Optimising sustainable mobility: A performance assessment of non-motorised transport infrastructure in Johannesburg, South Africa

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Transportation systems are somewhat incomplete without integrating non-motorised transport (NMT) facilities to ensure safety, security, convenience, productivity and reduced environmental impact from such projects. This study examined the performance of NMT infrastructure and services provided to ensure smart transport and mobility in Johannesburg, South Africa. Two projects were identified as case studies, and a total of 21 semi-structured, open-ended interviews were conducted with residents and other road users in the vicinity of the projects to enable the acquisition of relevant information. Data was analysed using thematic content analysis supported with Atlas-ti software. Findings revealed that, although the facilities are in good condition and adequately maintained, the usage level is low. Incidents of poor safety and security were reported. Nevertheless, new value-added businesses operate along the routes and users indicated some satisfaction with their travel experience. To achieve value creation where NMTs are provided, it is crucial to ensure that the "smartness" of the cities is achieved and sustained. The practical implication of this study is the provision of invaluable information towards assisting road and NMT infrastructure stakeholders in improving the planning and delivery of sustainable transport infrastructure. Future studies will benefit from using more case study projects to strengthen these findings further and improve the generalisability.

INTRODUCTION

The sustainability of transportation systems is a global concern, and has been for decades (Zhou 2012). Sustainable transportation could provide the present needs without compromising the ability of future generations to fulfil their own needs (World Commission on Environment and Development 1987). The essence of developing transportation infrastructure is to provide an all-inclusive means of mobility for users towards supporting daily opportunities with minimal externalities and environmental impacts (Wang *et al* 2018). Furthermore, sustainable transportation infrastructure results in economic growth, reduced poverty and improved quality of life in urban areas (Litman 2016; Tsikai 2016).

An indispensable aspect of sustainable and economically efficient transportation is non-motorised transportation (NMT). NMT, also called active transport and human-powered transport, includes all forms of travel that do not rely on an engine or motor for movement, including walking, cycling, using small-wheeled transport (skates, skateboards, push scooters and hand carts) and wheelchairs (Yazid *et al* 2011; Vanderschuren 2012; Jain & Patil 2015). In most South African cities there is an increase in population, and the reliance on NMT will become inevitable over time. Studies show that the adoption of NMT and technological developments enhances mobility and economic development in many cities, while the attendant negative impacts of motorised transportation cannot be overlooked (Vanderschuren *et al* 2014; Ligege & Nyarirangwe 2015). The inadequate management and poor maintenance of vehicles, carbon emissions, traffic congestion, road accidents and consumption of finite resources pose worrying concerns in transportation infrastructure delivery (Yazid *et al* 2011; Rastogi 2011; Balsas 2015). Therefore, the significance of NMT is crucial towards protecting the environment, improving lives and making cities more inclusive, as indicated in the United Nations' Sustainable Development Goal (SDG) number 11. NMT is important because it aims to reduce the environmental impacts

Okoro CS, Lawani K. Optimising sustainable mobility: A performance assessment of non-motorised transport infrastructure in Johannesburg, South Africa. J. S. Afr. Inst. Civ. Eng. 2022:64(2), Art. #1188, 10 pages. http://dx.doi.org/10.17159/2309-8775/2022/v64no2a6

TECHNICAL PAPER

JOURNAL OF THE SOUTH AFRICAN INSTITUTION OF CIVIL ENGINEERING
ISSN 1021-2019
Vol 64 No 2, June 2022, Pages 67–76, Paper 1188

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Keywords: non-motorised transport, infrastructure, South Africa, sustainable transportation, feasibility studies

of transport developments and maintains a clean and healthy environment for good quality of life (Steg & Gifford 2008). The role and the effectiveness of NMT infrastructure in enhancing economic development and achieving SDGs were emphasised by the World Bank (2017). The projections of SDG 11.2 indicate that by 2030 most societies should be capable of providing access to affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with particular attention to the needs of the vulnerable population (women, children, disabled and elderly) (UN Habitat 2020).

Economically efficient, equitable and sustainable urban transport planning can be achieved by delivering multi-modal transport systems inclusive of non-motorised modes (Rastogi 2011). Similarly, most people in many parts of the world are reliant on NMT as a travel mode because it is environmentally less damaging and improves accessibility and social cohesion (Nuriye *et al* 2014). However, the provision and sustainability of NMT infrastructure are fraught with challenges such as lack of existing infrastructure, poor traffic safety records, limited funding, lack of parking facilities, and affordability (Yazid *et al* 2011; Labuschagne & Ribbens 2014). Furthermore, NMT users are seldom given due consideration or consultation during the planning and provision of sustainable transportation infrastructure, making this study timely.

