

Sustainable Transportation in the 4IR Era: Case of the City of Johannesburg

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1 ABSTRACT

Sustainable transportation development promotes efficient and easy accessibility to socio-economic areas affording opportunities and good movement from one location to the next. High connectivity and the smooth movement of people and goods define a well-functioning city. Without technological change, the traditional, car-dominated cities of the 20th century will not survive rapid urbanization and increasingly stringent air pollution regulations. The City of Johannesburg has various modes of transportation from motorized transportation to non-motorized transportation, however, issues of sustainability in transportation are in question. This paper analyses the sustainability and sustainable development of public transportation in the 4IR era, modes of public transportation available for commuting and the level of non-motorized transportation used for completing a journey across the City of Johannesburg and how 4IR technology can be exploited and harnessed to promote smart transportation. Mixed method approach was deployed in this study where spatial approach and qualitative approach was used to glean data from commuters, relevant officials, and documented studies. Results revealed that there is high percentage of trips made by mini-bus taxis and railway trains. Moderate use of Bus Rapid transit system (Rea Vaya), Gautrain system, taxify/ubers, and other form of buses. Consequently, the results showed that there is low use of bicycles to make trips and cycling to connect to public transportation stations is not visible as most public transport users walk or drive private vehicles to connect to public transportation, and walking to complete journeys is only feasible for trips that are under 5km. In addition, there is sustainability in the current existing public transportation, however, with the population explosion that the city is facing there will be difficult movement for modes of transportation, increasing percentages of car accidents and air pollution. Further, there is lack of sustainability in non-motorized transportation as many trips are completed with motorized transportation. The paper concludes that there is visibility of 4IR technologies in public transportation but not all the modes of transport have deployed them to ensure efficient, reliable, safe, convenient public transportation system, hence, this calls for interventions for enhancement towards development of smart sustainable transportation systems as the level of private motorized transportation in the city are high. The paper recommends that there should be exploitation of 4IR technologies which will bring integrated intra- and inter-urban transport systems, reducing the need for private vehicles, promoting real-time transport and traffic management and monitoring, cleaner vehicles and low-carbon mobility solutions that allow people to walk and bike more freely, platforms to better utilize existing and new forms of shared and ambient mobility, e.g. bikes, buses, and autonomous vehicles.

Keywords: City of Johannesburg, 4IR, Public Transportation, Sustainability, Journey

2 INTRODUCTION

Sustainable transportation development promotes efficient and easy accessibility to socio-economic areas affording opportunities and good movement from one location to the next. High connectivity and the smooth movement of people and goods define a well-functioning city. Without technological change, the traditional, car-dominated cities of the 20th century will not survive rapid urbanization and increasingly stringent air pollution regulations. The City of Johannesburg has various modes of transportation from motorized transportation to non-motorized transportation, however, issues of sustainability in transportation are in question. Many people across the city with private motor vehicles prefer using their own transportation even if this leads to high congestion during peak hours and even with other factors such as petrol high price, and the cause mostly is due to different factors in unreliability in public transportation. The City of Johannesburg needs to find ways of affording public transportation that is attractive, integrated, hassle-free, good accessibility and that will provide ease of mind when travelling by public transportation. Smart sustainable transportation is critical in any city globally to avoid many road related challenges which these goes to such an extent of affecting many things including economy. This paper analyses the sustainability and sustainable

development of public transportation in the 4IR era, modes of public transportation available for commuting and their functionality, and gives a brief background on the existing level of non-motorized transportation used for completing journey's across the City of Johannesburg. Further, suggests the need of 4IR technologies on how their can be exploited and harnessed to promote smart sustainable transportation creating switch from private vehicles to more usage of public transport that will be leveraged by service providers and also benefits that could be gained by commuters.

3 LITERATURE REVIEW

3.1 Sustainable public transportation

The concept of sustainable transportation is vital to ensure clean environment, healthy and high quality. The concept also emphasis on the human life and the environment, to meet current and future needs. Today, the transportation systems in major cities have shown a bad image due to heavy traffic congestion, accidents, lack of good access to public transport and carbon emissions to the atmosphere of space contributes to environmental pollution and imbalance in terms of quality of life in general mobility. Along with the promising concept of sustainable transport services to consumers and at the same time ensure the safety of road users and also help towards the welfare and the environment. Transportation facilities and activities have significant sustainability impacts, including those listed in tab.1.

