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Exploring the Ecological Impact of BRT Rea Vaya on Klipspruit Valley Road in Soweto, Johannesburg

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Abstract

Public transport is one of the most important ways to help a country drive economic growth and alleviate poverty, but it can also have devastating effects on the environment. Increased rates of habitat loss and fragmentation, erosion, and loss, as well as noise interruptions, contamination, toxic pollutants, vehicle emissions that worsen air quality, and deforestation and habitat destruction, are some of the impacts public transportation has on the environment. The synthesis paper seeks to explore these ecological impacts. This study employed a phenomenological research design to address its goals. Moreover, qualitative data collection was employed. The study population was from Klipspruit Valley Station. The study employed a non-probability sampling strategy. In addition, purposive sampling was used to select the Rea Vaya station that was relevant for the research. Both primary and secondary data sources were employed. The observations done to collect data using ArcGIS and Google Earth as well as through site visit in order to formulate the results and findings constructively. Impacts on ecological factors because of transportation infrastructure, landscape, noise pollution, vibrations and heavy load were observed. Furthermore, Soil pollution by transportation projects and operations impacts were presented. These challenges resulted in traffic congestion, which further caused longer traveling distances and time. Qualitative data was analysed by using content analysis. Images and maps were utilized to depict the observations made on the ground. Therefore, an urban public transport framework that may be used to reduce the ecological impacts of the Bus Rapid Transit system was developed.

Keywords
Public transport, Bus Rapid Transit, ecology.

Introduction
Public transportation offers substantial economic benefits while also having an impact on ecological systems, which produces a contradiction in nature (Solaymani 2019). The complexity of the issues has generated significant debate on ecological policy and the function of transportation. The public sector frequently provides subsidies to the transportation industry, particularly through the building and upkeep of access-free road infrastructure (Moyo et al. 2022). Public interests in infrastructure, ports, and modes of transportation can occasionally conflict with ecological concerns. According to Goodsite et al. (2021), there are numerous environmental issues facing cities today, including vehicle emissions that worsen air quality and deforestation, particularly in urban areas like Johannesburg where the elimination of trees for the construction of transportation infrastructure has significantly altered the earth's climate. According to Sone et al. (2020) degradation of biological landscapes and ecosystem services are further environmental issues. Rapid depletion is harming ecosystems both locally and globally. Despite being essential to human well-being, ecosystem services are undervalued and taken for granted by current resource policy paradigms (Polasky et al. 2008). Staudinger et al. (2012) discovered that climate change has the potential to hasten ecological degradation and reduce the efficacy of ecosystem services. According to Paglia and Parker (2021), observed climate change has a negative influence on people's health, way of life, and essential infrastructure in metropolitan areas. Many of these ecological concerns are caused by the transportation system itself and act as obstacles to offering appropriate transportation and a high standard of living (Adams et al. 2020).

In 2011, Working Group II (WGI) estimated that the increase in the world's surface temperature would be over 1.09 [0.95–1.20] °C (IPCC 2021). The main cause of the predicted rise in global surface temperature after AR5 is more warmth. To encourage a sustainable environment, it is imperative to reduce car emissions and the environmental effects of transportation infrastructure. Countries including Tanzania have implemented BRT networks and the "green" bus project, on which people depend as their main form of transportation. In South Africa, BRT systems were introduced in several cities, including Cape Town, Tshwane, and Johannesburg, to try and alleviate these environmental concerns. The city of Johannesburg built the Reya-Vaya project, a BRT system in the province of Gauteng, to promote environmentally friendly transportation. However, it appears that this transportation system is causing an ecological catastrophe. The negative effects include habitat loss, noise disturbances, pollution, hazardous pollutants, automobile emissions that affect air quality, and degradation (Ajibade et al. 2021).

1.1 Objectives

The objectives of the study are

1. To investigate the ecological impacts caused by the Bus Rapid Transit system.
1. To develop an urban public transport framework that may be used to address the environmental impacts of Bus Rapid Transit system on Johannesburg environment.

2. Literature review

This section presents a literature review on public transport, ecological concepts which covers ecosystem services and landscape. Furthermore, it outlines the research gaps.

2.1 Public Transport

Public transportation is any form of shared passenger transportation that is offered to the entire public and is done so for the benefit of all (Fumagalli 2022). Buses, light rail, and subways are just a few examples of the transit alternatives available in public transportation networks. These services are open to the public, may have a fare, and operate at set times (Geurs and van Wee 2013; Saidi et al. 2020). Urban public transportation has drawn more attention recently as a means of enhancing sustainability and urban lifestyle. Increasing access to and usage of public transportation is the goal of introducing or expanding it, while also lowering motor vehicle miles traveled and traffic congestion (Sweet 2018). Public transport services can be formal and informal. Formal public transport services are transport services that comply with governmental rules and regulations while informal public transport services are transport services that are provided by the private sector and do not comply with government rules and regulations (Afolabi and Akibo 2020). These formal transportation services include Bus Rapid Transit (BRT) systems and Gautrain, and informal services include services provided by uber, bolt, and tuk-tuks. Babar and Burtch (2020) highlight that commuters make use of various public transportation especially when formal public transport is unavailable at a particular point. These include pedicabs in the Philippines and tuk-tuks in South Africa.

