A TOTAL SOCIAL COST APPROACH TO PUBLIC TRANSPORT PLANNING IN SOUTH AFRICA

M NKOSI[1], M ZUIDGEEST[2], M MOKONYAMA[3] and R HAWTHORNE[4]

[1]Planning and Traffic Engineering, SMEC South Africa, 267 Kent Avenue, Ferndale, Johannesburg 2194, South Africa; Tel: 011 369 0703; Email: Muzi.Nkosi@smec.com
[2]University of Cape Town, Private Bag X3, Rondebosch 7701; Tel: 021 650 4756; Email: mark.zuidgeest@uct.ac.za
[3]CSIR – SMART Mobility, Meiring Naude Road, Pretoria, South Africa; Email: mmokonyama@csir.co.za
[4]Workshop 17, the Bank, 24 Cradock Avenue, Rosebank 2196, Johannesburg, South Africa; Tel: 011 880 1673; Email: ryan@acaciaeconomics.com

ABSTRACT

Apart from direct costs in the provision of transport, other indirect costs are generated amongst others through accidents, emissions, and congestion. However, in most instances, these costs are not borne by users of the transport system (at least not directly). Appraising transport interventions solely based on operator and user costs is not sufficient. In this paper, the effectiveness of the Total Social Cost (TSC) approach to guide the provision of transport infrastructure and services was implemented and evaluated against the conventional modal hierarchy approach using the Atteridgeville-Pretoria CBD corridor as a case study. The TSC approach can account for both direct and indirect costs in transport provision and appraisal. The study's findings show that the TSC approach for the analysed corridor is important in unpacking the trade-offs required for determining the most (cost) effective mode of transport necessary to service demand along a corridor. This is then contrasted with the TSC approach results with those of the modal hierarchy approach and show the impact of not explicitly detailing the trade-offs between the operator, user, and external costs. This lack of detail might result in prioritising the wrong investments in transport in the long term, as such resulting in unsustainable cities.

1. INTRODUCTION

The *White Paper on National Transport Policy* sets out as an objective that the appraisal and provision of transport infrastructure and services should be done sustainably (DoT, 1996 & 2017). In South Africa, Fundamentally, Section 24 of the Constitution bestows ecologically sustainable development the status of a human right. Despite policy and constitutional prescripts, the selection of an appropriate mode of public transport is mostly influenced by financial and budgetary factors due to limited funding, which must also be allocated to other sectors such as housing and energy.

In South Africa, selecting an *appropriate* mode to service demand along a corridor is based on prescriptive or performance approaches. Prescriptive approaches focus primarily on allocating modes of travel as a function of demand, whilst performance approaches expand on that by introducing other public transport-related performance measures (Gauteng Department of Roads and Transport (GDRT), 2013; City of Cape Town (CoCT), 2016; TCT, 2013). The approach used by the *Gauteng 25-year Integrated Transport*

Master Plan (Gauteng ITMP25) is prescriptive, whilst that used in the City of Cape Town is a performance-based approach (GDRT, 2013; CoCT, 2016; TCT, 2013).

Albeit the significance of external costs, there is little research in South Africa to inform how public transport modes should be allocated to corridors by minimising external costs. Notwithstanding the work done by the National Treasury that looked at the financial and fiscal sustainability of the current system (CSP, 2018; Van Ryneveld, 2014). For instance, in the modal hierarchy used in the Gauteng Province, there is little documentation on how external costs are minimised (GDRT, 2013). Therefore, more research is required in South Africa to incorporate external costs in supporting decision-making regarding which mode of public transport should be allocated to which corridor.

This paper investigates the *effectiveness* of using a Total Social Cost (TSC) approach in determining the most suitable mode of public transportation to meet passenger demand along a specific corridor. By definition, total social costs comprise internal and external costs. Internal costs include all the costs borne directly by the consumer of the good or service in question, whilst external costs are borne by society, including costs such as the risk of accidents and emissions. The external costs can be significant. For example, it is estimated that, in the European Union, the proportion of external costs as a percentage of GDP (Gross Domestic Product) ranges from 3.4% in Norway to over 7% in Portugal and Luxemburg (European Commission, 2019).

The paper seeks to advance the understanding of total social cost in developing economies, with a focus on South Africa, and also aims to contribute to the broader literature on corridor analysis.