Economic	Social	Environmental
Traffic congestion	Inequity of impacts	Air and water pollution
Mobility barriers	Mobility disadvantaged	Habitat loss
Accident damages	Human health impacts	Hydrologic impacts
Facility costs	Community interaction	Depletion of non-renewable resources
Consumer costs	Community liveability	
Depletion of non-renewable resources	Aesthetics	

Table:1 Transportation impacts on sustainability [Source:Litman and Burwell, 2006]

The concept of sustainable development emerged from the Earth Summit in Rio de Janeiro in 1992, and concerns Brundtland Commission Report 1987 : Sustainable development “meets the needs of the present without compromising the ability of future generations to meet own needs.”(World Commission on Environment and Development, 1987) . Sustainable transport system can be defined also as a transportation demand but does not affect future transport demand (Black, 1997) and sustainability is not about threat analysis; sustainability is about systems analysis. Specifically, it is about how environmental, economic and social systems interact to their mutual advantage at various space-based scales of operation (World Commission on Environment and Development, 1987). For transport to become sustainable, in practice this means:

- (1) Boosting the uptake of zero-emission vehicles, vessels and aeroplanes, renewable & low-carbon fuels and related infrastructure - for instance by installing 3 million public charging points by 2030.
- (2) Creating zero-emission airports and ports – for instance through new initiatives to promote sustainable aviation and maritime fuels.
- (3) Making interurban and urban mobility healthy and sustainable - for instance by doubling high-speed rail traffic and developing extra cycling infrastructure over the next 10 years.
- (4) Greening freight transport – for instance by doubling rail freight traffic by 2050.
- (5) Pricing carbon and providing better incentives for users – for instance by pursuing a comprehensive set of measures to deliver fair and efficient pricing across all transport.

3.2 Smart transportation system

Smart transportation deploys new and coming up technologies such as Intelligent transport system (ITS), Internet of Thing (IoT), Artificial Intelligence (AI) etc., to make travelling across a city more convenient, efficient, more cost effective (for both the city and the individual), sustainable and safer (DIGI, 2022). ITS apply different technologies to control, assess, and keep track of transportation systems to improve effectiveness and safety (US Department of Transportation, 2009). Consequently, IoT provides excessive required communication speed for managing and controlling transportation systems in real time with minimal latency (DIGI, 2022). Further, AI improve transport planning by optimising routes for transport

operators, reducing commuters' journey times particularly significant move given our urban layouts (Marwala, 2020).

Digital technologies have the potential to revolutionise the way we move, making our mobility smarter, more efficient, and also greener. Innovation and digitalisation will shape how passengers and freight move around in the future if the right conditions are put in place. The strategy foresees, (i) Making connected and automated multimodal mobility a reality, for instance by making it possible for passengers to buy tickets for multimodal journeys and freight to seamlessly switch between transport modes, (ii) Boosting innovation and the use of data and artificial intelligence for smarter mobility, for instance by fully supporting the deployment of drones and unmanned aircraft and further actions to build a global common mobility data space (European Commission, 2021).

3.3 Global Roadmap of Action Towards Sustainable Mobility

Global Roadmap of Action (GRA) tackles head-on to this question faced by many decision-makers in transport without focusing on one policy goal at the time e.g. safety or access. It is unique in two ways, (i) it proposes a logical and integrated set of choices of policy measures to achieve the Sustainable Development Goals (SDGs), and (ii) accomplish the four policy goals specifying sustainable mobility (i.e., comprehensive access, effectiveness, security, and green mobility). Consequently, it defines a path for countries to follow to achieve the SDGs and achieve the four policy goals that define sustainable mobility. This path is made up of a series of action plans to be implemented over time depending on progress on mobility and the objectives of the countries themselves. Further, the GRA is a tool that enables any country in the world to: (i) measure how far it is from achieving that ambition, (ii) explore more than 180 policy measures that have been tested around the world, and (iii) prioritize those that are most impactful and lay out a path forward (The World Bank, 2022).

In 2020, the Global Tracking Framework for Transport (GTF) to the GRA online tool was added to enable to both diagnosing issues (based on data) and recommending policy action given country context. The GTF was expanded to include new indicators, updated data and time series for all indicators. With that, the international transport community is equipped with a structured framework to track country-level progress toward sustainable mobility (The World Bank, 2022). Therefore, with the successful release of the GRA 2019, sustainable mobility for all initiatives (SuM4All) has established solid foundations to engage countries on a comprehensive policy agenda for sustainable mobility, and the priority in 2020 was GRA implementation. Five workstreams were launched in 2020, each deep dive into the catalog of policy measures from the GRA with a focus on specific, cutting-edge aspects of the transport agenda (gender, data framework, e-mobility, energy and mobility nexus) that will have impact to transport knowledge work and investments.

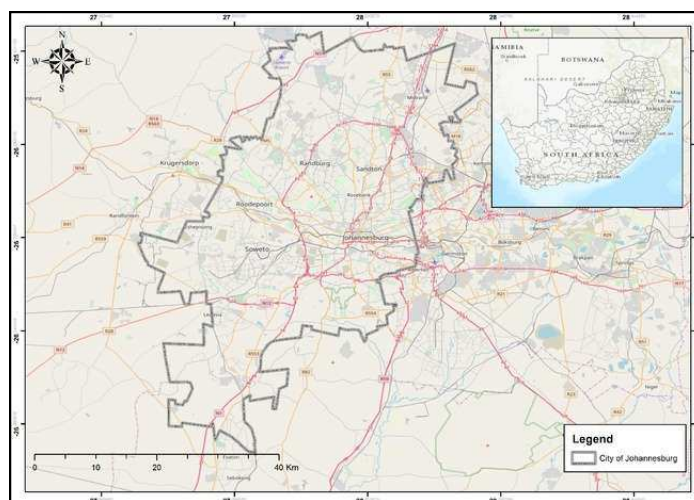


Figure 1: Study area [Source: Authors, 2022]

4 STUDY AREA

The City of Johannesburg is the focus area of study. The city is home to 7 regions and is the largest city in the country and contributor to the country's GDP. The City of Johannesburg is the biggest contributor to

South Africa's economic growth and is also the most polluted city in the country as of the 2011 population survey (Stats SA, 2012). The city was founded prior to the discovery of gold which led to high employment of the South African populace through gold mines (Rand Refinery, 2013). The city is home to numerous townships, one of which is Soweto, the oldest and big township in the country (Mbatha et.al., 2021).

