Cost Benefit Analysis of NMT Infrastructure Projects

UNEP

University of Cape Town · iYunivesithi yaseKapa · Universiteit van Kaapstad

Table of Contents

List of Figures

List of Tables

List of Equations

1 INTRODUCTION

Non-Motorized Transport (NMT) has immense benefits for individual users, as well as society at large, through improvements to physical health, air quality, the environment, climate change, personal finance, accessibility, mobility and the empowerment of vulnerable groups. Therefore, NMT infrastructure - particularly well-planned, high quality facilities in a comprehensive network - is essential to achieving economic and social equity, especially for the urban poor in developing countries.

Currently, there is no comprehensive holistic method for appraising the various costs and benefits of NMT projects in developing cities. Contemporary tools used in the developed world are thematic, focusing only one specific benefit of NMT, or require impractical amounts of contextual data. To aid the promotion of NMT infrastructure investment, the NMT Project Appraisal Tool (NMT-PAT) was developed to take into consideration the wide range of benefits (health, social, economic and environmental) while not requiring unrealistic amounts of data. The tool utilises common, aggregate transport and economic indicators where possible and provides the ability to use local institutional knowledge to supplement existing data or substitute data that is unavailable. The user can generate meaningful insight into the viability of NMT infrastructure in their city, which would be useful in planning, budgeting and decision-making processes.

This report and its supplement aim to advance the development of NMT-PAT for UNEP's 'Share the Road' programme. This advancement is facilitated by testing its suitability for the African context by analysing four case study scenarios in Nairobi, Kenya. The report begins with a background to the current state of non-motorised transport in Kenya (Chapter 2). An overview of the availability of relevant data in Nairobi follows, as well as a discussion around the options for procuring or substituting necessary data that is absent (Chapter 3). The four case study scenarios are then critically analysed based on NMT's major indicators of societal amelioration and compared by accounting for the scale of each project (Chapter 4). Finally, the applicability of NMT-PAT was further investigated through a Training workshop with local NMT experts and stakeholders in Nairobi (Chapter 5). The output of the project is a more advanced form of NMT-PAT that can analyse and compare multiple, simultaneous ex-ante evaluations of NMT infrastructure investments.

2 EX-ANTE CASE STUDIES

2.1 BACKGROUND

Nairobi, the capital of Kenya occupies a land size of about 684 km^2 (Tibaijuka, 2007) and has a population of about 3.5 million (World Policy Blog, 2014). The population of Nairobi is expected to grow and rapid urbanisation and economic growth provides both opportunities and problems within the urban environment. This has seen congestion soaring and costing the government close to Ksh 1.9 billion every year (Gachanja, 2015).

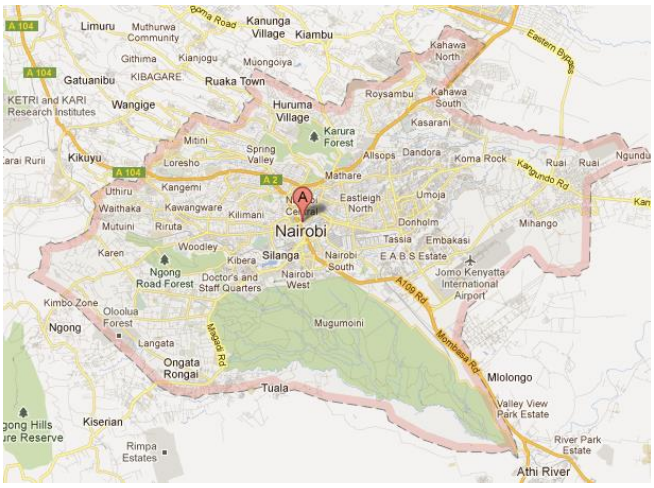


Figure 1: Map showing the boundaries of Nairobi (Source: Google Maps)

Nairobi's traffic conditions consist of congestion and roadways that are not safe for its various users. The Nairobi transport system was designed for a population of around 300,000 people, with the natural increase in population and urban migration, the transport system is forced to cater for over 3 million residents (Gonzales, et al., 2009). The projected population growth of Nairobi is shown in the figure 2.