The paper is organised into several sections, starting with an Introduction. Then the Background section follows, offering an overview of the case study area. Afterwards, the Approach for evaluating the Total Social Cost is presented. The Results of the case study analysis are then shown and discussed. Finally, the paper concludes with remarks on the use of Total Social Costs in South Africa.

2. BACKGROUND

2.1 Total Social Cost

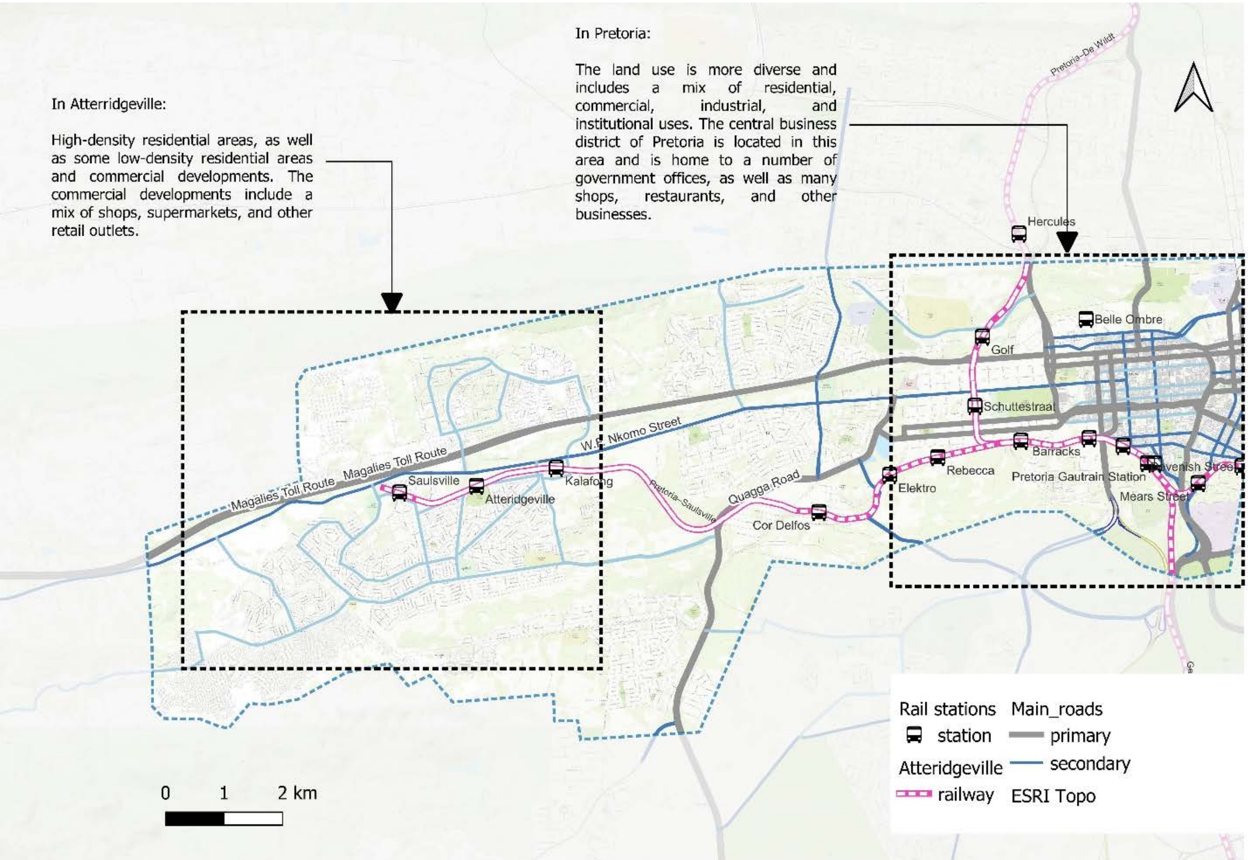
TSC approach is considered crucial in promoting sustainable transportation system provision (Litman, 1997; Gudmundsson et al., 2016; EC, 2019). TSC encompasses both direct and indirect expenses in the provision of transportation, which represent the complete cost of transportation. Research shows that external costs comprise a significant portion of the total costs in the transportation sector, including expenses related to accidents, pollution, noise, visual disruption, and loss of amenities (Ortúzar & Willumsen, 2011). According to a study by Jakob et al. (2006), external costs accounted for 2.23% of the GDP, with private transportation expenses being 28 times higher than those for public transportation. Another study found that the proportion of external costs to GDP in the European Union ranged from 3.4% in Norway to over 7% in Portugal and Luxembourg (EC, 2019). In the context of the economic benefits of internalising costs, Litman (1997) argues that failing to do so results in society bearing these costs, while capital investments that could have been used elsewhere are instead utilised to subsidise the under-pricing of the transportation system.