As the City of Johannesburg afford many economic and education opportunities, people come in numbers daily in the city for such opportunities and many believe that their lives will change when they get to Johannesburg "City of Gold", hence, the move. The city then is challenged in response to this with population explosion infrastructure becomes overwhelmed such as for public transportation. Therefore, a need to provide sustainable smart public transportation to accommodate people residing in and across the city.

5 METHODOLOGY

A mixed method research design was adopted where qualitative data and spatial data analysis was used. Various research instruments were employed in the study. Ten interviews were carried out with officials from different departments, including the Department of Transport and Metropolitan Municipalities transport planners whom assisted in providing insights for the study about the possibility of having a sustainable smart public transportation in the city. Accordingly, commuters were also interviewed to understand how commuting is with and without the use of 4IR technologies. Purposive sampling was adopted as it was necessary to conduct interviews with informed officials and can be able to give proper insight about the public transportation that exist in the city. Interviews, observations and documented studies relating to this study were the sources of data. Further, content analysis was employed to review previous documented studies and used for strategies to explain the methods of providing sustainable smart public transportation. Consequently, Geographic Information Systems (GIS) data was obtained from the City of Johannesburg Metropolitan Municipality (Transport Department) which assisted in creating various public transportation route networks and stations maps. Secondary information used was obtained from larger data base such as Scopus, Science direct, Sage and Google scholar.

6 RESULTS

The City of Johannesburg has various modes of public transportation across the city. Each and every part of the city has the provision of public transportation and many locations are serviced by more than one mode or system. The below tables 1 and 2 indicate the most popular public transportation found across the city and the available use of non-motorized transportation.

Public transportation	Minibus Taxis	Rea Vaya	Gautrain system	MetroBus	Eyakho PUTCO	MetroRail	Uber& Taxify
number of users daily	15 million trips made	50 000+	55 000+	90000	230 000	1.4million +	156 000
How many buses/trains/ taxis/ vehicles	150 000	277	24 trains and 125 busses	532	1600	270+	62 000

Table 2: COJ public transportation [Source: Authors,2022]

Non-motorized transportation	Cycling	Walking	Other (wheel-chair, chariots etc.)
Trips completed	1,5%	8%	0.5%
Users	3%	70%	1%

Table 3: COJ Non-motorized transportation [Source: Authors, 2022]

Table 2 indicates the number of public transportation daily commuting and how many fleets does each mode or system has. The table indicates that the most used mode of public transportation in the city is mini-bus taxis followed by the metrorail trains. The two modes of public transportation indicate that there is a huge difference of trips made by commuters daily as compared to the other modes and this indicates that there is lack of equal distribution and there is a challenge in other modes, and there is a need of balance in distribution. However, there can be different factors leading to such which could include price and locations serviced. Further, table 3 indicates the use of non-motorized transportation in the City of Johannesburg. Non-motorized transportation across the city is not a popular phenomena to complete journeys as there is less visibility of trips made by cycling and only few people cycle in comparison to the

residents that are found in the city and using public transportation. Consequently, walking is only natural for many people who use public transportation and many people walk to reach public transportation stations, however, they do not walk to complete trips. Only short distance journeys are completed through walking and many of them are done by residents who resides in the CBD and residents who resides few kilometres from bussiness, industrial and commercial areas, and other locations such as recreational areas. Therefore, it can be concluded that across the city there is high percentage of trips made by mini-bus taxis and metro-railway trains. Moderate use of Bus Rapid transit system (Rea Vaya), Gautrain system, Eyakho PUTCO, Metrobuses, Ubers and Taxify. Accordingly, there is low usage of bicycles, and walking to complete journeys. Consequently, there is sustainability in the current existing public transportation due to the number of daily commuters transported effeciently by the cities public transportation, however, with the population explosion that the city is facing and more private vehicles found on the roads there will be difficult movement for modes of transportation in the coming years, the numbers of car accidents will increase and leading to a higher rate of air pollution. Further, there is lack of sustainability in non-motorized transportation as many trips are completed with motorized transportation.

6.1 Taxify and ubers

Taxify and ubers are private motor vehicles that provide public transportation services to individuals. Services of this mode of public transportation operations are available everyday and 24hours a day ensuring that commuters can travel from origin to destination. They do not have proper stations where you can directly access them but they are mostly found in busy areas eg. business locations, commercial areas etc., and easily accessible through smart phone apps. They service all routes to complete destinations and pick up passengers from a location where the request was done. This mode provide smart transporation services, however, there are questions with security and safety for passengers using this mode as private motor vehicles get hijacked and on some occassions some drivers pretend to offer taxify/ubers services but kidnap passengers. Initiatives by service providers are made to ensure that the security is increased for this mode of public transportation through verifications a requestor engage.