2.2 Public Transportation in South Africa

Metropolitan areas in South Africa, such as the City of Tshwane, Johannesburg, Ekurhuleni, and Cape Town have implemented sustainable public transportation. Bus Rapid Transit (BRT) and rapid rail systems have been implemented in these areas to support the passengers by reducing the distance travelled, the number of accidents, and traffic congestion (Matubatuba and De Meyer-Heydenrych 2022). Furthermore, the BRT system was introduced to promote transit-oriented development to increase work opportunities and reduce natural impacts (Naranjo and Janive 2018; Ali et al. 2021). Both the BRT and rail systems utilize a smart card that passengers load with cash to pay charges and get access to bus or rail terminals.

2.3 Bus Rapid Transit, Rea Vaya

According to Reya-Vaya (2017), the Rea Vaya bus utilizes a dedicated lane in the middle of the street that is identified with paving and lane markers, roundabout lane markings, and stud separators (10 cm). To avoid vehicle moves, the stud separators split the other traffic. It has identifiable form of classification to distinguish it from other public transportation networks. Buses come equipped with doors consisting of double folding on both sides, low-emission technology, as well as a lot of boarding and departure places (Matubatuba and De Meyer-Heydenrych 2022).

The stations are situated near the road's median because the travel lane is where the lane is located. There are handicap ramps, opposite sections of the entrance have mechanized doors, an elevator, comprehensive climate change defence on both stands, telephones, security cameras, and information desks at each stop (Sekgale, 2020). The stations' configuration and aesthetic are typical. In certain locations, the midway of the road has been planted with a walkway, trees, or both. According to Reya-Vaya (2017), the stations have real-time information displays,

Closed-Circuit Television, maps, security, and Customized, compact temporary structures with seats providing physical ease and relaxation for travellers to use while they observe the upcoming bus. In order to improve passenger comfort, velocity, sanctuary, and protection as well as network dependability, displays of current information and Closed-Circuit Television are present in the bus locations as part of the Intelligent Transportation System (ITS) (Sekgale 2020).

Customers of BRT have several options for shortening their travel times. While maintaining the BRT's average speed at a reasonable 30 km/hr, the inclusion of segregated, exclusive BRT lanes on 53% of the route helps to eliminate postponements triggered by means of traffic on lanes for diverse transportation traffic (Matubatuba and De Meyer-Heydenrych 2022). The majority of users which accounts for 83% transferred from a taxi, private vehicle, or other mode of transport to Rea Vaya and they stand to gain from the Rea Vaya limited commuter time (ArriveAlive,2018). Level, pre-paid segments located near the doors of the bus at Rea Vaya stations reduces the time passengers must wait to enter and disembark the bus. Collectively, these factors enable each BRT user to save 13 minutes each trip on average (Wood 2022).

2.3.1 Ecological Benefits

Based on better infrastructure and streamlined traffic flow, it is predicted that there would be a decrease in traffic accidents (injuries and property damage alone). Rea Vaya buses and the elimination taxis off the road both help to reduce carbon dioxide emissions by transferring passengers from more polluting modes. Johannesburg plans to save roughly 400,000 metric tons of carbon dioxide emission for the two phases over a ten-year period and has verified the decrease in emissions for Rea Vaya Phases 1A and 1B with the Voluntary Carbon Standard (Khumalo and Ogra 2018.). According to ArriveAlive (2018), universal accessibility has been implemented gradually for everyone, including the seniors, individuals with disabilities, those carrying baggage or strollers, etc. Among the innovations are transitions from:

- Stations that go from high to lowest elevations
- Buses featuring lower entrance and wheelchair elevators
- Considerable tact tile navigation pavement may be found next to benches and stops, as well as within and around stations.
- Improved use of color schemes and fonts in the Rea Vaya app, webpage, and other materials

More achievements of the BRT

- Decrease in overcrowding of vehicles
- significant for trade and industry development
- Employment establishment
- alleviating poverty by making transportation more cheap, particularly for individuals who earn below the poverty line
- decreased traffic fatalities
- Eluded emissions of carbon dioxide
- Promotion of more modes of transportation to increase community cohesiveness

Both developed and developing countries cities have worked very hard to establish BRT, according to a survey of past studies (Sekgale 2020). Research on BRT's environmental impacts in both established and developing cities is not very extensive. Thus, the bulk of great achievements emphasize how BRT reduces pollution, boosts productivity, and is a practical and affordable solution. This makes it difficult to understand and reach conclusions on how installing BRT systems helps with ecological transportation challenges in developing nations, as well as to apply the lessons learned throughout the BRT implementation process in such places. It can be assumed that developing cities have not yet fully understood the importance of BRT implementation while attempting to protect the ecology more especially ecosystem services and landscapes and the advantages that such transportation systems have in promoting a sustainable development due to the lack of information and research studies on BRT in developing cities of developing countries.