To justify the provision of a public transport system in South Africa, it is necessary to estimate operator costs and revenue. In cases where the estimated costs exceed the revenue that the service may generate, the government will typically provide the shortfall through subsidies. This paper aims to evaluate the effectiveness of the TSC in the Atteridgeville-Pretoria CBD Corridor, with a focus on accounting for external costs in transportation provision, which is a pressing need.

2.2 Case Study Area

Figure 1 shows the map of the Atteridgeville-Pretoria CBD corridor located on the western side of the City of Tshwane, designated as part of region 3 for planning purposes. The City of Tshwane has long-term plans to transform this corridor, which includes the introduction of a Bus Rapid Transit system. As of the time of writing, the commuter rail services between Saulsville and Pretoria had resumed after being closed for rehabilitation in preparation for the operation of the new train set.

The corridor features various land uses, with residential land use being most concentrated in Atteridgeville, while job opportunities are concentrated towards the east in Pretoria. Additionally, the area contains a number of open spaces, such as parks and recreation facilities.



Source: Generated by author using open street maps in QGIS

Figure 1: Atteridgeville locality map

The estimated demand was derived from the Gauteng 25-year Integrated Transport Master Plan (ITMP25) transport model, which was developed using the EMME-4 platform, a transport forecasting model. The summary of the estimated demand is presented in

Table 1. According to the strategic transport model, 30 051 people are moving along this corridor per hour in both directions. The following assumptions were also made:

- A total of 30 051 trips along the corridor were assumed to be motorised.
- The modal split of 70%, which represents public transport within the corridor, was based on the Gauteng household travel survey of 2014.
- 80% of public transport users were assumed to be heading towards the town, while 20% were heading towards Atteridgeville.
- Sufficient feeder services will be provided to support higher capacity modes.

Table 1: Atteridgeville-Pretoria CBD corridor

Inputs	Value
Input Demand (1hr person demand)	30 051
Private vehicle split (30%)	16 528
Public transport split (70%)	7 437
Public transport split directional split (80:20)	5 950
Length of the corridor (km)	18

Source: Estimating by the author using the outputs from Gauteng EMME model and GHTS of 2013

2.3 Limitation

During the analysis, all modes of transportation were evaluated for the corridor; however, the rail service was not yet operational. As part of the TSC analysis, the calibration of the rail service was assumed to be a greenfield development. However, it is important to note that brownfield developments typically incur lower costs compared to greenfield developments. Furthermore, the resuscitation of rail service generally has a lower environmental impact than greenfield development.

The datasets used to determine the external costs associated with the rail service in South Africa are worthy of mention, as they were obtained during a period when the rail service was experiencing a significant decline, as highlighted in 2016/2017 State of Safety Report. However, it is important to note that since the analysis was conducted, national and provincial household travel surveys have been updated, potentially impacting the external costs associated with the rail service. Furthermore, the estimation of external costs was based on the Handbook on the External Costs of Transport, published by the European Commission (EC, 2019), which is primarily geared towards developed economies, thus further constraining the generalisability of the findings. Therefore, when interpreting the results of the TSC analysis, it is crucial to consider these limitations.