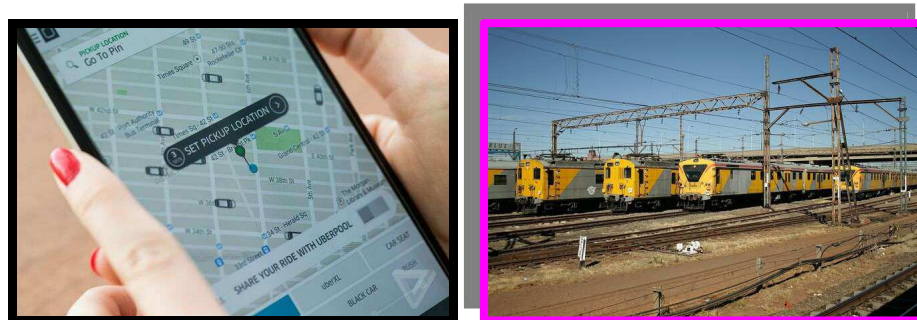


Figure 2 (left): Uber/Taxify [Source: Authors, 2022]. Figure 3 (right): Metrorail train [Source: https://en.wikipedia.org/wiki/Metrorail_Gauteng, 2022]

Taxify/ubers services are attractive to many City of Johannesburg commuters as they deliver services in a form appreciated by the city individuals or residents. These modes of transportation use technological innovations, a passenger does not need to have any physical communication or engagement with the driver as you switch on to the app select a pick up location and destination, the driver arrives in less than 5minutes unless rush hour. The navigation system give directions and the payment is done through the app or an individual can pay physically, and the trip cost is calculated per distance whereby all details are showed before a passenger can confirm to make a trip. Further, in selection of the trip a passenger has an option to request for a bigger motor vehicle if they will be travelling by a group of more than four people. The usage of taxify/ubers services are cheap when travelling by a group as the fare could be divided by individuals but expensive if its used by one person especially if its a long distance trip made.

6.2 Metro railway train

Metrorail rail is an operator of commuter rail services in the major urban areas of South Africa. It is the division of Passenger Rail Agency of South Africa (PRASA), a state-owned enterprise which is responsible for most passenger rail services in South Africa. The Metrorail services consists of 471 stations, 2228km

(1384 mi) of track, and carries an average of 1.4 million passengers per week (Metrorail, 2017). It is a dominant train system in the country that is found in most provinces and it was official know as Metrorail in 1996.

The metrorail does not service the northern suburbs of the City of Johannesburg. The services are provided from the south of the city to the centre and most of the areas serviced in the south are townships. This mode of transportation is used mostly by black population and mostly from low class income, the metrorail services are there to ensure that johannesburg residents manage to travel from origin to destination and reach areas of interest. The services are delivered effeciently but rather passengers might not feel the same way and the reason being, this mode is overwhelmed by the population using this mode. It is very cheap compared to all modes of transportation across the city and the Republic as a whole.

6.3 Gautrain System

The introduction of Gautrain system in the City of Johannesburg and Gauteng province as a whole was a game changer to public transportation as it provides three different modes in one such as train, bus and Midi-bus with technological innovations integrated within their services for information dissemination and payment system, and also has a provision of a mobile app that is effecient and precise for all its services. This system is evident of smart sustainable transportation and that the city is capable of having such a system and operating well.



Figure 4: Gautrain system network patterns [Source: Authors, 2022]

Gautrain system services the northern surburbs of the City of Johannesburg from the Johannesburg CBD. There are four Gautrain stations in the city which include Park station, Rosebank station, Marlboro station and Midrand station. The rail tracks run from the City of Johannesburg, to Ekurhuleni and City of Tshwane. The system has provided public transportation services to the northen surburbs that have lack enough services of public transportation, especially, rail services. The strategy of providing different modes to this system has made sure its a sustainable mode of public transportation as not all locations can be serviced by the train could be serviced by the bus and the bus penetrates through the inner locations of neighbourhoods and transport commuters from origin to destination as well as to Gautrain stations for commuters who switch in-between to complete their journeys or make journeys across the province. Locations such as Sandton/Brynston, Midrand and Randburg that afford some of economic opportunities in the city are serviced by the Gaubus system. This system has the provision of proper infrastructure and strategically located from surburbs to economic areas in the City of Johannesburg and the province as a whole. The bus and train services transport a large number of commuters effeciently with reliability and safety for all commuters using the system.

6.4 Bus Rapid Transit System “Rea Vaya“

Development of Rea Vaya system improved the services of public transportation in the City of Johannesburg as it provided bus services that transport commuters effeciently in large numbers and fast with special designed lanes designated only for Rea Vaya to provide rapid movement. With also the development of technological innovation in the system such as payment system consisting of smart card payment for bus fare and information dissemination which included the use of platform information display, inside bus

information display and online information distribution about the system with the provision of timetabling. Further, Rea Vaya provide free transportation for people with disabilities and 60 years and older pupil but must register for such services to be rendered.