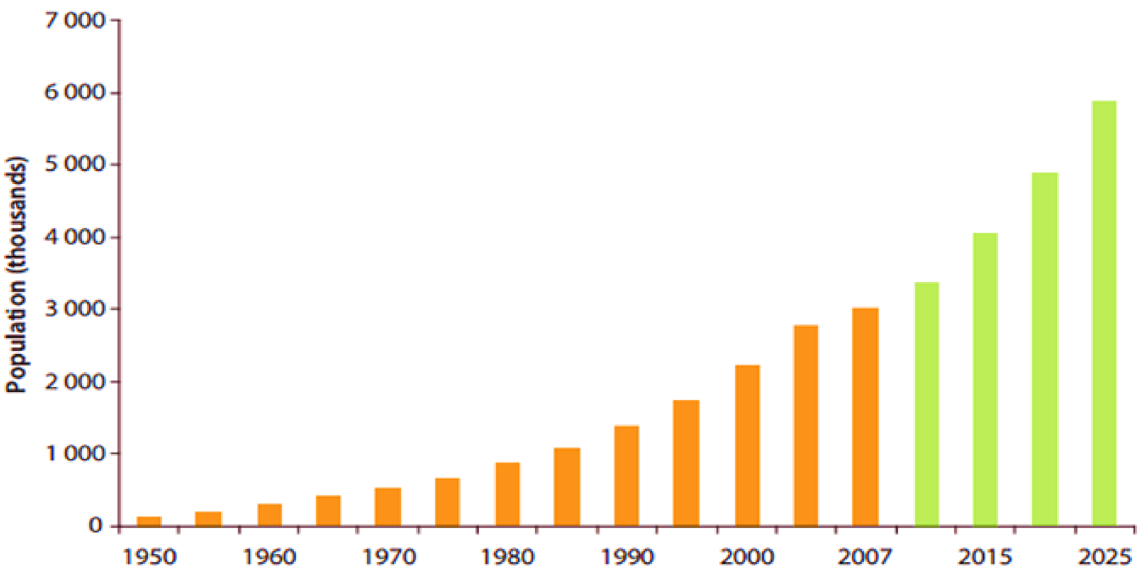
The city has a diverse transport user system which is comprised of matatus, private cars, boda bodas, walking, taxis and bicycles among others. About 6,700, 000 trips are carried out per day for different trip purposes (JICA , 2006). The modal split for Nairobi is given in Table 1 below, and this shows an overwhelming number of non-motorised trips.

Table 1: Modal Split in Nairobi

Mode	Modal Split (2002)[1,2]	Modal Split(2006)[3]
Walking	47%	47%
Two Wheeler	*[4]	1.2%
Matatus	42%	29%
LRT & rail	*	0.4%
Cars/Truck/Taxi	10%	15.3%
Buses	*	3.7%
Other	1%	0.2%

Over the past decade, the number of cars on Nairobi's roads has increased. Projected growth of car ownership showed that private cars in the city were estimated to be 207,339 in 2004, 327,366 by 2010 and 716,138 by 2025. This shows a tremendous growth in private car. In 2008, Nairobi accounted for

Figure 2: Projected Population Growth of Nairobi (Source: KNBS: 2008)



[1] (World Bank, 2002)

[2] Matatus percentage includes all public transport , the car percentage only includes private cars

[3] (JICA , 2006)

[4] No figures were found for these modes

30% of the country's private vehicle ownership. The rapid pace of urbanisation and motorisation has exacerbated congestion and has contributed significantly to air pollution (JICA , 2006). In 2011, Nairobi ranked the fourth most congested city in the world (Klopp, 2015). Flowing from high motorisation is the increase in demand for motorised transport infrastructure thus continuing the marginalisation of non-motorised transport and its infrastructure.

Table 3: Distribution of NMT Infrastructure in Nairobi by Road Class, 1998, Source: (Kayi, 2007)

Road Class	Footpaths (km)	%of Total	Foot/Cycle paths (km)	%of Total
International Trunks	14	34.15	1.4	1.71
Primary	10.2	24.67	31.1	37.97
Secondary	0.8	1.93	24.9	30.4
Access	11.95	28.9	19.1	23.32
Unclassified	4.4	10.64	5.4	6.59
Total	41.35	100	81.9	100

2.2 Non-Motorised Transport Infrastructure in Nairobi

In 2006, KIPRRA reported that the city had 12,145 km of roads and 8% of these roads were classified as paved roads. In 1998, the city had 1,530km of roads and only 8% of these roads were identified to have some form of non-motorised infrastructure. Table 2 shows the distribution of non-motorised infrastructure in Nairobi in 1998.

Given the dominance of walking as a mode of transport, one would expect that the coverage of NMT infrastructure to be extensive. Further, the condition of the infrastructure (1998) also points to the discrepancy in non-motorised maintenance and state. Out of the 123.5 km, only 7.3km were classified to be in good condition (Kayi, 2007), which is a mere 6%.

Table 3 provides a summary of the conditions of the NMT infrastructure in 1998. These findings save as a starting point to ascertain whether there have been improvements and dedication of the fiscus towards NMT infrastructural maintenance and availability between 1998 and 2009.

A report by the International Road Assessment Programme (2009) showed that about 95% of the urban roads in Nairobi have high pedestrian flow, with only 20% having pedestrian foot path. These figures do not present a significant change in the provision of infrastructure between 1998 and 2009. Non-motorised transport users are still underserviced despite their high share in modal share.