There are existing studies on NMT infrastructure. Nuriye *et al* (2014) showed the predominance and distribution (nature) of NMT usage by households in Ethiopia, while Mitullah and Opiyo (2012) highlighted the challenges of implementing NMT infrastructure in Nairobi. These studies indicated that policy challenges, inappropriate design and location, lack of supporting measures to prevent encroachment on NMT infrastructures such as footbridges, traffic-calming measures and pedestrian crossing signs hinder the implementation of NMT infrastructure. Mkhize *et al* (2009), and Labuschagne and Ribbens (2014) focused on policies and planning framework to support the delivery of NMT infrastructure, and indicated the role of NMTs in South Africa as an independent and primary mode in transport planning and feeder systems to public transport services. Mokitimi and Vanderschuren (2016) investigated the state of NMT infrastructure in the Limpopo Province of South Africa, emphasising pedestrian safety improvement. The City of Johannesburg's (CoJ) efforts to improve the state of NMT infrastructure along major Bus Rapid Transit (BRT) linkages were also captured in the planning and feasibility studies (CoJ 2016). This study evaluates the performance of NMT infrastructure through the lens of the end-users to proffer ways of improving its performance and sustainability in two areas served mainly by the BRT in Johannesburg. The study is significant because there is a dearth of literature focusing on the actual performance of such NMT infrastructure in South Africa.

LITERATURE REVIEW

Non-motorised transport infrastructure

NMT infrastructure plays an essential and unique role in providing an efficient transport system, thereby providing essential mobility and accessibility to daily opportunities. NMT is a sustainable form of mobility and is considered by most people in any country as a reliable travel mode (Nuriye *et al* 2014). In cities in Japan, Germany and the Netherlands, 40% to 60% of all trips are made by walking and cycling, and in large African cities like Kinshasa in the Democratic Republic of Congo, and Dar es Salaam in Tanzania, walking accounts for two-thirds of total trips (Vanderschuren 2012). Provision and improvement of NMT infrastructure result in the prevention of several diseases, increased life expectancy, reduction in health care costs, and improvement in health and wellbeing – thus a beneficial investment (Skayannis *et al* 2017; 2018). Sustainable NMT infrastructure also reduces the environmental impacts of transport developments towards maintaining a clean and healthy environment for a good quality of life (Steg & Gifford 2008). Therefore, major cities are progressively moving towards NMT as a sustainable transportation system (Mkhize *et al* 2009; Rastogi 2011; Yazid *et al* 2011).

Performance indicators for non-motorised transport infrastructure

The adoption of performance measurement involves analysing how well policies, programmes and projects perform concerning their intended goals (Dhingra 2011). It includes monitoring and evaluating different aspects that commonly affect operating conditions, such as traffic flow, safety, road maintenance conditions, accessibility and environmental impact (Fancello *et al* 2014). Key performance indicators for road transportation infrastructure have traditionally been associated with technical measures, emphasising functional performance, visual appearance and structural integrity (Horak *et al* 2001). However, road infrastructure user surveys should include various kinds of users, including NMT users (Parkhurst *et al* 2015).

The performance of NMT infrastructure can be viewed as sustainable when there are good traffic calming and management measures in place, reduced traffic injuries and incidents, improvements in infrastructure, reduction of environmental impacts, enhancement in the quality of life and health of users, as well as benefits to the functionality of the city (Vanderschuren 2012; Skayannis *et al* 2018). Therefore, the evaluation of the performance of NMT projects was considered based on the following indicators by authors Kenworthy (2006), Vanderschuren (2012), Vanderschuren *et al* (2015), Mokitimi and Vanderschuren (2016), and Baufeldt and Vanderschuren (2017):

- Level of usage of the facilities – sustainable NMT mobility considers the fact that NMT has a robust desire line approach, which is based on identifying the shortest and most used paths.
- Traffic management (in terms of speed and volume) – traffic that conflicts with NMT must be managed, and existing traffic calming measures put in place to control the speed and volume of traffic.
- User satisfaction – an integrated approach to providing NMT facilities, which considers the various stakeholders involved and their level of satisfaction.
- Level of service – the services provided by NMT infrastructure should serve the needs of multiple users at a reasonable cost within the physical constraints of the available road reserve.
- Safety and security – the perceived safety and security by users should be improved with NMT infrastructure.
- Quality of facilities – the condition of non-motorised modes and facilities is a key dimension in the development of sustainable cities.
- Improved commercial activities along the route.
- Comfort and convenience.

The performance of NMT infrastructure was also assessed based on intended objectives for implementing the projects at the time of planning, such as the end-users' priorities and needs (Ramorobi *et al* 2010). The projects included in this study were intended to enhance accessibility to nearby BRT stations and improve the users' quality of life.

METHODS

Research design

This study adopted a multiple case study approach to obtain in-depth information regarding the performance of NMT infrastructure based on the end-users' perception from selected case study areas. The case study method was fundamental because it explores a real-life contemporary system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple sources of information, and reports a case description and case themes (Creswell 2013:97). It can involve an in-depth investigation of a single or small number of units at a specific point in time. Case study approaches are sometimes criticised for being biased or capable of selecting wrong cases, which could result in the lack of theoretical generalisation, but the use of multiple cases helps overcome this shortcoming, and the use of a case study approach is becoming increasingly popular, thus demonstrating its credibility (Thomas 2011; Hyett *et al* 2014). Adequately contextualising this study meant investigating the core issues through the lens of the end-users of the NMT infrastructure relative to their experiences, perceptions and how they attribute meaning to specific events through semi-structured interviews (Creswell & Creswell 2018).