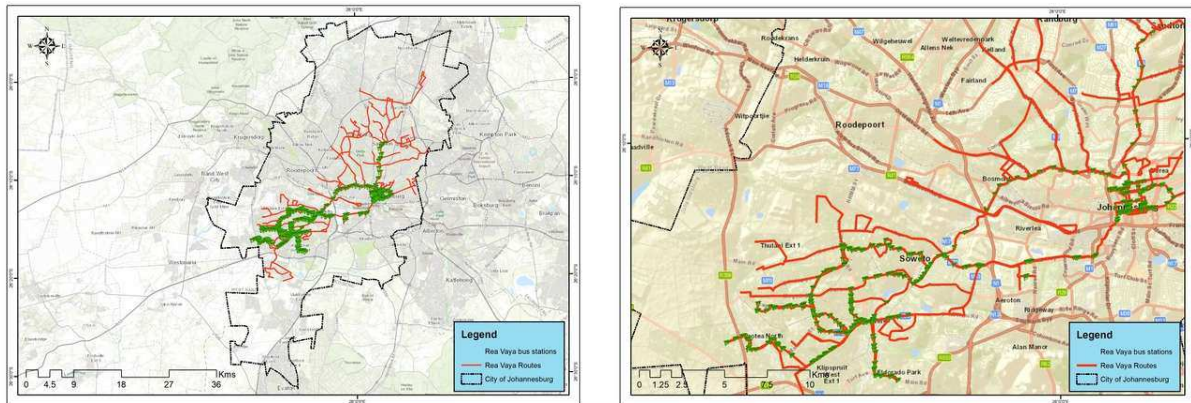


Figure 5 (left): Rea Vaya network patterns. Figure 6 (right): Rea Vaya most serviced areas [Sources: Authors, 2022]

The above figures 5 and 6 indicate the network patterns of the routes and locations serviced in the City of Johannesburg. The Rea Vaya system services most of the southern areas to Johannesburg CBD. Most stations are developed in Soweto which is the biggest township in the city and the country as a whole. Most of the neighbourhoods in Soweto are serviced by Rea Vaya from starting point in Protea Glen, Thokoza Park servicing many location to Orlando East and Diepkloof then moving out of Soweto to Johannesburg CBD. The fleet of buses are the most modern available, with sophisticated engineering to ensure carbon emissions are as low as possible. This mode of transportation has brought another perspective in transportation planning moving towards the direction of the 4IR as it shows technological innovations are important in public transportation to provide smart sustainable transportation for commuters. Looking at that it is one of the newly developed modes of public transport in the city and there are still extensions taking place to servicing the entire city, transport planners are still finding technological innovations that can fit well in this system as there are developments of self-service payment systems that are being installed in the bus stations, there is a high tech area that track all bus movement and the conditions of commuting in the bus stations providing communication to bus drivers to provide rapid movement and ensure solutions are there for eventualities.

6.5 MetroBus

Metrobus services are very vital which is indicated by its daily usage or commuting. Its services are mostly used by the working class and students or school learners. It is mostly found in the morning to deliver commuters to schools and areas of work, and in the afternoon and evening transporting commuters from work or school to home. This mode of public transportation is there to provide another dimension of commuting, it is not a mode that an individual could just use as an alternative during the day to travel around but has a specific targeted group.

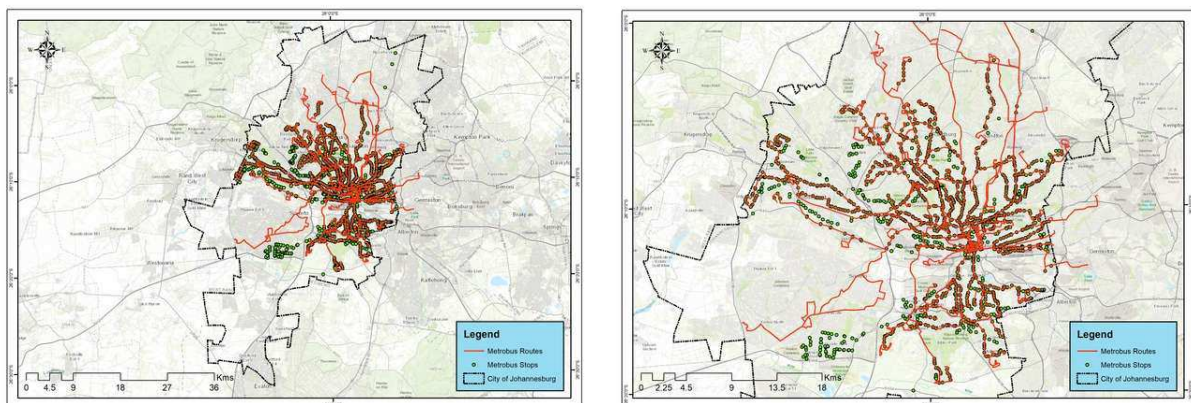


Figure 7 (left): Metrobus network patterns. Figure 8 (right): Metrobus most serviced areas [Sources: Authors, 2022]

Figure 7 and 8 indicate the network patterns of this mode of public transportation and the northern and eastern areas in the city are the most serviced areas, and western and south western areas are fairly serviced by this mode of public transportation. This mode does not service all locations in the city and could be stated that it services 50% of the city. However, locations that it services, it transport a large number of commuters daily. The Metrobus system has usage of technological innovations as it provides an online app that assist commuters with timetabling, routes they can use to complete a journey. Further, the app assist with bus fare as it assist individuals to know how much a trip would cost for a certain trip. This mode provide both smart and sustainable public transportation for commuters.