A site visit on Mbaghathi[5] road (2015), corroborates the inadequacy and unfavourable conditions of pedestrian walkways and crosswalks. The picture below shows a section of the pedestrian walkway along the corridor.

Figure 3: Pedestrian Walkway along Mbaghathi Road, 2015

Table 2: Conditions of Footpaths and Cycle Lanes in Nairobi, 1998, Source: (Kayi, 2007)

Type of Condition	Footpaths (km)	% of Total	Foot/Cycle paths (km)	% of Total	All NMT Network	% of Total
Good	5.9	14.26	1.4	1.71	7.3	5.92
Inadequate	6.1	14.75	4	4.88	10.1	8.19
Poor	13.9	33.62	21	25.64	34.9	28.32
Very poor	10.25	24.79	55.5	67.76	65.75	53.35
Non-Existent	5.2	12.58	----	----	5.2	4.22
Total	41.35	100	81.9	100	123.25	100

[5] This is not a representative of the state of pedestrian on the whole network but it points to the need for an improvement on the state of the infrastructure.

The quality of the infrastructure and sometimes its absence along some of the major transport corridors, forces non-motorised transport users to resort to using the road dedicated to vehicular traffic thus leading to NMT related road accidents. The International Road Assessment Agency provides a star rating[6] to measure how different road users view road sections. A star rating is only produced on sections of the road where there is demand for use of a facility by each road user type. A study by iRAP (2009) on roads inside Nairobi showed the star ratings shown in Table 4 below. For the purposes of this report, special attention is paid to cyclists and pedestrians and how they viewed the non-motorised infrastructure.

On the 119km of road that was evaluated, both pedestrians and cyclists did not give a 5 star or 4 star rating to the roads. The highest that the roads scored for both pedestrians and cyclists was a 2 star. This indicates a poor quality and service of non-motorised transport infrastructure.

2.3 Summary of Nairobi's Transport System and its Accompanying Problems

The city has a wide range of transport related issues which include but not limited to:

- inadequate integration of city development planning
- poor integration of the transportation network system
- inadequate public transport system to meet the rising travel demand
- long commuter distance and travel time
- high cost of transport compared to low level of income
- inadequate development of non-motorised infrastructure network
- poor safety and high incidence of motor traffic accidents
- increased pollution and deterioration of the urban environment

2.4 Perception and Attitude towards NMT in Nairobi: Users and Non-Users

The extent of use of NMT is reflective of social, economic and cultural dimensions in different areas (I-ce, 2000). Further the state of the infrastructure also plays a large role in influencing mode choices. With that in mind, it is important to understand the perception and attitude towards NMT and the environments from which users and non-users come from. It is through understanding these different aspects that policy and strategies to attract or retain NMT users can be developed. Salon and Aligula (2012) in a study in Nairobi found that respondents who did not own bicycles stated that even if they owned a bike they would not cycle as it is not safe to do. However despite the risk associated with cycling, some respondents also indicated that they would cycle as it is affordable. One key outcome from the study was that the provision of proper cycling paths would be a starting point in encouraging cycling as a mode.

2.5 Towards Interventions: Nairobi's NMT Policy

The NCCG recognised the extent of the transport problem in Nairobi and seeks to find solutions to

Table 4: Percentage of network by Star Rating and road user type inside Nairobi, Source: (International Road Assessment Programme, 2009)

Star Rating	Car Users		Motorcycle Users		Bicycles Users		Pedestrian	
	Length (km's)	%	Length (km's)	%	Length (km's)	%	Length (km's)	%
★★★★★	0km	0%	0km	0%	0km	0%	0km	0%
★★★★	42km	35%	39km	33%	0km	0%	0km	0%
★★★	43km	36%	37km	31%	0km	0%	37km	31%
★★	22km	19%	2km	2%	65km	55%	82km	69%
★	12km	10%	0km	0%	3km	2%	0km	0%
	0km	0%	42km	35%	51km	43%	0km	0%
Total	**119km**	**100%**	**119km**	**100**	**119km**	**100%**	**119km**	**100%**

(International Road Assessment Programme, 2009).

address some of the problems related to accessibility and mobility in the city especially those concerning NMT users. In response to the needs of this cohort of individuals and also the issue of congestion within the city, the NCCG launched its first NMT policy which will serve as a supportive framework for provision of safe, affordable and environmentally friendly transport for Nairobi.

The overarching objective of the NMT policy is to have a transport system that fully incorporates NMT infrastructure such that NMT users are safe. Further, the policy aims at ensuring that strict regulations are put in place to ensure that NMT infrastructure is not used for other activities (e.g side walk markets) and is also respected by other modes of transport.