Sampling

A qualitative research method using a purposive non-probability sampling strategy was adopted as the most appropriate strategy. The rationale for using purposive sampling is to focus on specific predefined groups (NMT users) assumed to be representative (a cross-section) of the population (Creswell 2014; Creswell & Poth 2017). A total of 21 semi-structured interviews were conducted in 2018, and it was identified that no new information was emerging and therefore having additional participants would not necessarily add more value (Mason 2010). Qualitative studies do not require large sample sizes because the aim is not generalisability but rather to obtain rich information on the participants' experiences. Furthermore, saturation can occur among a relatively homogenous population of multiple case studies with a sample of 12 participants (Boddy 2016). The 21 participants comprised thirteen males and eight females, i.e. four students, two street vendors, two security guards, two shopkeepers, one receptionist, one delivery man, one restaurant owner and one antiques shop owner, while seven participants failed to disclose their occupation.

Interview data collection

The data collection was based on the perception of the users of the NMT infrastructure, and adopting a semi-structured open-ended interview approach was useful in gaining more insight through their lens. The interview schedule addressed the following context: perceived safety using the improved routes, level of usage, cleanliness, cost, maintenance, interference of motorists and land-use patterns, the mode of transport they predominantly use (demand or level of usage), the improvements made in the area, the level of satisfaction with the quality/condition of infrastructure, frequency of infrastructure maintenance and quality, traffic management and control, safety management programmes in the community, value-added elements such as the attractiveness of the area, street furniture and the emergence of new business ventures. Other aspects included accessibility of the infrastructure to all, including the disabled (sidewalks with wheelchair access and ramps) and community involvement in maintenance. These items further build on existing contexts identified in literature as performance measures for NMT infrastructure (Kenworthy 2006; Vanderschuren 2012; Vanderschuren *et al* 2015; Mokitimi & Vanderschuren 2016; Baufeldt & Vanderschuren 2017; Skayannis *et al* 2018).

Out of the 21 interviews, 10 were in two South African native languages (Zulu and Sotho) because the people felt more comfortable being engaged in their native language. Therefore, the questions were translated from plain English to Zulu and Sotho, while the responses were transcribed and translated verbatim to plain English by the researchers. Eleven participants preferred to be interviewed in the English language. The average length of the sessions was 25 minutes. The purpose of the study was explained, and participants' consent was sought to audio-record the sessions before commencement.

Data analysis

The data was thematically analysed with the aid of ATLAS-ti scientific software to identify common themes related to the performance of NMT infrastructure. The six-phase approach in Braun and Clarke (2006) was adopted to ensure trustworthiness in the research. These entailed familiarisation with the data (immersing oneself to understand the meaning of the words in the transcriptions); generating initial codes (identifying and collating codes relevant to answering the research question); searching for themes (identifying codes with similar patterns); reviewing themes (against the collated data extracts and research question); defining and naming themes (in relation to literature, to capture many realities and provide accuracy); and writing up (compiling the report logically). The two projects were analysed on a case-by-case basis, but the ensuing discussion collectively used cross-case analysis to identify the factors captured in the performance of both projects. Through cross-case analysis, it was possible to identify, compare and validate attributes common to these cases (Ghauri & Firth 2009; Beermann 2017).

REFERENCE CASE STUDIES

The two case study projects are the Rosebank–Sandton and Soweto–Johannesburg Central Business District (CBD) Line 1B NMT infrastructure. These are presented in terms of the brief feasibility studies and factors considered during the planning phase. Table 1 gives a profile

Table 1 Profile of the case study projects

No	Project	Project characteristics					
		Description	Feasibility study timeline	Procurement/ financing structure	Number of private partners	Project amount	Number of years in operation
1	NMT–Soweto, Johannesburg CBD and Line 1B	New	2012–2013	Public	Nil	R2 315 000	3
2	NMT–Rosebank–Sandton	Upgrade	2014	Public	Nil	N/A	2

of the projects, which have been operational for three and two years, respectively. Figure 1 shows the NMT routes as proposed in 2009 along BRT lines within the CoJ Metropole (Figure 2) in the Gauteng Province of South Africa.

Case Study 1: Rosebank–Sandton NMT infrastructure

The Rosebank–Sandton NMT project was a rehabilitation project that entailed improvements on existing NMT infrastructure. The CoJ undertook these improvements to cater for walking and cycling passengers on these routes. The facilities included sidewalks, cycle paths and lanes; lighting to improve security; signage, route markers and information kiosks; landscaping and street furniture; special needs passenger accessibility; and pedestrian crossings (CoJ 2016). These improvements were intended to address critical aspects of the Johannesburg Growth and Development Strategy outcomes, including economic growth, environmental quality, accessibility and connectivity, liveability (create a vibrant public realm with high-quality public space), social cohesion and inclusivity; and public transport orientated development and intermodal integration. The implementation comprised four routes in the area, including Route 1, which connects Rosebank to Sandton; Route 2, which serves the Parkview area and links to the Rosebank CBD; and Routes 3 and 4 linking Melrose Arch to Rosebank. The Rosebank–Sandton NMT project was included in this study because of the sustainability and socio-economic impact and the availability of rich data on the feasibility studies conducted for the project.