6.6 Mini Bus Taxi system

The City of Johannesburg offers a public transportation mode that is found in every part of the city known as mini-bus taxi which is a sixteen (16) seater and is deemed to be informal public transportation mode. Mini-bus taxi system was established in the 1975 which has been struggling to be formalised to date (Baloyi, 2013). It is a mostly used mode of public transportation nationwide due to network flexibility that this mode of transportation offers, it is more accessible than trains (rail transport) and easily connect to public than any other mode thus far with a cheap fare, therefore, more intensely used. Consequently, it is also much faster than the bus services as it does not operate on a fixed schedule (Binza & Siyongwana, 2012).

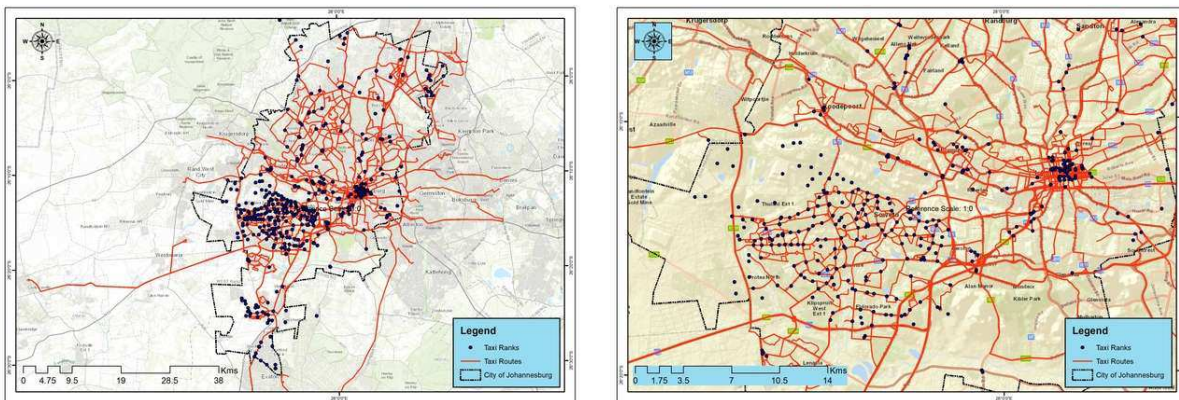


Figure 9 (left): Mini-bus taxi network patterns. Figure 10 (right): Mini-bus Taxis most serviced areas [Sources: Authors, 2022]

Figure 9 and 10 indicates the mini-bus taxi routes and ranks that are found in the City of Johannesburg. This is the largest system of public transportation that is found in the city and the country as a whole. All locations across the city even the hidden locations are serviced by this mode of public transportation. Most serviced areas by this mode of transportation is the southern areas of the city which include the Soweto neighbourhoods as they are the mostly highly serviced locations. However, other locations across the city are very much serviced by this mode. There are different kind of association from different location that regulate the taxi industries. Each location is serviced by the taxi association from that area to a specific destination. Taxi's registered from a certain location are not allowed to service another area they are not registered to and also with routes serviced, a taxi should remain servicing that particular route is registered for. Passengers on certain specific routes are not allowed to be transported by taxi drivers not registered to service that specific route, if such is done, it leads to taxi war fighting for routes which this become a serious war as there are shootouts and many people get injured and some shootouts results to death. Further, this also lead to mini-bus taxi strikes leading to un-availability of this mode in that particular area for a number of days. Consequently, when there are new initiatives and developments of new public transportation by the city this leads to taxi strike and war.

This mode of public transportation is efficient, however, it does not use any form of technological innovations as there is no information dissemination distributed to commuters, information can only be received at a taxi rank or in the taxi by word of mouth and payment system is hard cash payment in the taxi. The taxi fare differ by locations and some are fixed from origin to any destination. The increase of prices increase mostly with petrol price increase but not by big margins. This mode lacks smart transportation elements, it is sustainable to a certain point as it also have its own negative impacts due to lack of commuter safety at points and can not deliver commuters in time at points in some locations. Which this bring question

of how much sustainable is this mode of public transportation and the importance of introducing technological innovations within the mini-bus taxi system to improve the reliability, efficiency and safety.