In 2010, the football World Cup was held in South Africa., which profited substantially from the implementation of BRT. Attempts to lessen the extent of travel necessary for the event were incorporated in the strategic planning developed by each host destination, especially Johannesburg, Pretoria, Cape Town, Durban, Mbombela, Polokwane, and Mangaung (Wood 2022). The majority of these strategies resulted in the implementation of Intelligent Transportation System (ITS), particularly in cities that had already incorporated BRT before the FIFA World Cup, continued to improve transportation system, mass transit, enhanced police enforcement and safety of transportation infrastructure, the revamping of railroad coaches, and the improvement of minibus regulatory

requirements. At least 60% of the populace now recognizes using public transportation as a sustainable mode of transportation (Rea Vaya 2-017). However, little research on how the BRT system affects the ecology, whether it landscape or ecosystem ecology, has been conducted because of its adoption.

2.4 Ecology in Transport Planning

Haeckelin invented the term "ecology" in 1866 to denote the study of "the economics of nature" and "the intricate interrelations alluded to by Darwin as the fight for survival" (Jackson and Barnett 2019). Ecology is the science of how living things interact with their surroundings. Understanding the number and distribution of living creatures in the physical environment is one of ecology's main objectives (Balasubramanian 2021). This area of biology primarily focuses on the interactions between organisms, including their interactions with one another, their interactions with shared resources, their interactions with the shared space, and even their interactions with non-living elements in the environment (Escobedo 2021). Ecology is the investigation of how organisms interact with their surroundings. Physiological ecology, behavioural ecology, population ecology, community ecology, evolutionary ecology, and ecosystem ecology are some of the subfields that make up modern ecology (Sanderson 2020). Ecology is essentially the study of nature and life. It is concerned with how living things interact with their surroundings.

2.5 Ecological Impact of BRT Infrastructure

However, BRT infrastructure also contribute to ecosystem degradation and habitat fragmentation, which can lower or even completely remove the population numbers of some species found in the region (Mandle et al. 2021). One of the primary contributing factors to deforestation, which significantly affects biodiversity and carbon sequestration (especially in tropical forests), is the building and upkeep of transportation infrastructure (Kumar et al. 2022). Furthermore, building new BRT infrastructure that harm ecosystems might have a disastrous effect on a nation's economy by deterring tourists (Kurthet et al. 2022). For instance, the Serengeti-Ngorongoro ecosystem in Tanzania, a protected region well-known for its yearly wildebeest migration, generates over $100 million in tourism revenue annually (Kirkland 2021). The Serengeti Route, for example, would go across the area where wildebeest migrate, upsetting the environment. This area's degradation would result in a decline in tourism and foreign investment, which would have a significant negative impact on Tanzania's economy and those who depend on the natural resources (Kirkland 2021).

Increasingly frequently, disregarding ecology leads to negative outcomes, including the eradication of native ecosystems, water contamination, landslides and floods, and the development of urban heat islands (Dreoni et al. 2022). The Clenaga-Barranquilla motorway in Columbia was developed without taking into account the value of mangroves. Due to this, a roadway was left vulnerable to erosion, some fish populations declined, and the poverty level of the locals who depended on fishing rose (Mandle et al. 2021).

2.6 Lessons Learnt and Research Gaps

According to Kong et al. (2021), the majority of the literature on sustainable mobility, focuses on motorized transportation and its repercussions, which include but are not limited to climate change, heavy traffic, and traffic noise. Many academics emphasize how private motor vehicles have a significant negative influence on the environment and occupy the majority of the road space, causing traffic congestion. Nevertheless, there has not been much discussion of how transportation systems like the BRT system affect the ecology. In major cities like Johannesburg, many of these BRT systems have their own track. Different landscape elements, such as trees, grass, and trees that serve to regulate CO2 are removed when these roadways for BRT systems are being built. The development of BRT roadways further leads to the landscapes change. Additionally, the development of the transportation infrastructure results in the removal of several ecological functions that are advantageous to both biotic and abiotic services, such as regulating. The environment pays the price for the BRT systems, despite how much the public benefits. Scholars have further continued to illustrate how private vehicles contributes to global warming leaving behind another pressing issue which is related to the preservation of ecology. According to Vanderschuren (2016), private automotive pollution is one of the main causes of global warming. Due to the limited investigation on how BRT system affects ecology, one cannot be able track down the environmental impact assessments done and if the conducted assessments were suitable enough to support any form of public transportation development.