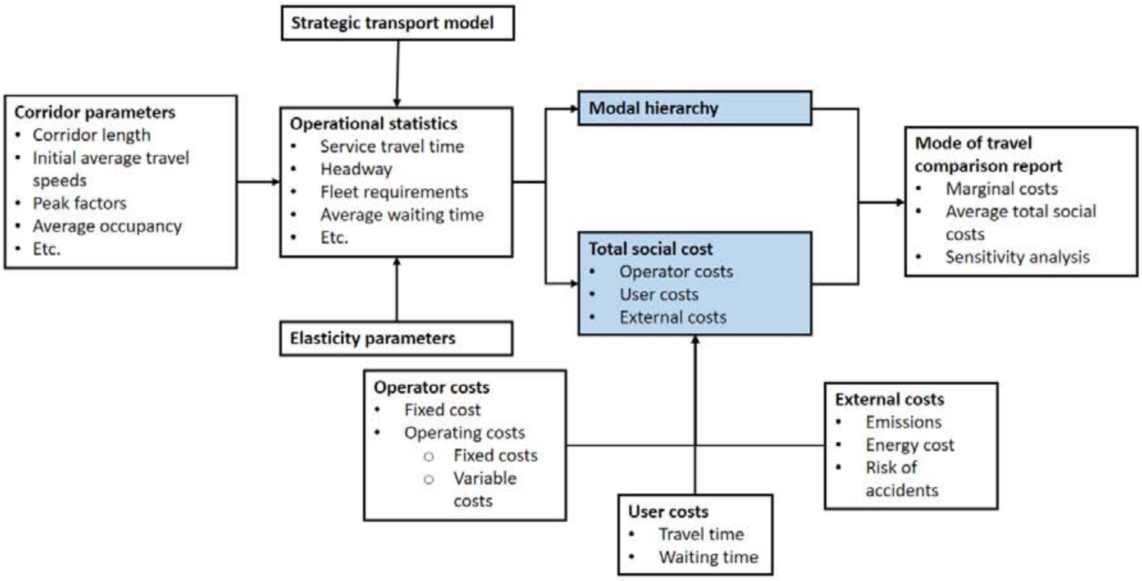
The TSC analysis can be valuable in identifying the optimal transportation mode for a specific corridor. However, it is crucial to acknowledge its limitations. Typically, transportation projects undergo two assessments to determine their feasibility. The first evaluation considers the operational costs and revenue from passengers, which establishes the business case. If the result is negative, additional subsidies are required from the government. The government then conducts a comprehensive socio-economic cost-benefit analysis, which considers the total societal costs, including infrastructure and the broader benefits. Although the TSC analysis can contribute to this evaluation, it is only a partial solution and depends on what is included in the analysis. Moreover, there are limitations to the TSC analysis, such as its inability to account for non-monetary criteria in the analysis, which can be addressed through approaches such as Multi-Criteria Decision

Analysis. Therefore, it is essential to recognise the TSC analysis's limitations and conduct a comprehensive assessment to make well-informed decisions on transportation projects.

3. APPROACH

3.1 Overview

The approach of estimating the TSC for the Atteridgeville-Pretoria CBD corridor is shown in Figure 2. This paper considers external costs related to air pollution, climate change, and accidents. The external cost rates used in this study are based on the Handbook on the external costs of transport published by the European Commission (EC, 2019). The effectiveness of the TSC was evaluated against the modal hierarchy, a mode selection approach used in the Gauteng ITMP25. This approach was chosen because the selected study corridor is located within Gauteng and is subject to planning as outlined in Gauteng transport planning.



Source: Drawn by author, adapted from work done by Li and Preston, 2015

Figure 2: Conceptual evaluation approach for the paper

This section will discuss the estimated operator costs, user costs, and external costs. While these costs are subject to debate, especially user costs and external costs, this paper aims to utilise published information to achieve the set objectives. Although there are debates surrounding the methods and figures used by other researchers, this paper does not aim to evaluate those approaches but rather use them as a reference. It is worth noting that costs such as fares have been excluded as they are considered a transfer between operator costs and user costs.

3.2 Modes

The following modes were evaluated to determine the effective mode for the Atteridgeville-Pretoria CBD corridor:

- **Minibus taxi**: This technology uses low-volume vehicles with a common capacity configuration of 14 seats (standing not allowed).
- **Standard bus**: This technology operates using medium to high-capacity modes, with the most common mode being the 55-seater.

- **Articulated bus**: Similar to standard buses in terms of schedules and routes, this technology offers a higher passenger capacity at 105.
- **BRT (Bus Rapid Transit) standard bus**: Refers to technologies that operate on exclusive lanes, with the assumed capacity being a 55-seater.
- **Commuter rail**: These high-capacity services operate on fixed routes and schedules, with a typical vehicle capacity of 170 seats per coach.