6.7 Eyakho PUTCO bus

Public Utility Transport Corporation (PUTCO) was established many decades ago in 1945 which is still operating to date. This mode of public transportation is popular in transporting working class and operates during the morning transporting passengers to work and in the evening transporting commuters back home. It has many city commuters that depend on it as it provides cheap services and it transports a large number daily.

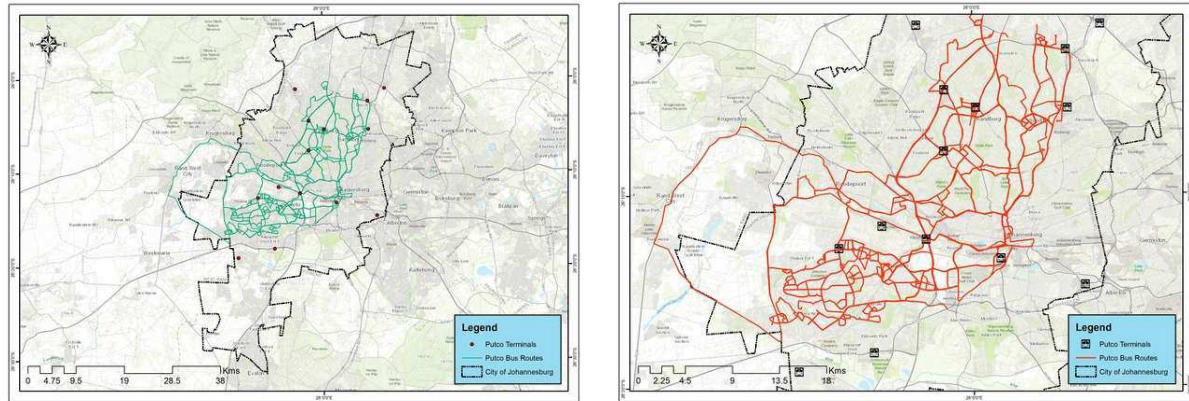


Figure 11 (left): PUTCO network patterns. Figure 12 (right): PUTCO most serviced areas [Sources: Authors, 2022]

The above figure 11 and 12 indicate PUTCO route network patterns and most serviced areas. Accordingly, this mode of public transportation services many areas across the city. However, most commuters using this mode come from Soweto neighbourhoods to the CBD and northern areas of the city where there are many economic opportunities as this mode is used for the working class. Most commuters prefer this mode as it collects commuters inside the neighbourhoods servicing many main roads and collecting commuters from different locations even the undesignated bus terminal areas. There is a provision of many buses that service different locations from different neighbourhoods some travelling to the CBD, some travelling to northern areas such as Sandton, Midrand, Randburg, Brynston and others to Roodeport etc. This mode of transportation lacks technological innovations in many areas including smart payment systems, information dissemination, and on many occasions it has had many broken down buses through making journeys and there are complaints which happen daily regarding such inconveniences by this mode. Further, this mode of transport has been found in many accidents across the city which all these raises the questions of lack of safety, reliability and efficiency. This mode needs many interventions to improve its services and the consideration and deployment of the 4IR technologies could make a difference.

7 DISCUSSIONS

Smart transportation is not just a theory for the future; it is being implemented today in several cities with their successes and failures being used to improve systems in new locations. Some of the cities that are implementing new transportation technologies. Of course, global hubs like New York City have embraced smart transportation for their ever increasingly intelligent city. However, the rural state of Wyoming is also a leading testbed for connected vehicles. This is because the state is a major freight corridor autonomous transportation of goods across the country can drastically improve supply chain efficiency and reduce the need for long-haul drivers forced to balance tight timelines with their human need for rest (European Commission, 2021). Smart transportation provides fast commuting for public transportation users with convenience in different aspects of using public transportation which is improving transportation services in every form as it provides modern technology applications in every aspect and enhanced management systems in transportation. In the City of Johannesburg some of the advanced technologies in transportation are used such as car navigation which uses satellite navigation to get position data which is then correlated to a vehicle's position on a road. When directions are required, routes are calculated in-real time; traffic signal control systems whereby newer traffic control systems are adapted to function smart, the developments correspond to its surrounding adjusting to traffic as when driving at rush hour and seeing green light all the way from

origin to destination its dynamic signals that have turned all traffic lights to green to maintain traffic flow; automatic number plate recognition which deploys character recognition on images to identify and scan vehicle registration plates as this creates vehicle location data, used for law enforcement, electronic toll collection and pay-per-road systems; speed cameras use detectors placed on roads or radar technology to detect vehicles exceeding the speed limit of a particular road, and the digital image is captured and forwarded to the driver which this is a solution to prevent accidents caused by excessive driving and encourage safer driving.

In South Africa, the Development Bank of Southern Africa (DBSA) is working with the World Bank and SuM4All partners to pilot the use of the GRA to guide the future investment program of the country and accelerate progress towards the SDGs. These include: (i) the GTF to diagnose and benchmark country performance relative to the rest of the world; and (ii) the GRA to prioritize policies and investments based on global experience. This is a unique undertaking in which expertise and data from partner organizations are collated with those from the World Bank to engage with decision makers in South Africa on the investment programs of South Africa (The World Bank, 2022).