3. Methods

This study employs a phenomenological research design to address its goals. A phenomenological research design remains one that attempts to explore point of view of individuals and conceptions of a certain event. Descriptive phenomenology, as it is presently defined, is a paramount widely used qualitative research methodologies to describe how people view a specific circumstance. To achieve the goals of this research, qualitative data collection is employed. Creswell (2014) states that qualitative research is a process of understanding built on several

methodological approaches of investigation, and therefore it examines socioeconomic or psychological issues. The study population was from Klipspruit Valley Station. The study employed a non-probability sampling strategy. Non-probability sampling means that characters within the population do not have the same chance of being selected (Molina-Azorin and Fetters 2016; Dawadi et al. 2021). In addition, purposive sampling was used to select the Rea Vaya station that was relevant for the research. Both primary and secondary data sources were employed in this research. The researcher used observations, ArcGIS and Google Earth to collect primary data. For secondary data, literature which consisted of relevant journals, books, statistics, policies and articles was used to support the data that collected using questionnaires and observations. In research work, using many data gathering strategies is better than using only one (Cresswell 2014). The selected method of collecting data was observation. As Creswell and Hirose (2019) stated, an observation is a process of closely observing or keeping under systematic review over a period of time to achieve an aim. Several trips were undertaken at the Klipspruit Valley Station to observe the operation and accessibility of the Rea Vaya buses station, how badly are the ecological factors affected by the road infrastructure and the inconveniences the ecological factors interference has caused. In addition to that, pictures were taken. Observation was done once a week in July, during peak hours preferably from 16:00pm-17:00 pm in the evening. Data were analysed utilizing qualitative data analysis. Qualitative data was analysed by using content analysis. Images and maps were utilized to depict the observations made on the ground. The images showed the sinkhole on the Klipspruit valley road and how it had affected the road.

3.1 Description of the Study Area

The largest and fastest-growing city in South Africa is the City of Johannesburg Metropolitan Municipality. According to the City of Johannesburg Annual Report, (2020/21), the estimated population of the Johannesburg Metropolitan Municipality in 2022 will be 6,065,000, a rise of 2.33 percentage points from 2021. Furthermore, the City of Johannesburg Annual Report (2020/21), indicated that the city provided 14.9 percent of the overall o country's GDP in 2018. In comparison to other cities in the Gauteng province, the city also offers the most jobs. For instance, the City of Johannesburg Metro employs 41.88 percent of the total number of all employment in the Gauteng province (City of Johannesburg Annual Report 2020/21). Johannesburg, located in Gauteng, South Africa, has an urban region known as Southwestern Township (also known as Soweto). Soweto falls under region D (see Figure 1). Before becoming part of the City of Johannesburg, it existed as a distinct and was closely associated with the finding of gold in the 1880s. The marks of the Apartheid past are still clearly visible in Soweto. The majority of the black inhabitants in Soweto speak all the official languages of South Africa. Klipspruit Valley road is a segment found in Soweto (See Figure 1). It consists of Bus Rapid Transit (BRT) system infrastructure such as the station and pathway that the Rea Vaya buses make use of.