3.3 Operator Costs

The operator costs were informed by the databases developed by Del Mistro and Bruun (2019), Del Mistro and Aucamp (2000) and Ackerman (2015). These databases were used to estimate capital and operating cost for the various modes of travel considered in this paper. The South African Reserve Bank Inflation rates were used to update the operational costs and capital costs. In this paper, the 2021 inflation rate of 5.5% was used (South African Reserve Bank (SARB), 2021).

3.4 User Costs

The total user cost includes time-related expenses, such as the cost of walking, being in the vehicle, and waiting time. The estimated values of time from Hayes and Venter (2017) were used to convert travel time into monetary values.

3.5 External Costs

Table 2 shows the external cost rates used to estimate the total external costs for this paper. The external cost considered in this paper are costs related to air pollution, climate change and accidents. The external cost rates used in this paper are based on the *Handbook on the external costs of transport* published by the European Commission (EC, 2019). This is a detailed resource on how to estimate direct external costs. As already mentioned, the approaches are the subjects of various debates. As such, the purpose of this paper is not to evaluate the merits of the approaches used by other researchers. However, it is to use what is published to address the objectives of this paper. It is sufficient to say that the external cost rates for this paper were estimated using a top-down approach. To convert the costs reflected from euros to rands, a rate of 1:20 has been used. Each of the external cost components are given in rand per vehicle kilometre. Further adjustments were made to the rail inputs in accordance with the documents used, including the published State of Safety Report 2016/2017.

Table 2: Estimated external costs rates

Mode of Travel	Air Pollution [R/veh-km]	Climate Change: [R/veh-km]	Accidents [R/veh-km]
Minibus taxi	0.23	0.38	1.44
Single bus	2.84	1.77	3.78
Articulated bus	2.89	1.64	3.78
BRT standard bus	2.84	1.77	3.78
Commuter rail	9.40	4.02	10.44

Source: Estimated by the author using the *Handbook on the External Costs of Transport of 2019*