The City of Johannesburg has different kinds of public transportation mode and systems which function differently but all with one goal to provide a sustainable public transportation services. Most of the public modes that are found in the city are old public transportation that have been offering public transportation services for many decades which are technological behind and still lack the 4IR innovation as they are still focusing on traditional ways in their services. (i) The mini-bus taxis have no technology adopted in their services including payment system which is still done by hard cash in and payment is done while travelling or entering a taxi, (ii) Eyakho Pucto buses is one of the modes that focuses on working class and operate during working days in the mornings and later afternoons, it does not have well developed infrastructure and does not afford any advance technological innovations for users, (iii) Metrobus provide services for both working class and school learners or students, this system of transportation has invested in technological innovations and already working towards shifting to smart sustainable transportation, (iv) MetroRail is the oldest train system in the coutry which transport a large number of commuters and favoured mostly by low income class as it is very cheap, there is somewhat technology used by this mode of transport such as platform information display, however, still use paper ticket system, and this mode is not safe as during peak hours it transport too many passengers in one train and there will be no movement for a passenger in a train, (v) Bus Rapid Transit system (Rea Vaya) is one of the innovative public transportation implemented in the city with proper infrastucture, servicing most areas across the city and uses technological innovations in their services which also need advancements such as information distribution in real-time, (vi) Gautrain System offer services with high technological innovations in their services as they provide accurate platform information displays and inside train information display as well as an online app for the system services, with proper infrastucture, (vii) Taxify/ uber provide services for an individual commuter or group of four people which also uses technological innovations such as on-line payments, information dissemination and navigations.

The city is thriving to have a world class public transportation and in regards to providing sustainable transportation, one could agree that public transportation that is found across the city is sustainable transportation as it manages to offer different modes that transport commuters effeciently in large numbers. With regards to smart public transportation, the city's public transportation still need improvement and be more technological equipped to provide smooth services that elliminate reasons for a need to have more private motor vehicles on the roads. The use of technologies in public transporation makes commuting easy for both public transportation users and service providers. Service providers are able to strengthen their services through data that is collected to ensure that commuting is better, by ensuring that areas that lack services are provided with. Further, 4IR technologies can bring integrated intra- and inter-urban transport systems, reducing the need for private vehicles, allowing real-time transport and traffic management and monitoring, producing cleaner vehicles and low-carbon mobility solutions that allow people to walk and bike more freely, platforms to better utilize existing and new forms of shared and ambient mobility, e.g. bikes, buses, and autonomous vehicles.

8 CONCLUSION

The paper concludes that there is visibility of 4IR technologies in public transportation but not all the modes of transport have deployed them, with a promising development of sustainable transportation but calls for interventions for enhancement as the level of private motorized transportation in the city are high. The city is well serviced by public transportation, as different areas are serviced by different modes and some modes and systems services the whole city. Further, there is a need to formally integrate these available modes of public transportation to provide seamless travelling across the city, and with proper understanding of 4IR technologies and proper analysis it is a possibility. Consequently, the city is not very far to have a smart sustainable public transportation as critical initiatives need to be ventured. Looking at the technological innovations used by other transport systems in the city such as Rea Vaya system, Ubers/taxify and Gautrain system, there is a possibility of enhancement for other modes or systems of public transportation. The intervention of the 4IR at present could be looked at and be undermined by many but it could prove to be the answer for challenges faced in transportation as it offer unmatched technological innovations that has never existed before.

The paper recommends that there should be exploitation of 4IR technologies which will bring integrated intra- and inter-urban public transport systems, reducing the need for private vehicles, real-time transport and traffic management and monitoring, cleaner vehicles and low-carbon mobility solutions that allow people to walk and bike more freely, platforms to better utilize existing and new forms of shared and ambient mobility, e.g. bikes, buses, and autonomous vehicles. The benefits of technology and advantages they bring to transportation include; smart transportation is safer: by combining machine learning with IoT and 5G, autonomous transportation systems (both in vehicles and in stationary infrastructure such as intersections) have proven to reduce the “human factor” in accidents. Computers don’t get distracted or fatigued or emotional; smart transportation is better managed: data collection is an important key to responsible public management of infrastructure. Smart transportation not only provides detailed data points for every aspect of the transportation system, but allows administrators to better monitor operations, track maintenance needs, and identify key sources of problems that need to be fixed; smart transportation is more efficient: with better management comes more efficient use. Quality data can help to pinpoint areas where efficiency can be improved. Maybe a slight adjustment in train schedules would provide for better fill rates, or, perhaps bus routes would better serve the community if stops were allocated differently; smart transportation is cost effective because smart transportation makes better use of the resources available, it can cut down costs thanks to preventative maintenance, lower energy consumption, and fewer resources used towards accidents. Cost savings can also be gained by riders when inexpensive public transit is efficient enough to compete with private vehicle ownership; smart transportation provides rapid insights: city traffic management centers (TMCs) can get rapid visibility and notifications for trouble spots or city-wide issues affecting congestion on city streets, public safety and emergency response systems, in order to take action or communicate more effectively with other agencies and emergency responders (European Commission, 2021).

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