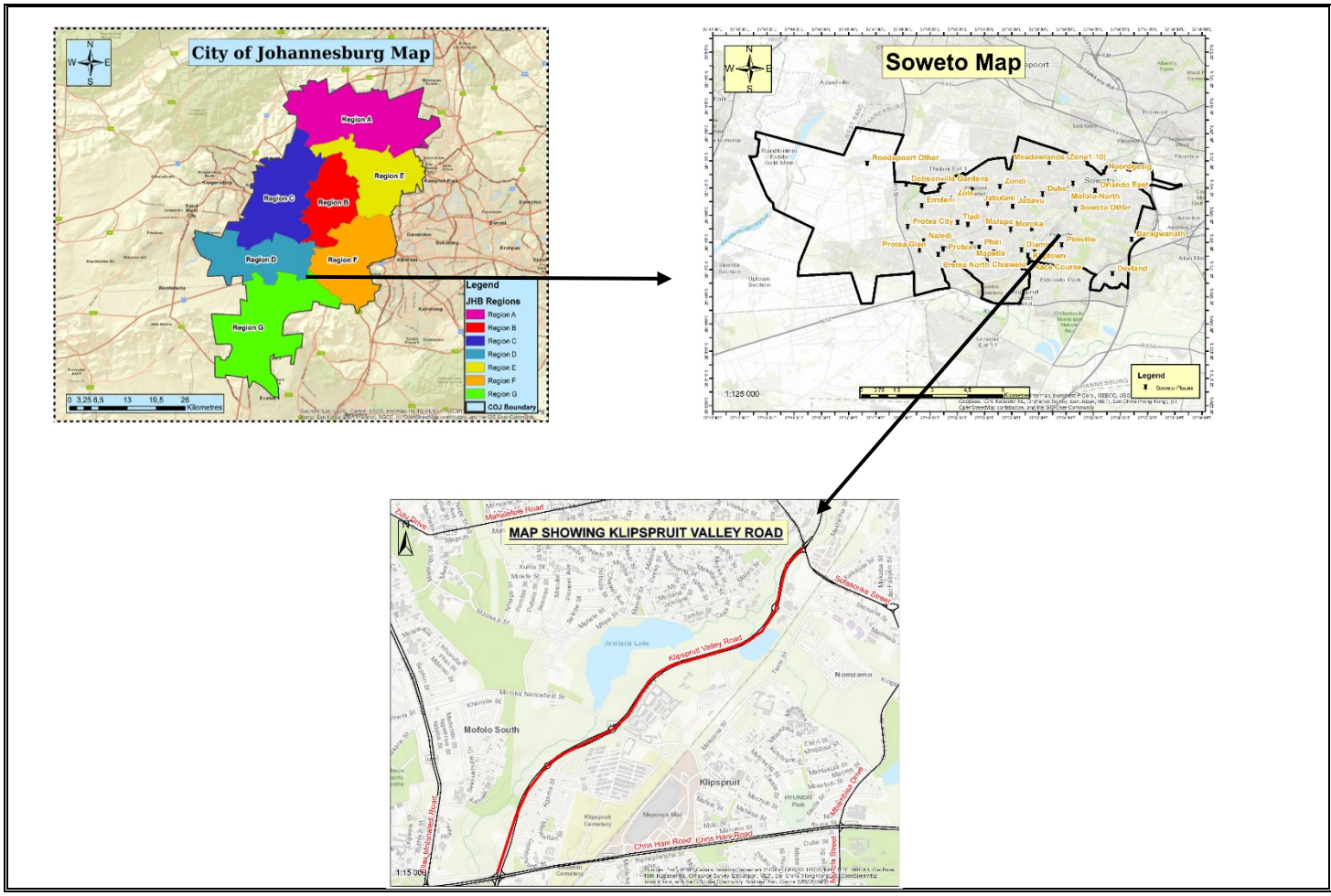

Figure 1. Maps of City of Johannesburg, Soweto Township and Klipspruit Valley Road

According to Jacobsen (2020), Rea Vaya BRT in the City of Johannesburg is utilized every day by 45,000 passengers. BRT, Rea Vaya has designated lanes. The lanes cover the southern and northern areas. It collects passengers at Rea Vaya stations. The passengers pay the bus fare by tapping on the scanner using smartcards when entering the bus or station, and when exiting (Mbatha and Gumbo 2022). Masingi (2019) stated that the BRT systems operate on arteries called "corridors of freedom" that provide increased freedom of movement and economy to passengers.

The BRT system is also in operation in Soweto whereby the Rea Vaya has various stations and routes. These station includes Thokoza park, Lakeview, Klipspruit Valley, and Orlando stadium station (Khumalo and Ogra 2018; Sekgale 2020). The Rea Vaya routes in Soweto include T1 which operates from Thokoza Park to Johannesburg central business district (CBD) and Doornfontein and F1 which runs from Naledi to Thokoza Park and Johannesburg CBD (Sekgale 2020). Last, but not least, the Rea Vaya routes also include F10 which operates from Pimville to Lakeview.

4. Data Collection

The selected method of collecting data was observation. An observation is a process of closely observing or keeping under systematic review over a period of time to achieve an aim. The purpose of observation in this research was to observe the places or positions of persons using Rea Vaya buses. In addition, the observations were made of commuters to determine issues of accessibility. Several trips were undertaken at the Klipspruit Rea Vaya station study areas to observe how the Rea Vaya affects the ecology and in addition to that, pictures were taken. Observation was done once a week, during peak hours preferably from 16:00pm-17:00 pm in the evening. This is done to determine the accessibility and convenience integration of Rea Vaya. In addition to the primary data collection tools, ArcGIS and Google Earth were used to create maps for this study. The maps from Google Earth were used to interpret the changes in land cover in the Klipspruit valley road from 2009 to 2022. F

5. Results and Discussion

This section presents the ecological impacts of Bus Rapid Transit (BRT), Rea Vaya on Klipspruit Valley Road, which is located in region D Soweto, in the City of Johannesburg. The impacts observed by the researcher included impacts on ecological factors because of transportation infrastructure, impacts on the landscape from transport infrastructure, traffic congestion, and impacts from noise pollution. The section also presents soil pollution caused by transportation projects, operations, and impact from vibrations and heavy load. These impacts were obtained through observations Google Earth. Pictures, maps, and graphs were used to present and analyse the data.