Rationale, processes and business case

The feasibility study for the project was conducted in 2014, and it compared and considered the proposed routes and initiatives with other NMT projects planned in the area to align and integrate them with existing proposals. Similarly, traffic counts were conducted to determine the demand along routes and major intersections. The NMT policy guidelines and framework, as well as national, provincial and municipal policies, included the National NMT Policy 2008, Pedestrian and Bicycle Facility Guidelines 2002, National Public Transport Action Plan 2007, Gauteng Province Draft NMT Policy 2011, 2025 Gauteng Integrated Transport

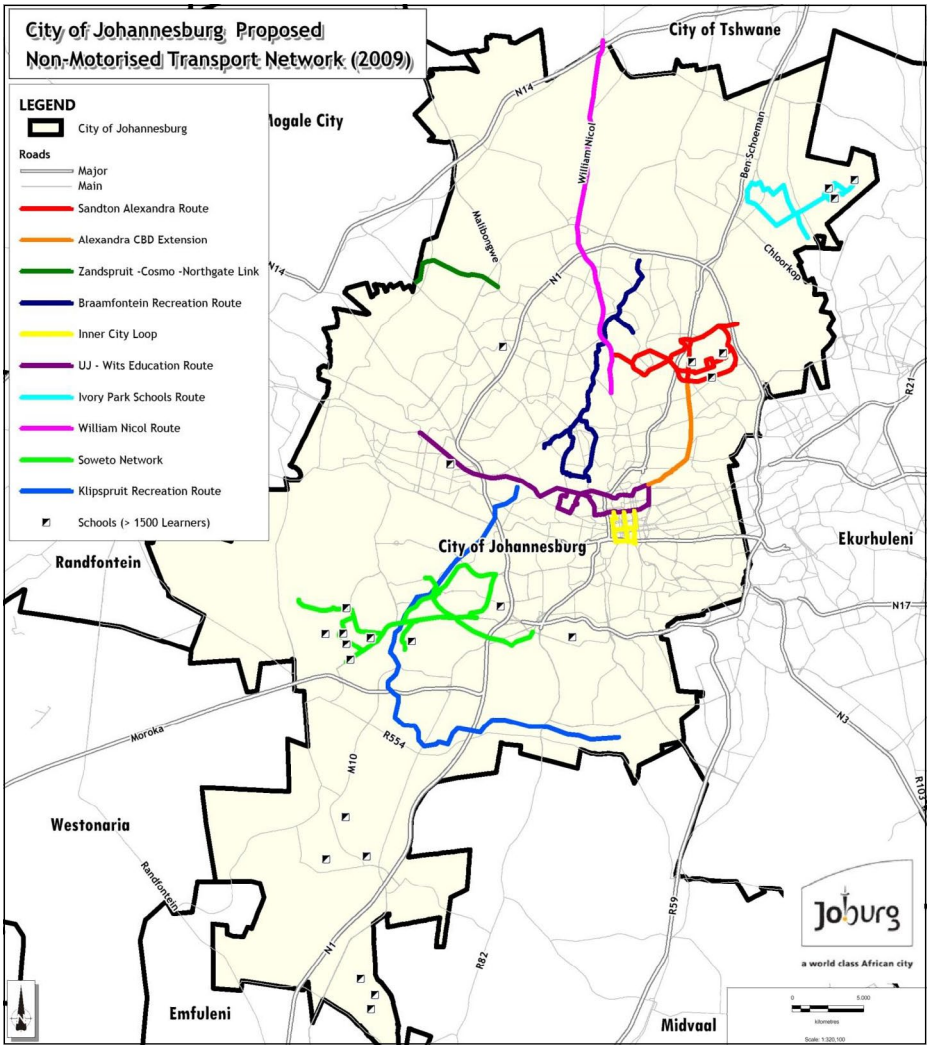

Figure 1 Non-motorised transport routes as proposed in 2009 (CoJ 2013b)

Figure 2 Map of Gauteng showing the City of Johannesburg Metropolitan (SA Venues 2021)

Master Plan 2013, the CoJ Draft NMT Policy, and the Department of Transport's NMT Facility Guidelines 2014. Another international guideline and planning document was the 2009 Connect2Greenways Guidelines, Sustrans, United Kingdom (Wray & Gotz 2014).

Selection criteria

For the Rosebank–Sandton NMT, factors such as congestion levels (traffic), usage of (demand for) the services, needs of the users, safety, design, condition of existing infrastructure, natural environment, parking facilities, accessibility (distances

to users), and cost were considered. In addition, other specific conditions of the environment (topography, condition of land use, walking distances and integration with existing motorised transport facilities) were paramount considerations, similar to the study conducted by Yazid *et al* (2011). The provision of NMT facilities should cater to a wide range of users by ensuring the safety of road users, improved liveability, welfare, and the environmental and sustainability issues (Vanderschuren *et al* 2015).

Case Study 2: Soweto–Johannesburg CBD and Line 1B NMT infrastructure

The CoJ proposed new pedestrian linkages and infrastructure along the Soweto–Johannesburg CBD and Line 1B routes requiring facilities for NMT for ease of access to BRT stations. The routes included streets providing major linkages to the Rea Vaya Stations in Soweto, and the Johannesburg CBD and Line 1B project (including the UJ–Wits route, i.e. University of Johannesburg and University of the Witwatersrand) within the CoJ. The estimated cost for the projects was approximately R2 315 000 ($170 000) (CoJ 2013a:9). These included cost for lighting, sidewalks and cycling infrastructure improvements. This study evaluated the NMT projects because they are a strategic form of transportation that attracts little attention even though it provides variety and contributes to a holistic inclusion of all forms of transportation infrastructure.

