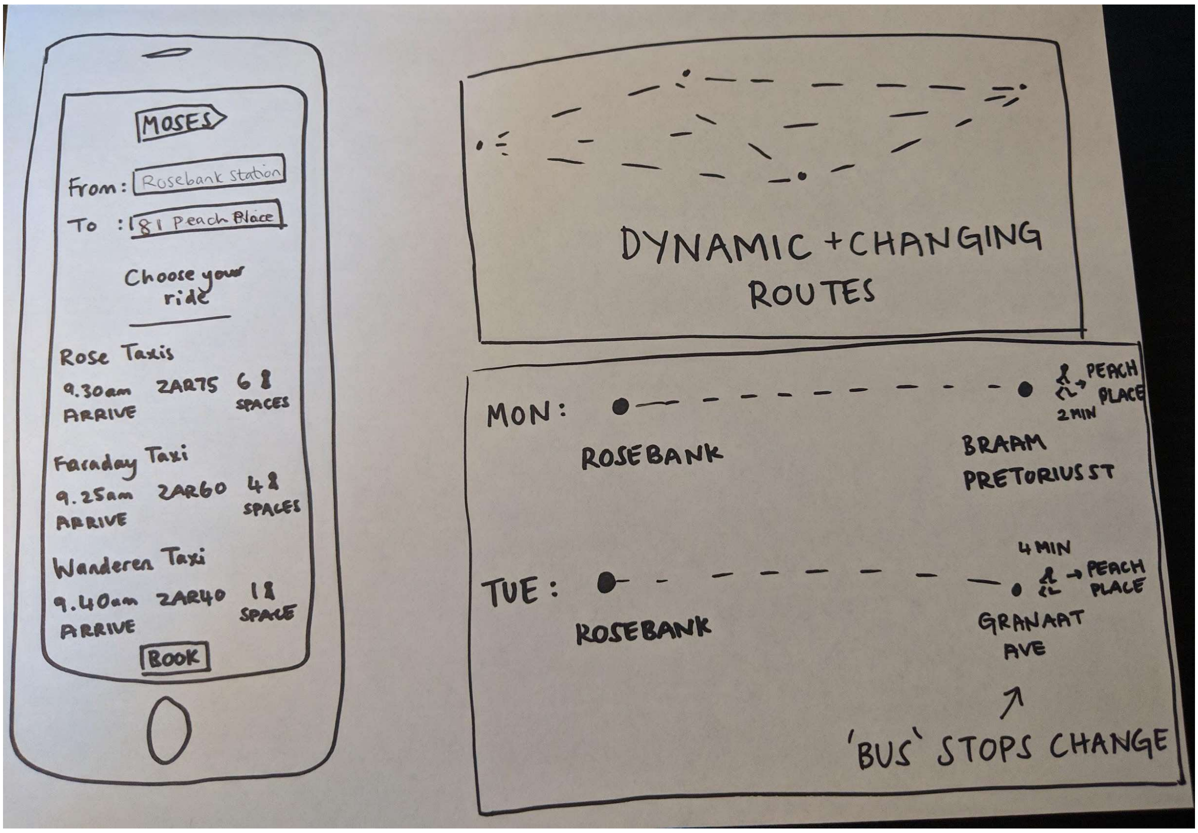
VALUE PROPOSITION 3

DIGITISED CURRENT SYSTEM
Aimed at low-income communities The current system improved through digital means resulting in more information available for decision making ● Fixed routes ● More information on minibus taxi routes ● More choice of minibus taxis ● Matching individuals based on end-location ● Capacity of vehicle is kept at legal maximum ● Possibly text-message based



VALUE PROPOSITION 4

LOW-CARBON: ROUTE OPTIMISATION
Aimed at both low-income communities and middle-to-high-income communities ● All dynamic routes ● Virtual bus stops regularly change ● Routes are based on efficiency



COMMENTS

Do you have anything you'd like to add?

Future research
Would you be interested in getting involved in further research or testing with us?
Is there any you could recommend us to speak with?

Thank you very much for your time.