5.1 Impacts on Ecological Factors Because of Transportation Infrastructure

Figure 2 below represents a map of Klipspruit Valley Road for 2009. During the year 2009, the Rea Vaya route infrastructure was not present, but the road infrastructure for other automobiles was present. The land consisted of ecological factors such as water, soil, natural vegetation, and landforms. . Klipspruit road consisted of a wetland that was saturated with water. Wetlands are vital to the ecosystem because they purify water, prevent flooding, and stabilize shorelines. Wetlands, which support a varied range of plant and animal life, are the most ecologically diverse of all naturally occurring landscapes (Sayer 2013). Wetland systems have greater ecological deprivation than any other ecosystem on Earth, according to the UN Millennium Ecosystem Assessment (MEA 2005). During the year 2009, the land consisted of a stream, which is a body of water that flows on the surface of the ground. The advantages received from nature are what determine the health of individuals. Nutrition, wellness, power, housing, environmental conservation, and other fundamental effects to sustain livelihoods and sustainable growth depend on ecological factors. Humans also cherish nature for the non-material advantages it offers, such as transcendent upliftment, ethnic relevance, and inventive stimulation.

Figure 2. Kipspruit Valley Road- 2009

Figure 3 below represents a map of Klipspruit Valley Road for 2020. During the year 2020, the Rea Vaya infrastructure was up and running. The Soweto residents were receiving Rea Vaya services frequently. Furthermore, designated lanes for Rea Vaya buses at Klipspruit Valley Road were still in operation. Therefore, it allowed for shorter distances and travelling time. The above-mentioned ecological factors and landscape observed from figure 2 were still present however, not recognized as the key concern yet. The term "ecology" refers to human reliance on the environment and how human actions affect it (Balasubramanian 2021). It provides a way to methodically take into account the worth of ecology in all spheres of the economy and society. It also outlines the fundamental justification for selecting eco-friendly development strategies that will honor and uphold these advantages. Ecological considerations should therefore be given top priority when considering the expansion of the transportation sector. This will lessen the budgetary and resource loss for infrastructure. A complicated dynamic interaction that results from a heavyweight automobile traveling across the road puts a heavy response into the soil surface. The produced subsurface disturbances expand rapidly and may cause irritation to the surroundings and damage to the road.

Figure 3. Klipspruit Valley Road Map – 2020

Figure 4 represents a map for Klipspruit Valley road for 2022. During the year 2022, the Klipspruit valley route for Rea Vaya was not utilized due to reconstructions. As seen from figure 2 and 3 above, Klipspruit Valley Road had severe ecological factors and a wetland. Furthermore, figure 3 above, disclosed that the road had a separate lane for Rea Vaya and the other lanes were for other automobiles. These road transportation modes caused severe vibrations and brought a heavy load mainly from Rea Vaya buses which led to a sinkhole. The experienced catastrophe further affected the Rea Vaya infrastructure. As a result, the road was closed for reconstruction. One significant issue is that decision-making has historically placed too little emphasis on the ecology. The policies, laws, and values that influence people's production and consumption habits, investment decisions, land uses, and resource management techniques have largely ignored the benefits and costs associated with the protection and destruction of ecology. This indicates that many choices have been made based merely on imperfect knowledge, which has caused environmental deterioration. As much as the road infrastructure has been present before the Rea Vaya route, more pressure is now being applied to the road since the Rea Vaya buses also make use of the road. As a result, development possibilities have been lost, and there have frequently been enormous financial expenses and losses.

Figure 4. Klipspruit Valley Road Map – 2022

5.2 Impacts on landscape From Infrastructure.

The researcher also observed how the route was affected as portrayed in figure 5 below. From the observation, it was revealed that the route had a sinkhole. The layer of tar observed was thin and it was supposed to be thick. The below image was taken before the reconstruction of the route after the incident. The image indicates that sufficient research was not conducted to avoid the above condition. The heavy load of Rea Vaya buses was not considered when contrasting the road. The developers would have identified the existing ecological factors within the areas and indicated the priority ones. Furthermore, the developers, surveyors and planners would have researched how

the ecological factors benefit the community and how the proposed development is going to affect those factors and hinder the community from being beneficiaries of the factors. Furthermore, the developers would have also identified relevant policies, legislations framework, literature, and other useful documents to assist them with decision-making. This would have easily helped them to decide whether the environment is suitable for development or not, and what other measures can be taken to protect the ecological factors, such as building a storm water structure to protect the road infrastructure from being affected and increasing the thickness of tar to accommodate the heavy load.

Figure 5. Klispruit Valley Road Sinkhole

5.3 Traffic Congestion

The researcher also drove around the affected area at around 4 o'clock in the afternoon and it was observed that the Rea vaya bus is now using the alternative roadway used by other automobiles. As presented on figure 6 and 7 below, during peak time traffic congestion was witnessed. Too many cars on the road cause delays and further inconveniences passenger (Mthombeni et al., 2022). High number of cars on the roads further cause confusion, which further lead to severe accidents. In addition, the total emission from the vehicles also increases since they become concentrated in one area foe a long time. Public transportation contributes to a greener future by improving land use restrictions, using less oil, and reducing emissions.