Rationale, processes, and business case

The feasibility study was conducted in 2012–2013. It entailed site investigations, interviews, and surveys to determine the community's needs based on passenger volume and needs, the condition of facilities and safety within the areas in accessing the Rea Vaya stations by walking and cycling. The stakeholder routes and preferred lines were identified, and the needs of the community members and users were investigated using interviews and site observations. A passenger interview survey was introduced to establish the peak hour for commuter volume, station passenger counts, condition of facilities, amenities and pedestrian links, and accident occurrence rates along the networks. The UJ–Wits proposed routes in the Johannesburg CBD were further verified and updated with stakeholder consultations and site visits (CoJ 2013a), with references to existing infrastructure audit observations.

Selection criteria

The criteria for selecting priority passenger volume, community facilities, quality of infrastructure (percentage of inadequate or non-existent), pedestrian infrastructure (areas with the greatest needs within the station precinct), distances walked >30 minutes to access the stations (proximity to stations), and pedestrian accident occurrence (places within the station precincts which are unsafe for pedestrians to use) (CoJ 2013a:8). The feasibility study (Johannesburg CBD – UJ/Wits route) incorporated topography, current land use and desire lines, urban quality, impact on current accesses and businesses, and personal security in addition to traffic volume and speed. These variables were deemed to influence the performance of projects during the operational stage because they pose potential risks to the project and stakeholders (private investor or society) and were considered at the feasibility stage (Bracarense *et al* 2016).

FINDINGS

The analysis identified common themes related to the performance of NMT infrastructure. The performance of the Rosebank–Sandton NMT infrastructure was evaluated based on the intended objectives of improving accessibility and quality of life of users viz-a-viz aspects, including the level of usage (demand) for the non-motorised facilities, state of the facilities, congestion, new business ventures, universal accessibility, safety, and satisfaction with the transport infrastructure condition and services. Likewise, the performance of the Soweto–Johannesburg CBD NMT projects was assessed based on accessibility, quality of infrastructure (pleasant cycling and walking environment and state of the sidewalks provided), as well as perceived safety while accessing the Rea Vaya stations. This study also reflects on the maintenance of the facilities, the transport needs and satisfaction, concerns with noise pollution, and community involvement in cleaning and maintenance of the facilities. In addition, issues related to safety and security of users residing farther from the stations and needing to walk longer distances were considered.

Level of usage

The high level of dependence on privately owned cars in urban areas and the low population densities and developments in the rural areas, coupled with lack of accessibility to transport links or hubs, can make mobility and commuting onerous. Moreover, in developing countries there is very little consideration of or a sense of awareness regarding planning for mobility in cities to incorporate NMT infrastructure, and little attention is paid to the needs of NMT users in terms of road space, crossings and other amenities, thus resulting in increased accidents (UN Habitat 2009).

Although the NMT infrastructure facilities were improved in the case study areas to increase access to nearby BRT stations, participants reported that the facilities were in low demand as they (the participants) had alternative modes of transport besides the BRT (including taxis and Uber), so they had little or no need for NMT infrastructure nearby the BRTs. According to the respondents:

> There are cycling lanes along the route … but I do not think anybody uses them … maybe they use them at night or early in the morning … but I seriously doubt it.
>
> I have not used the BRT in a long time. I drive now or use taxis when I want to save fuel.
>
> I use taxi. I have no other options. Access is not easy. I find it easier to use taxis – I want to use it, but I can't, because they do not have stations where I live. It is about a 45-minute walk to access the BRT.
>
> I use the BRTs more than taxis; there are delays, but it is more efficient in the morning [when] there are a lot of buses …
>
> I do not use the BRT … I sometimes use taxis. But mostly, I use the bike.
>
> I use Uber when I need to get to work quicker or to the airport or in a rush. Otherwise, I use Gautrain …

The participants' perceived level of usage indicated minimal uptake of the use of the NMT facilities. Issues highlighted were accessibility and availability of alternative modes of transport. The improvement of the NMT facilities seemed to meet the general needs of the pedestrians, but those of the cyclists are inadequate.

Traffic congestion

Traffic congestion in South Africa relative to other parts of the world contributes to environmental, social and economic costs in the form of high resource consumption and greenhouse gas emissions. Therefore, developed nations and major cities around the world are strategically improving their transit

networks with greener alternatives and complementing these with NMT to avoid traffic congestion. Regarding traffic congestion, the participants in both areas reported:

> … There are spaces for cyclists at the back of the mall. That improved because of the Rea Vaya. They had to make provision for the cyclists, but the problem is that whenever they improve and add demarcations, Uber and taxis always find a way to block those …
>
> The road is very busy because there are taverns and food stalls there … so instead of using two lanes, they use one lane … most cars are parked by the food stalls … so it is not that there is traffic congestion. Traffic is flowing, just that the road is busy … generally, the busier roads get congested sometimes … for example, a circle by N17, there's a lot of traffic there … it's a central road … traffic officers control traffic there during peak hours …
>
> Traffic flow is horrendous and with construction happening in each corner. … Those construction companies are operating at the same time when we're supposed to be getting to work.
>
> There is too much maintenance on the roads now … we are all sharing one lane and it is heavily congested.
>
> From 14:00 to 19:00 the traffic is bad … the buses just stop on the roads … there is no bus stop. Even Rea Vaya stops on the road. On some roads, there's just a shelter and signpost … they cause traffic congestion …
>
> There are no lanes for the Rea Vaya …

The participants' accounts indicated that NMT facilities were being misused due to inadequate parking facilities for motorised transport and ongoing maintenance. Plans to improve NMT infrastructure delivery should include measures to incorporate and manage design elements that could impact traffic management and calming measures in the areas. For example, strategies may include lowering the speed limits of motorised traffic, and increasing the number of road traffic officers and speed cameras. In addition, attention to design elements, such as the provision of dedicated lanes for BRTs and parking facilities for cyclists would alleviate traffic problems (Vanderschuren *et al* 2014).