Appendix 6: Stakeholder Analysis and Meeting Notes

The stakeholder analysis

Stakeholder	Need	Example
National Government	To provide its citizens with efficient transport, which is accessible, affordable and reliable.	The uGoMyWay ridesharing app has recently closed and shows the impact of little government support. The company needed governmental and corporate support to deliver what the market demands.
Local Government	To have public transport provide its citizens with modes of transport that are safe, accessible and reliable.	The City of Johannesburg has launched free bus and minibus taxi services for disabled people and older people. The City of Johannesburg is motivated to have a safe city and safe taxis.
Taxi Association	To serve the local community by providing affordable, demand-driven services.	These associations will need to be involved in Moses in Johannesburg.
Taxi Operators	To provide quick and affordable transport to the local community and to have low competition on routes.	There are taxi operators dominating and guarding the taxi ranks. For Moses to use these, they will need to develop relationships with these groups at the ranks that need to be used.
Taxi Drivers	To give rides to local residents, to complete a high number of routes and to make a personal profit.	Taxi drivers are used to being treated as freelance drivers and a business owner - how would Moses operate if it is in the formal sector? How will it incentivise and pay taxi drivers to ensure they do not behave unsafely?
BRT Operators	To provide the local community with safe, reliable and efficient bus routes and vehicles.	BRT operators would need to be involved in connecting passengers to onward taxi journeys that are safe, reliable and efficient, where their routes do not reach.
RRL Operators	To offer the local community public transport on main routes which is reliable, affordable and safe.	RRL operators would need to be involved in connecting passengers to onward taxi journeys that are safe, reliable and efficient, where their routes do not reach.

End-User	To get to the workplace or undertake personal business using transport which is close by, available, convenient, safe, timely and reliable.	Moses unique selling point may be to provide safe transport, which is efficient, convenient and cheap, where people can compare different rides to help them decide which is best for them.

There were a number of learnings from the stakeholder meetings.

A Re Yeng	● A Re Yeng has 90,000 passengers per week ● Ticket-system for A Re Yeng based on top-up card is being used (was previously cash) ● Difficulty in people using it e.g. requires card which takes time, so minibus taxis are competing with it instead ● Taxi providers have been paid to not operate so A Re Yeng can run at improved capacity - see https://citizen.co.za/news/1569286/tshwane-pay-taxis-not-operate/ ● The City of Tshwane were interested in the product, it has tried to use minibus taxis as feeders but there were issues in that the A Re Yeng had long queues for payment and people decided to continue on the minibus taxi rather than using A Re Yeng. This is an issue because A Re Yeng paid minibus taxis to stop operating but they have continued to operate as it is easier for passengers to use them. ● There is a 'cash culture' ● Want people to book the A Re Yeng as part of their journey rather than separately due to issues with payment.
Gautrain	● Gautrain is advanced but there are problems with metred taxis and Uber. There is a proposal to incorporate taxis, which is an opportunity for Moses to integrate metred taxis with Gautrain and then suggest Uber if no metred taxis are available. ● There are issues of Uber operating too close to the station and have been attacks on them, Uber must drop passengers off close to the station but not at the station. ● Gautrain understand MaaS and end-to-end journeys and want to use midi and big buses in conjunction with trains ● High-income communities live in security compounds and regular shuttle services are needed in the morning and evening for this community to get the Gautrain ● Car parks can get too full ● Want more people to use Gautrain