Figure 6. Traffic congestion *(A)*

Figure 7. Traffic congestion (B*)*

5.4 Impacts From Noise Pollution.

Traffic congestion also led to noise pollution. The buses contributed to atmospheric and noise pollution. Other principal reasons for pollution caused by buses are poor vehicle maintenance and inadequate enforcement of rules and regulations. Poorly maintained buses use more fuel and emit excessive exhaust. This is a common problem where maintenance standards, and exhaust emission standards, are not set and enforced. It is compounded where

the number of vehicles in the system is excessive, or where many small vehicles are used instead of fewer large buses.

5.5 Soil Pollution by Transportation Projects and Operations

Road traffic and maintenance induce continual heavy metal pollution in roadside soil and runoff water. A portion of these pollutants is dispersed into the atmosphere or deposited onto soils because of wind dispersion. Heavy metals and other pollutants concentrations are carried from the ground to the plants, especially to the plant generation. Therefore, the concentration increases, and it is passed on to the food chain. Plants absorb metals mainly via the roots and the leaves where the pollutants are seated. Forages or meadow grass pollution by which cows are fed in several years may accumulate in their meat, reaching a high concentration degree which may be harmful and dangerous for human's eating this meat health.

5.6 Impact From Vibrations and Heavy Load

The impacts on landscape and ecosystem services led to reconstructions of Klipspruit valley road and heavy vehicles were to be utilised. These Heavy vehicles cause vibrations and noise which disturbs people close to the road, and further cause damage to buildings and sensitive equipment which can give rise to damage claims. Furthermore, the heavy load of Rea Vaya buses way too heavy to be sustained by the route. A bus is certified to carry a lot of passengers; however, the road was not strong enough to accommodate it. Vibrations, and noise can also affect the local fauna. Moreover, vibrations can cause damage to geological and archaeological objects. Methods and equipment that minimize vibrations and accommodate all sorts of vehicles should therefore be employed. This is often difficult in practice however, since roadworks demand specialized mechanical equipment such as diggers, heavy trucks, etc.

5.7 Discussions

This section will summarise the impacts of public transportation mode, particularly Bus Rapid Transit, Rea Vaya on Soweto environment that is part of Region D in City of Johannesburg. The impacts included impacts on ecological factors because of transportation infrastructure, impacts on landscape from transport infrastructure, traffic congestion, and impacts from noise pollution. Furthermore, the researcher also presented soil pollution by transportation projects, operations, and impact from vibrations. The researcher observed Klipspruit Valley Road that was one of the routes for Rea Vaya using maps from Google earth. It was found that during the year 2009, the Rea Vaya route was not present. However, the road infrastructure for another automobile was present. The land consisted of ecological factors such as water, soil, natural vegetation, and landforms. Klipspruit road consisted of wetland that was saturated with water. During the year 2020, the Rea Vaya infrastructure was up and running. The Soweto residents were receiving Rea Vaya services frequently. There ecological were still present however, not recognized as the key concern yet. Due to the road having various ecological factors and having a separate lane for Rea Vaya and the other lanes for other automobile, severe vibrations were caused which led to a sinkhole. The experienced catastrophe further affected the Rea Vaya infrastructure. As a result, the road was closed for reconstruction. This further led to traffic congestions since the Rea Vaya bus now had to resort to other roads used by automobiles. Traffic congestion caused. In addition, road maintenance and traffic induced continual heavy metal pollution in roadside soil and runoff water.

5.8 Proposed Improvements

This section details a proposed urban public transport framework that can be used to address the identified environmental challenges.