Quality and condition of infrastructure

One of the significant difficulties with NMT facilities is the ability to consistently maintain the quality, cleanliness and condition of these facilities to meet the needs of users such as pedestrians, wheelchair users and cyclists. The following are examples of study participants' mixed feedback, ranging from satisfactory maintenance and cleaning to relatively good infrastructure (pedestrian walkways and cycle lanes):

> Road works are done … stormwater and drainage issues are fixed …
>
> The streets mostly are clean … waste disposal is okay … dumped in a field, incinerated at times …"
>
> The roads are clean.
>
> There is always someone doing something … In terms of cleanliness, they are number 1.
>
> … there are no potholes … Diepkloof [in Soweto] is an area that is developed, there are not a lot of things that need to be improved … there aren't much issues there … they are in good condition …
>
> Phase 2 is okay and clean because it is relatively new … the cleaner side of Soweto.
>
> Happy with maintenance and cleaning … but when there is a strike, no one comes around.

Some of the participants strongly believed that the level of maintenance could be better:

> Sandton roads are not good, even though it is a nice area. I have never understood that. It is not that amazing.
>
> … they do the paving … drainage issues happen once in a while …
>
> They have done the sidewalks, although they are not in good condition, not maintained regularly. They do not maintain the pavements anymore.
>
> There are streetlights, but they do not work; things get vandalised … there are no cycle lanes around this side.
>
> The condition of the roads [pavements] is not good … some potholes here and there … but the sidewalks are fine, clean and maintained.
>
> … Generally, the quality is good, but there is always room for improvement.

Other comments on community participation in cleaning and maintenance were proffered:

> The residents clean their part of the street … It is how we grew up … so that the part of the street looks presentable … other than that, some people clean these roads.
>
> There is this program called Jozi-At-Work … they do waste management, try to maintain the parks and roads … they are community members … Pik-It-Up also collects waste.
>
> Pik-It-Up comes once a week on Thursdays to clean.

Other issues raised were poor visibility and lack of appropriate road demarcations and markings. There was evidence of inadequate maintenance with vegetation, waste and loose paving along the walkways in some of the areas. For the CoJ to achieve cleaner streets and sustainable NMT infrastructure quality, there should be well-structured longterm strategic policies for urban planning to effectively ensure that the quality and conditions of the available infrastructure are fit for purpose, meet the demand for connectivity, safety and community goals (Handy & McCann 2010). Decisions about where and how to invest in NMT infrastructure and how to prioritise investments that can improve facilities are critical for metropolitan areas (Handy & McCann 2010). Furthermore, the maintenance cost of NMT facilities requires careful consideration and planning, as it can become significantly overwhelming for a municipality's budget. However, proper implementation of such projects can improve accessibility, inclusivity, acceptance and usage in the local communities.

Safety and security

Safety and security issues are barriers to NMT use, including other socio-economic and geographic factors such as land use developments that restrict users' movement, freeways and rail lines with inadequate safe crossing points, high-traffic roads, and security issues. Therefore, adequate consideration regarding pedestrian safety, and minimising high traffic volumes and speeding are requisite decisions relevant to enhancing safety within the locations. There are also safety-related issues regarding cycling in the lower-income areas of Johannesburg, which explain the limited number of cycling activities.

Overall, the participants were concerned about safety and security while using NMT infrastructure due to recurring incidents and lack of resolving such issues by the authorities:

> The road is always congested, which is not safe for cyclists … but there are streetlights …
>
> … once you leave the stations and have to walk, it is not safe, especially at dawn or at night …. when an incident occurs, you find communities meeting and people walking around at night, keeping an eye … we have community police forum … they rotate vigilance …
>
> … it is the hood … there is always crime, but there's guys from the security company, they come and say maybe every household should contribute so that they can do vigilante shifts … the police are not reliable, even when they are around there is always crime and people vandalising.
>
> Security guards are around, but these days, they all go next to the mall, then there is a higher rate of crime this side and phone snatches.

Some areas tend to be generally associated with more crime and road safety issues (Morgan 2017). Therefore, users of NMT, such as cyclist and pedestrians, perceive that the facilities should have more direct links to public transport stations and increased safety and security levels (Vanderschuren *et al* 2014). Approximately 40% of the total road traffic accidents recorded in South Africa in 2012 were NMT-related (Cooke *et al* 2017; Mokitimi & Vanderschuren 2017). Increased CCTV surveillance and continuous patrol of law enforcement officers increased the perception of safety for NMT users in eThekwini Municipality in Durban, South Africa (Cele 2018). Also, awareness initiatives focusing on road safety education can provide opportunities for behavioural changes (for motorised and NMT users (Cele 2018)).