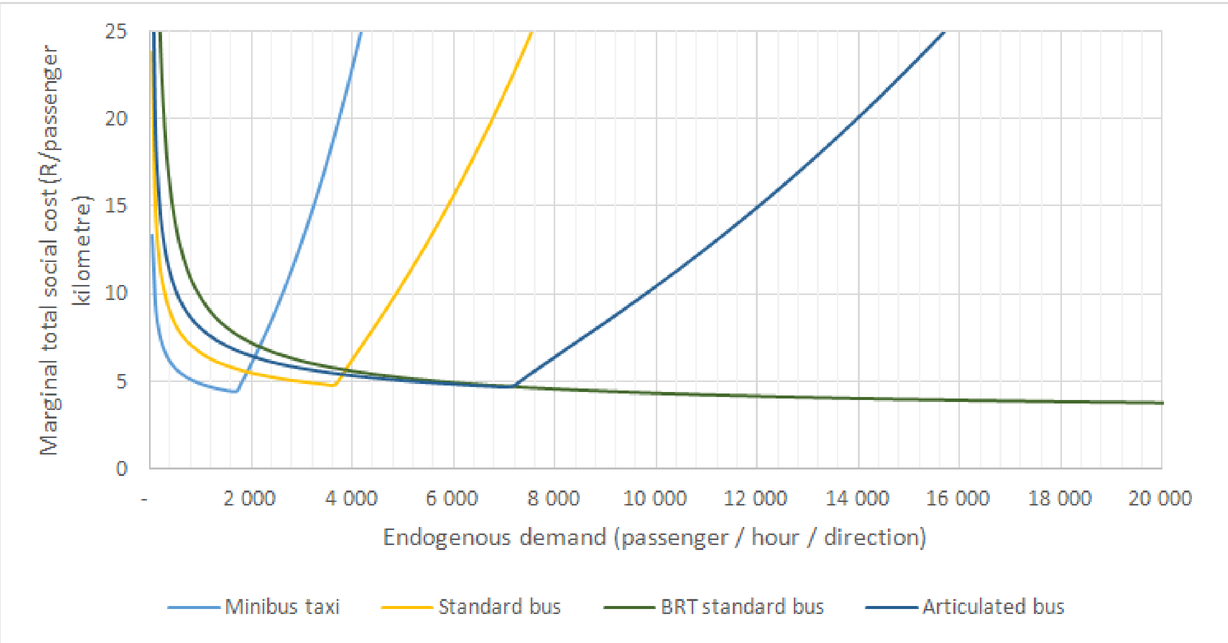
4. RESULTS AND DISCUSSION

Based on the described methodology and databases a computational model was developed. Figure 3 and Figure 4 shows the estimated total social cost curves for land-based modes of travel. The curves display three features, viz., a negative sloping section, which reflects the fixed costs being spread over smaller traffic units, a vertex, which reflects optimal conditions for a mode of travel and a positive sloping section, which reflects sub-optimum conditions for a particular mode with respect to demand for travel.

In summary, the findings for the 18 km corridor for varying demand levels are as follows (measured passenger per direction in hour):

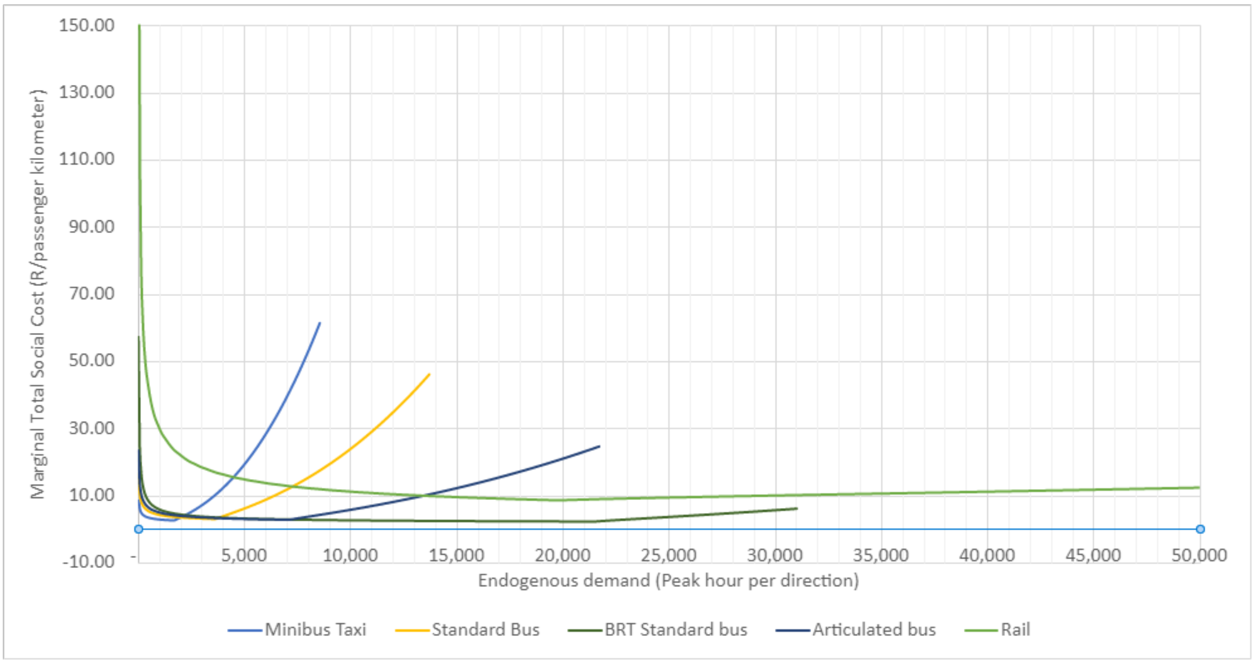
- Minibus taxi: 0 – 2 000.
- Standard bus: 2 000 – 4 000.
- Articulated bus: 4 000 – 7 000.
- BRT standard bus: > 6 500.

In comparison, for the studied 18 km corridor, the proposed modes as per modal hierarchy as detailed in the *Gauteng 25-year Integrated Transport Master Plan*, are comparable to those estimated recommended using the TSC. The findings of the paper are also consistent with the performance-based measures of the City of Cape Town, although, the performance-based measures for the City of Cape Town allow for different modes to be applicable for the same demand level.