Minibus taxis	● 1,300 taxis in the region ● 40-60% dwell time ● Operator owns the car, operator hires a driver, drivers pay operator back a minimum amount per day for use of the car and the rest is kept by the driver ● Approximately 6,000ZAR per week = cost to driver to use vehicle ● Driver will make approximately 600 to 1,500ZAR per week (£33 – £82) ● Minibus taxis are economically powerful ● Taxi associations are mafia-style operations ● Regulation is limited - no insurance ● Servicing of vehicles is low cost and low quality (if it is not broke don't fix it) ● Majority of the cars are paid off now (~15-year-old vehicles) ● Cash-based system: there are barriers to exposing numbers: ○ Drivers and operators do not want to disclose income (tax) ○ Drivers do not want operators to know how much they are making
Local Population	● 30% of residents are living "hand to mouth" on a day to day basis, therefore payment by card (especially in advance) is an issue ● There are initiatives to promote a basic bank card called "Capitec"[1] ● Barrier to adoption of Uber payment model as people prefer to pay the driver direct and the driver prefers to receive the money direct ● The 'banked' and 'unbanked' population were some have bank accounts and can pay by card and the other does not and is only able to pay in cash.
Carbon Emissions	● Currently targeting national/international targets for carbon emissions - no other targets mentioned *"Minibuses are part of the solution"* *"We are currently under utilising their benefits for the last mile"*

Licencing	● The government has general "meter taxi" licence and e-hailing companies come under this category ● An operator applies for general meter taxi operator and after that point it is up to the operator what they do with the licence e.g. what apps they wish to use (Uber, Taxify) ● Operator licence also includes specified ranking space for vehicle ● E-hailing companies seem to operate in advance of licence being approved. They work for 3 months 'pending licence' but actually they operate for a lot more time without licence formally approved ● Licences are linked to size of vehicle - there is a "shuttle service" licence for larger vehicles with 5-9 seats, there is an "organised labour" licence for rural/late/special work, this includes worker shuttles
E-hailing	● Uber and Taxify are more competitive than standard meter taxis ● Apparently there are 10,000 minibus operators working under about 40 taxi associations. These associations are led by the Taxi Industry Steering Committee. ● An economic upside is required to motivate change. Government is at mercy of operators. ● There is currently an 800m max limit to walking distance from train/bus starting point. Aim is to reduce this to 500m. ● There was a previous study looking at tuk tuk usage in the city centre. There were issues from Meter Taxi opposition and safety issues. It was not a successful outcome. ● It is important that new taxi operators do not step on the toes of existing operators that have existing areas and routes. We should not encroach on their routes. Instead, it would be a better strategy to work with them in partnership with economic upside.

Cape Town	● Two markets in CT: 1. Existing car owners 2. Existing public transport users ● Informal taxis currently issues with outstanding fines, insurance and comfort. ● Blablacar matching listing model to match people needed ● Children school transport - alternative to parents dropping kids at school. Currently a company looking at it. Safety is a prime concern. ● Sweep South app - cleaners based on your needs, platform with ratings, homeowners also have ratings. Punctuality is important. 300/400 rand per day. People would pay extra 50 rand to have improved punctuality. ● Safety: vulnerable at station waiting. If this waiting time can be reduced it would have potential to improve safety. ● Door to door as an option versus express. Personal preferences such as accessibility. ● Potential 'shopping service' helping people to get to main shops at schedule time. Needs blablacar approach to get rides planned. ● Potential for 'hospital shuttles'. ● Dial a ride is popular in SA. Month waiting list. ● Mothers with babies may be interested in less squashed alternative to busy public transport. ● Payment with "airtime" Econet. Ecash. Used in Kenya. Google Mobile Money in Kenya. ● MyCiti has a lot of room for improvement and the City of Cape Town want to incorporate buses for a bigger infrastructure