User satisfaction

User satisfaction was assessed in terms of reduced cost in using NMT facilities due to increased walking and accessibility near the Rea Vaya, which were some of the objectives for the provision and improvement of NMT infrastructure in the selected case study areas. However, the participants reported mixed feedback about savings and accessibility to the stations:

> For some people, they have to take more than one taxi to get to the Rea Vaya.
>
> I am satisfied, we do not have a choice, there [is] no train station, there are no options, we just have to use what is available …
>
> Accessibility for the disabled is okay …
>
> The facilities are not wheelchair-friendly for anyone. There is nothing that accommodates the disabled. Even the road from Starbucks is slanted. So, if you roll off, you roll off.

User satisfaction information captured over a period of time has the potential to contribute to infrastructure planning processes for municipalities with the capability of demonstrating user trends, patterns and behaviour, e.g. cycling activities within the lanes could serve as a basis for future developments. Furthermore, with NMT infrastructure users can enjoy benefits such as reduced fuel costs, vehicular expenses, licence fees, registration rates and related taxes, as well as saving on public transport fares (Cooke *et al* 2017). Similarly, to promote social inclusion, NMT infrastructure should be accessible to all, including the disabled (Vanderschuren *et al* 2015; UN Habitat 2020).

New business ventures

Some key infrastructural components of NMT have resulted in the funding of citywide bicycle-transport infrastructure networks. Bicycle micro businesses have sprung up from NMT infrastructures, including other schemes and initiatives such as lockers, secure parking of bicycles, Wi-Fi, bicycle repairs/maintenance services and shops, and sellers of refreshments and light food along the routes. According to the participants, such new businesses have been established since the improvement of NMT facilities in the areas:

> There are business ventures there, the ones with bicycle lanes … coffee shops, printing places, lots of stuff going on at the sides, restaurants.
>
> There are a lot of stores/businesses that have come up definitely.
>
> I think Rosebank is attractive … it's central business-wise, so there [are] a lot of smaller businesses …
>
> Street vendors have mushroomed …

Therefore, the provision and improvement of NMT facilities add value in terms of the emergence of street vendors along the routes and thus economic opportunities (Baufeldt 2016). Consultation with local communities and businesses is vital towards managing the expectations of local projects in terms of investment and informal businesses, and supporting initiatives for job and wealth creation within the local communities as poverty relief measures.

Table 2 Key findings on the performance of the case study projects

Performance measures/themes	Case 1: Rosebank–Sandton NMT	Case 2: Soweto–Johannesburg Line 1B NMT
Level of usage	Usage (demand) for the non-motorised facilities is low.	Level of usage (demand) is high.
Traffic congestion	High, partly due to on-going road maintenance.	Evident at peak hours and where Rea Vaya buses stop along the road because there are no dedicated bus lanes.
Quality and condition of infrastructure	Good; sidewalks and cycle lanes are in good condition.	Good; the roads are clean; good condition of the sidewalks and cycling lanes.
Maintenance	Maintenance on roads is on-going; sidewalks and cycling lanes are well maintained.	Well maintained streets/facilities; the community participates in cleaning and maintenance of the facilities.
Safety and security	Poor safety and security reported.	There are no safety management systems in place, but effort is made after an incident.
User satisfaction	Users are somewhat satisfied with infrastructure condition and services.	Users are satisfied with the condition of transport facilities and traffic management; users' transport needs are satisfied.
New business ventures	Exist along the routes.	Exist along the routes.

The performance issues identified from the projects are summarised in Table 2, based on the participants' statements on the performance of the NMT infrastructure in the selected areas.

DISCUSSION

The provision of road infrastructure and maintenance is seen as a social responsibility to the citizens (Wang *et al* 2018), and road networks should offer safe, convenient and efficient transportation services, and adequate access to communities (Karlaftis & Kepaptsoglou 2012). It is worth mentioning that users derive value from the use of the road infrastructure assets and facilities (Okoro *et al* 2018). For such users the value for time and money, safety aspects, comfort, amenities and road condition are essential performance indicators (Suanmali *et al* 2015). Furthermore, quality of service is usually established based on customer experience, and this study acknowledges that NMT users pay fees for using the facilities and thus their expectations and input, in a bid to improve the performance of such infrastructure, are vital.

On the Rosebank–Sandton project, the performance of the NMT infrastructure is considered somewhat unsatisfactory concerning safety and security in the area. These findings further reinforce the reports on crime and accidents in the study area (Magwaza 2018). The findings identify that, although the NMT facilities in the area are maintained, they are not being put to good use, which may be a result from the relatively higher demand for motorised facilities in the area, and thus limited space for cyclists on the road networks, with most road users in Sandton being private vehicle occupants (Labuschagne & Ribbens 2014). These findings are also consistent with views expressed in Morgan (2017) that more than 70% of households in Johannesburg do not own bikes. According to the 2014 Household Travel Survey, only 28.7% of households within the CoJ owned bicycles in working order (Morgan 2017). The issues of safety, congestion and culture, in addition to social values, alternative transport systems, priorities and topography, pose significant hindrances to the use of NMTs (Ana *et al* 2014; Morgan 2017). In addition, poor maintenance and inadequate cleaning discourage using NMT infrastructure, as rubble or blockages could result in cycle accidents (Morgan 2017). These challenges affect the optimum use of NMT facilities, and as such, sustainability of such infrastructure may be unattainable in the long term. Attention to the different elements that affect how people move around could help garner more demand for NMTs, and support the development of policy and sustainable delivery of NMT infrastructure (Okoro *et al* 2016; Morgan 2017). Furthermore, increased uptake of NMT infrastructure can positively affect congestion and the quality of life of the citizenry. These effects include reduced congestion with dedicated lanes designed for cyclists, lower carbon footprint and increased health benefits associated with walking and cycling, as well as reduced costs of motorised transportation (estimated at 2.6% of GDP) (Ana *et al* 2014; Vassi & Vlastos 2014).