Source: Drawn by author using the calibrated spreadsheet model

Figure 3: Estimated road-based total social cost curves for the 18 km Atteridgeville-Pretoria CBD corridor



Source: Drawn by author using the calibrated spreadsheet model

Figure 4: Estimated land-based total social cost curves for the 18 km Atteridgeville-Pretoria CBD corridor

The corridor chosen for the study is 18 km long and it was estimated to service 5 950 passengers per hour per direction in the peak direction. The assessment of the findings is as follows:

- **Modal hierarchy**: Bus Rapid Transit is the appropriate mode of travel when a modal hierarchy approach is used for technology selection. This is because the estimated public transport demand along the corridor is between 4 000-8 000 passengers per hour per direction.
- **Total social cost approach**: Table 3 summarises the total social cost analysis done in this study for the Atteridgeville-Pretoria CBD. In terms of the estimated total social cost for the corridor, the BRT standard bus technology is the appropriate technology to service the demand along the corridor. Society would pay R 2.81 to produce a passenger kilometre for BRT standard bus services. In terms of marginal operator costs, articulated bus service would cost the least of all the technologies considered, requiring the operator to pay R 1.66 to produce a passenger kilometre for articulated bus services.

Table 3: Total Social Costs for the Atteridgeville-Pretoria CBD

Mode of Travel	Marginal Operator Costs	Marginal User Costs	Marginal External Costs	Total Social Cost
Minibus taxi	35.94	8.13	0.57	44.64
Standard bus	9.34	3.27	0.42	13.02
Articulated bus	1.66	1.23	0.11	3.00
BRT Standard bus	1.91	0.75	0.15	2.81
Commuter rail	9.99	2.56	0.04	12.59

The paper found that for an 18 km corridor under examination, the total external cost constituted between 0.6% to 6% of the total social costs. This contrasts with a study conducted in Italy by Avenali et al. (2020), which compared bus and rail services and found that external costs made up 8% to 25% of the total social costs for rail services and bus services, respectively.

Different scenarios were considered, including current estimates and estimates assuming a 50% or 25% increase in input rates of external costs, which refers to raising the unit rates of air pollution, climate change, and accidents. Upon examining the impact of a 50% increase in external costs, the estimates for each mode increase, suggesting an associated increase in external costs. It is noteworthy that BRT standard buses exhibit the highest increase, rising from 5.2% to 7.5%, while standard buses also demonstrate a significant increase, climbing from 3.2% to 4.4%.

Table 4 shows the estimates of the proportion of external costs relative to total costs for various types of public transportation systems across three distinct scenarios. Different scenarios were considered, including current estimates and estimates assuming a 50% or 25% increase in input rates of external costs, which refers to raising the unit rates of air pollution, climate change, and accidents. Upon examining the impact of a 50% increase in external costs, the estimates for each mode increase, suggesting an associated increase in external costs. It is noteworthy that BRT standard buses exhibit the highest increase, rising from 5.2% to 7.5%, while standard buses also demonstrate a significant increase, climbing from 3.2% to 4.4%.

Table 4: Sensitivity of the external costs unit rates

Mode of Transport	**% Proportion of External Costs as a Ratio of Total Costs**		
	(Current estimates)	**25% Applied**	**50% Applied**
Minibus taxi	1.5%	4.1%	3.4%
Standard bus	3.2%	5.2%	4.4%
Articulated bus	3.7%	3.7%	3.1%
BRT Standard bus	5.2%	8.9%	7.5%
Commuter rail	0.4%	0.6%	0.5%

The findings of this sensitivity analysis suggest that a minimum increase of 50% in external costs is required to provide an accurate assessment of such expenses, with the exception of rail service, which displayed relatively lower external costs. These results underscore the necessity of establishing appropriate external cost parameters tailored to developing countries' unique characteristics.

This is especially relevant in contexts such as South Africa, where the Road Traffic Management Corporation (RTCM) has estimated that the costs of accidents accounted for 3.4% of the country's GDP. This highlights the significant economic impact of external costs in transportation decision-making and the importance of appropriately accounting for such costs to ensure that transport policies align with the broader socio-economic goals of the country. Therefore, developing EC parameters relevant to developing nations is critical to improving transportation decision-making and promoting sustainable development.