[1] https://www.capitecbank.co.za/

Appendix 7: Carbon Emissions

Method

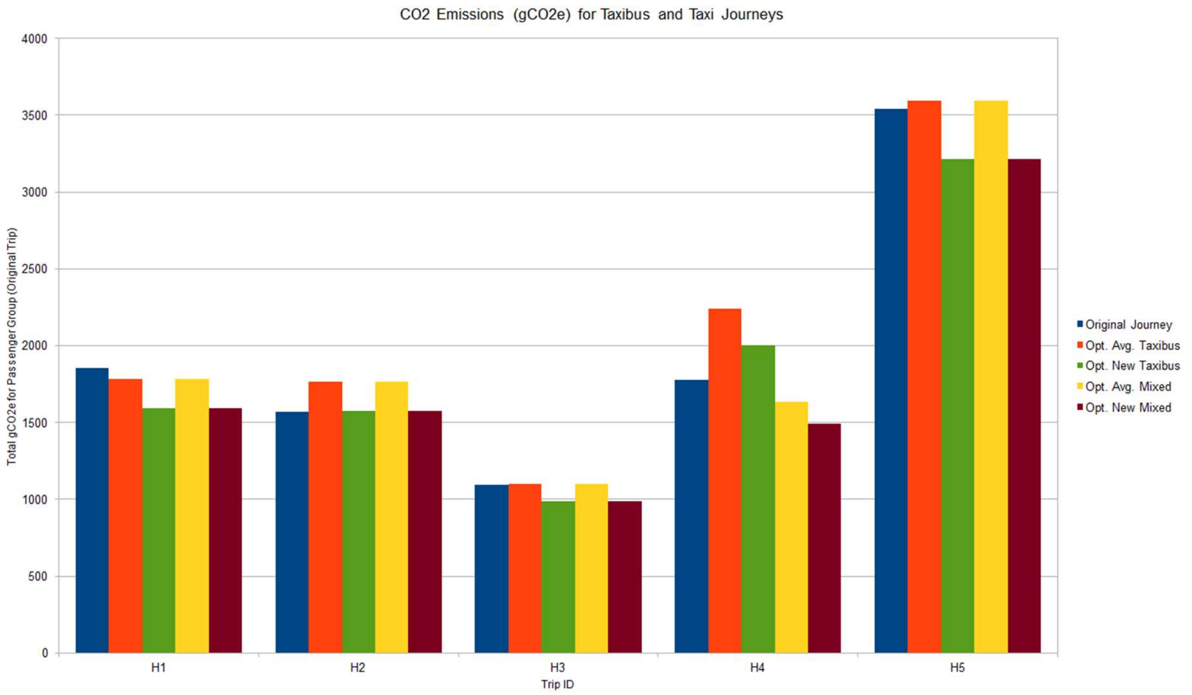
The full steps taken for the data analysis are as follows:

1. Construction of gCO2e measures for the original trips
    a. Calculate the distance between each Lat, long point in the list of GPS points for the journey
    b. Sum these distances to produce the total distance for the journey
    c. Use the fuel consumption details, GHG conversion factor, and the distance of each journey to work out the total gCO2e for each of the original trips
2. Construction of distance measure for the optimised trip or trips
    a. Read in the data on the actual trip and the boarding and alighting locations of each passenger
    b. Identify all of the stops where passengers board or alight
    c. Use the GraphHopper routing engine[77], and the Openstreetmap data for South Africa, to construct a distance matrix containing the distances from every stop to every other stop (with a unique distance for each direction)
    d. Construct a Capacitated Vehicle Routing Problem using the jsprit library[78]
        i. Define a service requirement for each passenger (i.e. passenger N must be picked up at Lat, long and dropped off at Lat, long)
        ii. Define the vehicles available (we experiment with four different fleet combinations: average minibus taxis only, average minibus taxis and average taxis, new minibus taxis only and, finally, new minibus taxis and new taxis)
        iii. Define the cost of each vehicle per unit of time and per unit of distance. In this problem the cost per unit of time is set to 0 and the cost per unit of distance is set to the vehicles gCO2e per meter
    e. Run the CVRPs and obtain the total optimised distances for each of the four fleet scenarios described in 2.d.ii (above)
    f. Use the fuel consumption details, GHG conversion factor, and the distance of each of the optimised journeys to work out the total gCO2e for each of the optimised journeys (note that the algorithm may split passengers in to multiple separate vehicles if this will improve the overall gCO2e cost)
3. Comparison of the gCO2e costs of both the original journeys and the four theoretical optimised journeys (for each of the four fleet combinations).