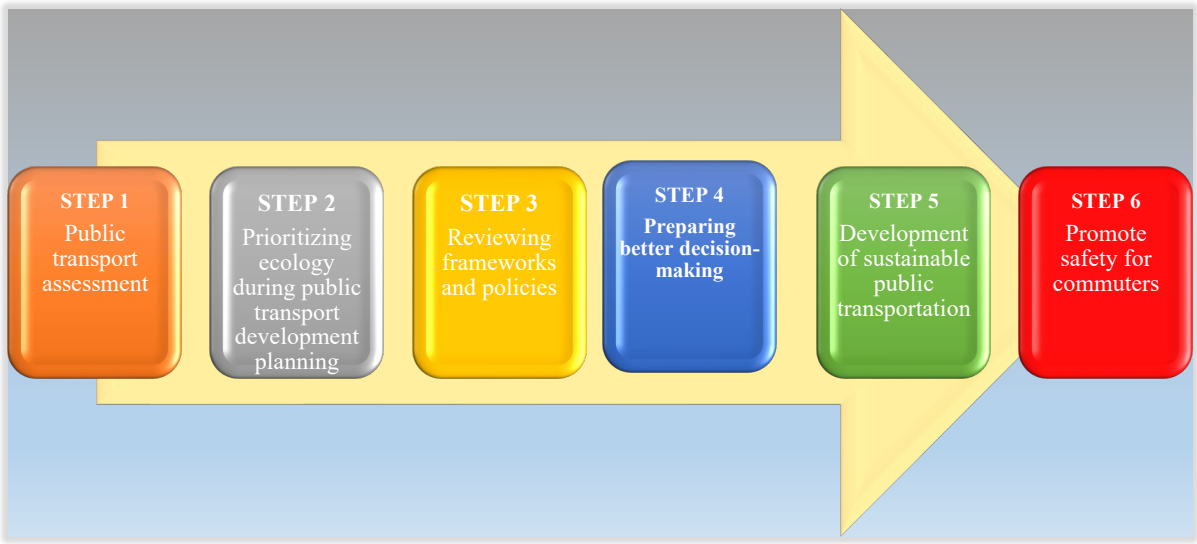

Figure 8. Stepwise approach for urban public transport

Choosing Stakeholders

Identifying relevant stakeholders will assist in making sure that the project is a success. Stakeholders give practical and fanatical support to the project. Furthermore, they provide ideas and help in taking actions. Moreover, public participations need to occur. These are the individuals that could possibly be impacted by these environmental challenges. Therefore, their voice matters.

5.8.1 Public Transport Assessment

The public transport and environmental assessment should be done to pinpoint all the environmental challenges that are caused by the Bus Rapid Transit, Rea Vaya through identifying the key performance areas, key performance indicators based on the identified environmental challenges. For every development project, there should be proper consultations with responsible authorities such as the Department of environmental affairs so that they can give a proper environmental assessment through Environmental Impact Assessment (EIA). Furthermore, assessments to check the structural composition of the related rigid pavement should be conducted. All these assessments will also assist in developing the strength, weaknesses, opportunities and threats analysis (SWOT analysis) of the public transportation to be developed and the environment that surrounds it. Furthermore, it will assist in knowing the relent stakeholders to be involved of the project.

5.8.2 Reviewing Frameworks and Policies

The information gathered above contribute extra features to the process of reviewing frameworks and polices. This particular step identifies and reviews policies, frameworks, acts of existing literature and other necessary incentives for public transport and ecology. It is advisable to review the identified trends in the aforementioned steps and how they fit into the policies being reviewed. This will also ensure that there is consistency between the identified framework objectives and are adequate and able to be executed within the local context. All the reviewed frameworks, policies and necessary documents on the short list should be evaluated to see if it is feasible, doable, and agreeable. A comparison of a several mechanisms and already existing policies will be necessary. Before moving forward, it is also important to do a more formal study to determine if the necessities of a development can be encountered within the cost, agenda, and performance limitations. In some cases, necessary procedure or authorizations may even be necessary, particularly if executives will be overseeing the project.

5.8.3 Preparing Better Decision-Making

All the information that was collected above needs to be brought forward in order to assist in better decision making. Firstly, assess how public transport interacts with the SWOT analysis. Secondly, assess how the public transport influences the ecology and how it further depends on it and lastly thoroughly look at the suggested policies, frameworks, acts and other necessary incentives for public transport and ecology. Furthermore, planners and developers needs to make sure that there is a relationship between the various steps that have been taken to create a logical flow between public transport and the environment. All the above mentioned will assist in identifying the gaps and pointing out measures that needs to be added in order to assist with the implementation process. In addition, it will also assist in pointing out the development risks that may be further encountered.

5.8.4 Development of Sustainable Public Transportation Infrastructure

The world consists of a fragile environment that consist of scarce resources (Sanderson, 2020). As urbanization continues to increase, large amounts of energy are necessary to sustain the growth. When relevant stakeholders are chosen, EIA is performed, policies are reviewed and better decision is done, sustainable infrastructure for public for urban public transportation can now be achieved. This can be achieved through inventing 100 % rechargeable Rea Vaya buses that are economically, socially and environmentally friendly. It will assist in reducing greenhouse emission impacts on the environment and pollutant emission experienced in Johannesburg. Rechargeable buses also will assist in protecting the environment for future generations to benefit from it as well. . Public transportation should go hand in hand with ecology. Both need to be protected because they play a fundamental role in socioeconomic growth.

6. Conclusion

Through observations, it was found that the Klipspruit Valley route had a sinkhole, which further lead to the route being stopped from being used. Buses had to now use alternative pathways for other automobiles which further caused more traffic congestion and increased time spent on the road hence commuters were dissatisfied with the time and distance travelled while using Rea Vaya buses. Therefore, a framework to address the environmental challenges was developed. Future research could focus on how the framework assisted in reducing unforeseen circumstances on the BRT infrastructure. The framework also proposed 100 % rechargeable Rea Vaya buses; however, South Africa is faced with power failures whereby electricity cuts are being experienced for several hours. Therefore, scholars can now investigate how best these rechargeable buses can be developed in a way that power cuts do not affect their functionality.

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