5. CONCLUSION

This paper compared the Total Social Cost (TSC) approach and the conventional modal hierarchy approach for developing the Atteridgeville-Pretoria CBD corridor. The TSC approach recommends the following effective road-based public transport modes for the 18 km corridor, based on passengers per hour per direction:

- Minibus taxi (0-2 000).
- Standard bus (2 000- 4 000).
- Articulated bus (4 000- 8 000).
- BRT standard bus greater 6 500.

Policy and planning are essential in ensuring that user prices align with the external costs linked to their selected transportation mode. A comprehensive understanding of these costs is crucial to effectively plan and develop policies that guide transportation systems. However, the external cost calculations, such as those outlined in the European Commission's Handbook on the External Costs of Transport (EC, 2019), require further refinement to better reflect the unique conditions present in South Africa. Developing countries often face high external costs associated with their transportation systems, which are not fully captured in the current framework. Thus, additional work is necessary to adapt the external cost calculations to the specific context of South Africa and address the gaps in the existing framework.

6. REFERENCES

Ackerman, JS. 2015. Optimal investment strategies for bus-based transport under low to medium passenger demand conditions. Master of Science mini-thesis. Pretoria: University of Pretoria.

City of Cape Town (CoCT). 2016. Comprehensive Integrated Transport Plan 2018-2023. Cape Town: Transport and Urban Development Authority.

Cities Support Programme (CSP). 2018. Integrated Public Transport Network (IPTN) Plan Development Technical Guidance version 4. Pretoria: National Treasury: Cities support programme.

CoT. 2021. *Locality map for Atteridgeville/Sausville.* Available at: https://www.tshwane.gov.za/sites/about_tshwane/MapsAndGIS/Locality%20Maps/Atteridgeville_Saulsville_Arena_Locality.pdf. Accessed 3 October 2021.

Del Mistro, RF & Aucamp, CA. 2000. *Development of public transort cost model.* Pretoria, South African Transport Conference.

Del Mistro, RF & Bruun, E. 2019. *Appropriate operating environments for Feeder-Trunk-Distributor or Direct road-based public transport services in cities of developing countries.* Instanbul, s.n.

Department of Transport (DoT). 1996. White Paper on Transport Policy, Pretoria: Department of Transport.

Department of Transport (DoT). 2017. Draft Revised White Paper on Transport Policy. Pretoria: Department of Transport.

European Commission (EC). 2019. Handbook on the external costs of transport. Luxembourg: Publications Office of the European Union.

GDRT. 2012. *Gauteng 25-year integrated Transport Master Plan,* Johannesburg: Gauteng Department of Roads and Transport.

GDRT. 2014. *Gauteng Household Travel Survey,* Johannesburg: Gauteng Department of Roads and Transport.

Gudmundsson, H, Hall, RP, Marsden, G & Zietsman, J. 2016. *Sustainable Transportation: Indicators, Frameworks, and Performance Management.* 1st ed. Heidelberg Germany: Springer-Verlag.

Hayes, G & Venter, C. 2017. A meta-analysis of two Gauteng stated preference data sets. Pretoria, Southern African Transport Conference.

Jakob, A, Craig, J & Fisher, G. 2006. Transport cost analysis: A case study of the total costs of private and public transport in Auckland. Environmental Science & Policy. 9(1):55-66.

Li, X & Preston, J. 2015. Reassessing the financial and social costs of public transport. *Proceedings of the Institution of Civil Engineers – Transport,* 168(4):356-369.

Litman, T. 1997. Full cost accounting of urban transportation: Implications and tools. *Cities,* 14(3):169-174.

Ortúzar, JDD & Willumsen, LG. 2011. *Modelling Transport.* 3rd ed. Chichester, West Sussex, England: John Wiley & Sons, 2011.

South African Reserve Bank (SARB). 2021. Monetary Policy. Available at: <resbank.co.za/en/home/what-we-do/monetary-policy>. 23 December 2021.

Transport for Cape Town (TCT). 2013. Comprehensive Integrated Transport Plan: 2013-2018. City of Cape Town: Transport for Cape Town

Van Ryneveld, H. 2014. Expenditure and performance review of South Africa's public transport and infrastructure system. Pretoria: Government Technical Advisory Centre.