[77] See https://github.com/graphhopper

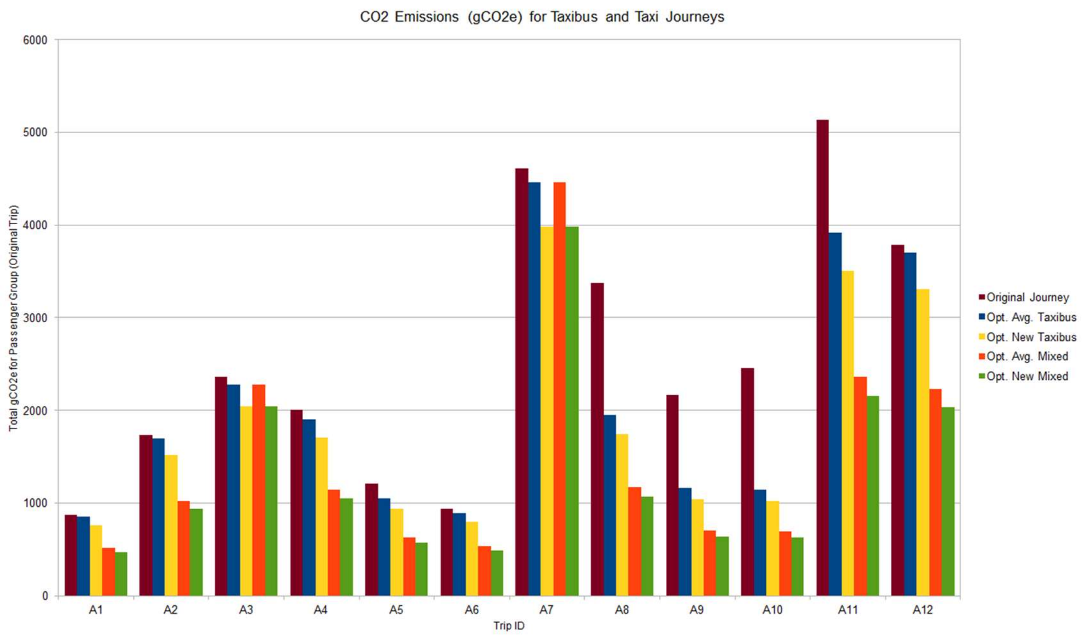
[78] See https://github.com/graphhopper/jsprit

Hatfield



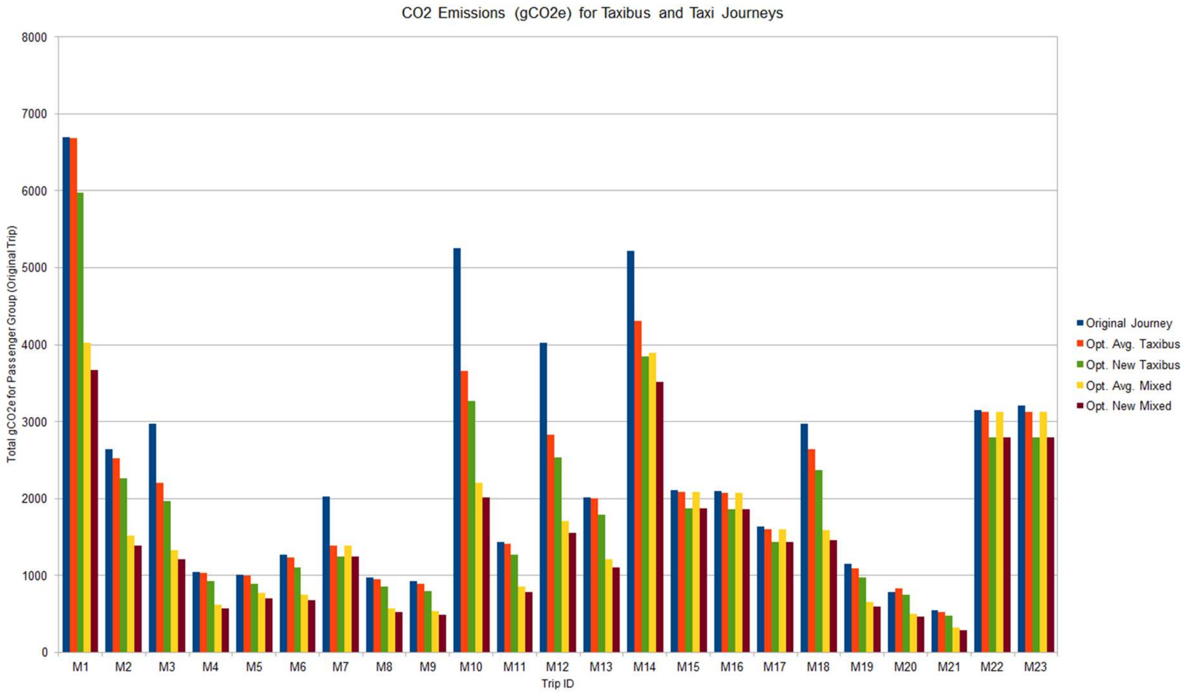
The chart above presents gCO2e emission levels for the Hatfield area. The key is the same as on the Atteridgeville chart. Whilst the Hatfield improvements are less pronounced than in the other two regions, there is still some improvement via the application of optimisation and/or fleet modification.