The performance of the NMT infrastructure is considered to be of an acceptable standard for the Soweto–Johannesburg project. The inspection of the NMT facilities and participants' accounts of the condition and impact of the facilities in terms of users' satisfaction regarding accessibility, affordability, condition, maintenance, traffic, safety management and performance were perceived as satisfactory. These findings are consistent with results reported in the National Road Users Satisfaction Survey (NRUSS) in 2013/2014 in the United Kingdom, in which users rated their overall satisfaction level highly (89.63%) about journey time (congestion), safety, information provision, as well as network management and upkeep (Parkhurst *et al* 2015). Although the NRUSS survey was based on motorists, it indicated that sustainable transportation should cater to various users and elements, including pedestrians and pedestrian crossings, ease of crossing side roads, availability of cycle lanes, and condition of cycle lanes and pavements.

In addition, design aspects such as universal accessibility, physical dimensions and network specifications to properly integrate NMT with other modes of transport, traffic-calming measures, and alternative design and delivery directions are critical considerations in NMT infrastructure delivery (Ana *et al* 2014). Improving the design aspects would also ensure that road space and safety are prioritised for NMT users to have the same experience and service as motorised transport users (Baufeldt 2016). Non-prioritisation of NMT, among other reasons, results in high rates of pedestrian accidents (Cooke *et al* 2017; Mokitimi & Vanderschuren 2017). Therefore, attention to safety aspects in design is critical. Design for safety initiatives that prioritise the end users should be holistically embedded from the planning phase of such projects. Further, it is important to prioritise NMT educational programmes for users and vehicle drivers to improve their attitude and behaviour on roads (Cele 2018).

Additionally, maintenance and operational concerns are paramount, as posited in the NMT Facility Guidelines (Vanderschuren *et al* 2014). Non-motorised transport should offer expected services, and its appearance should be maintained without compromising the value of the facilities. Improvement in NMT facilities results in improved levels of safety for both cyclists and pedestrians and all categories of users, including school children, physically challenged or disabled people, and the elderly (Vanderschuren *et al* 2015; Baufeldt & Vanderschuren 2017). A view shared by the CoJ indicates that NMTs should cater to a wide range of users to justify managed lanes in the inner CoJ (COJ 2016). There needs to be a shift from the use of private cars for the existing NMT network to become more efficient and deliver significant economic and environmental benefits to the CoJ, alongside tangible lifestyle benefits (Vassi & Vlastos 2014; Baufeldt 2016). NMT networks can be promoted through discrete investments by improving the way cities are planned or regulated, projects and services are financed, and streets are designed to achieve a *Complete Street* concept (with features including roads with sidewalks, bike lanes, and safe pedestrian crossings) (World Bank 2017). Optimised operational efficiency through traffic management and roadside parking delineation can improve the quality of services to NMT users (Baufeldt & Vanderschuren 2017) and increase the usage (demand) of the facilities in the long run. Furthermore, since cities are different geographically (urban and traffic attributes), strategies to promote NMT use could be tailormade to suit particular localities. In some parts of the world, for instance in Brazil's third most populous city Salvador, cycling is used for rental and passenger (public) transportation in line with the needs of most of the populace (Ana *et al* 2014). However, this requires careful planning and integration between different transportation modes, land uses and design of public spaces to encourage the use of NMT by diverse users including the vulnerable

(Vanderschuren *et al* 2014). The CoJ's Draft Integrated Development Plan 2020/2021 outlines plans for integrating NMTs in other parts of Soweto and Turffontein near railway stations (CoJ 2021). It is recommended that future developments like these take into account the identified performance aspects, ultimately with the end-users at the forefront of the planning and implementation processes.

CONCLUSION

This study established the performance of non-motorised transportation infrastructure using two case study projects, i.e. the Rosebank–Sandton and Soweto–Johannesburg CBD NMT projects. The findings indicated that the performance of the NMT projects on quality and maintenance, and services provided, were considered satisfactory by the users. The NMT projects have also facilitated new start-ups (small businesses) and some of these businesses are rapidly developing to become scalable business models, and these have further improved accessibility of the NMT infrastructure. However, traffic management and safety issues were highlighted as concerns due to conflicts with motorised transport and road maintenance, and risk while using NMT facilities.

This study provides useful user-focused evidence beneficial to transportation infrastructure planners and stakeholders in designing, providing and managing NMT infrastructure geared towards sustainable mobility in South African cities. The essence of sustainable transportation infrastructure initiatives is to cater to all and cover different dimensions and perspectives, including end users. This should be geared towards providing access to daily opportunities, social inclusion and improving the liveability prospects for all through economically efficient and sustainable transportation. Also, the 2030 Agenda for Sustainable Development recognises that sustainable urban development and management are crucial to the quality of life of South Africans in fostering community cohesion, employment, personal security and a means to stimulate innovation. Further studies are recommended using alternative research techniques and additional case studies to strengthen these findings towards improved and evidence-based decision-making for implementing these types of NMT projects in South Africa.

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