Atteridgeville



The chart above displays the gCO2e emissions for each of the original journeys in the Atteridgeville area data gathered by GoMetro. Each of the four alternative scenarios are displayed side-by-side with the original gCO2e emission levels. The key may be read as follows. The “Original Journey” columns indicate the gCO2e emission levels for each of the original journeys (labelled A1 to A12). The “Opt. Avg. Taxi bus” columns indicate the gCO2e emission levels when the routes of the original minibus taxis are optimised. The “Opt. New Taxi bus” columns indicate the gCO2e emission levels when the routes of the minibus taxis are optimised and the fleet is upgraded to new vehicles. The “Opt. Avg. Mixed” column indicates the total gCO2e emission levels when both minibus taxis and taxis are available and the journey is optimised. Finally, the “Opt. New Mixed” column indicates the total gCO2e emission levels when both minibus taxis and taxis are available, the journey is optimised and the fleet is upgraded. We can see that, each of the modifications yields some improvement when taken separately but that when implemented together the improvement is even more pronounced.

Mamelodi



Finally, the chart above presents gCO2e emission levels for the Mamelodi area, featuring services (trips) M1 to M23. The key is the same as on the Atteridgeville chart. We can again see that the gCO2e emission levels are improved as a result of the optimisation and fleet modifications.

Appendix 8: Themes

Theme	Explanation
Culture	● People are used to waiting and being late ● A culture shift to move toward digital ● People are used to sharing transport ● There is a car and no car divide
Payment	● There are the 'banked' and 'unbanked' communities ● Cash culture - although Taxify have a mix of digital and cash ● Employers would pay for their employees ● Drivers can't keep up with the payments for their vehicles and do not want to share their intake with employer
Politics	● Taxi associations have economic and political power ● Lack of regulation of taxis ● The politics between the formal and informal public transport sectors ● Government has a lack of authority over taxis
Safety	● Driver safety as Uber drivers have been attacked and drivers should feel safe ● Passenger safety due to dangerous driving ● Safe pick-up and drop-off points
Customer Experience	● Convenience, availability and reliability are all customer needs ● Long waiting times due to high dwell times ● Public transport too expensive ● Use of data - already restricting it for transport apps
Integration	● Lack of integration means that there are empty buses and full minibus taxis ● Lack of digital use ● Lack of integrated transport ● Not much multi-modal transport - usually go direct on one

	mode of transport
Information Sharing	• Person-based face-to-face transport system and information sharing • Cost of data is high and data is turned on and off when needed for information
Taxi Gains	• Taxis have high economic and political power • Minibus taxis serve low-income communities • They are a preferred option to A Re Yeng due to payment issues and long queues
Challenges	• Taxi associations having high economic and political power • Changing from cash payments • Car vs. no car divide and changing the car owners' behaviour to share transport • Cultural shift toward digital
Opportunities	• People already sharing transport • The need for employees to be at work on time • Intelligent routing • Change how drivers are incentivised • Minibus taxis can be better utilised • Minibus taxis still in high use alongside or instead of formal public transport