Flowing from the need to accommodate NMT users within the broader Nairobi transport system, five key aspects are identified within the NMT policy:

1. Increase mobility and accessibility- that is through ensuring that there is good infrastructure and a reduction in congestion
2. Increase transport safety- catering for the needs of NMT users who are the most vulnerable on Nairobi's roads.
3. Improve amenities for NMT;
4. Increase recognition and image of NMT in Nairobi County.
5. Ensure that adequate funding/investment is set-aside for NMT infrastructure.

With well thought consideration for NMT users in the design of the road infrastructure that is by having crosswalks, cycle paths, sidewalks and increased level of service for pedestrians there may be an increase in the modal share of cyclists and public transport users. Further this may contribute in the reduction of NMT related accidents hence improving multimodality in Nairobi (Nairobi County Government, 2015).

In order to fulfil the objectives within the NMT document, the city indicated that there will be a new moratorium where at least 20% of its existing and future budget is dedicated to NMT and Public Transport infrastructure. However, there is still no implementation that shows the City's commitment to NMT and PT infrastructure improvement.

2.6 The current "cost" of Nairobi's Transport system

The structure of Nairobi's transport system results in "costs" that range from, environmental, economic, health and social.

2.6.1 Environmental issues in Nairobi

Nairobi was ranked as the fourth most congested city in the world in 2011 (Klopp, 2015). Further urban sprawl is rampant and this continues to displace parts of the natural environmental and in some cases fragmenting co-dependent ecosystems. Within the current discourse of sustainable growth, protection of the natural environment and the provision of housing, the urbanisation trajectory of the city provides challenges to create a balance between all these keys issues (Tibaijuka, 2007).

Hence it is important to come up with strategies that provide more travel mode options. Given the absence of proper infrastructure for non-motorised and intermediate transport, mode choices are limited to private cars, matatus and other forms of motorised transport. This goes against the notion of sustainable modes despite walking having the highest number of captive users (JICA, 2014).

2.6.2 Economic costs of Nairobi's Transport system

The amount of time that people spend commuting to work has an impact on the productivity of different sectors and the economy as a whole. In 2008, the economic costs due to congestion were estimated at Ksh 1.9 billion annually (Gachanja, 2015). This also includes the additional time that people spend travelling to work. In 2014, it was reported that around Ksh 50 million was lost per day due to lost productivity as a result of traffic congestion (McGregor & Doya, 2014). This is an unsustainable trend as it will continue to weigh on the country's economic growth. Restructuring transport provision and shifting the mode priorities with regards to investment and financing may be a starting point to shorten the journey to work. This may aid in reducing the economic costs and perhaps recoup some of the economic losses.

Upgrading of non-motorised transport facilities has been cited to contribute significantly to economic gains. A study by INFRAS (2003) showed that investing in non-motorised transport is more economically efficient compared to other modes of transport. Investing more in non-motorised transport projects in Nairobi, is a step in the right direction in facilitating a more efficient transport system which may contribute to economic growth.

2.6.3 Health

Several studies that investigated the contribution of NMT to better livelihood have shown that the improvement in NMT facilities can increase physical activities thus reducing the risk of heart disease, diabetes, strokes and other chronic diseases (Angira, 2001). Further, the health risks also emanate from particulates of car exhausts (Tibaijuka, 2007) and with the growth in motorisation in Nairobi, the risks will become even higher.

In the Nairobi context, the health threats also emanate from safety concerns as there are no viable non-motorised infrastructure. Given that about 40% of the trips are made using walking, it is pertinent that appropriate infrastructure is put in place. The current state of the road infrastructure in Nairobi presents an environment that favours motorist at the expense of pedestrians. This has resulted in 524 non- motorised fatalities in 2014 (JICA, 2014). If there is no provision of appropriate road space and infrastructure for this cohort of individuals, non-motorised road fatalities will continue to grow.

2.6.4 Social

Transport poverty is a phenomena where people spend more than 10% of their income on transport expenditure (RAC Foundtion, 2012). From a Nairobi perspective, the cost of travel is high compared to monthly income for most low income individuals. These are captive public transport user. Respondents that took part in a study along Jogoo and Juja road corridors indicated that they used non-motorised transport because it was a more affordable transport option. This translates to money savings. One of the issues raised was that using non-motorised transport reduced their journey time as they would have avoided congestion (Nairobi County Government, 2015). However in spite of all these benefits inherent in the use of non-motorised transport, the absence of infrastructure remains a challenge. The social benefits derived from non-motorised transport infrastructure range from journey quality, security and liveability, reduction in transport costs among others and all these benefits can be accessible to individuals if there is sufficient investment and financing of NMT projects.

3 Data availability

The rapid pace of urbanisation, motorisation and its accompanying congestion in Nairobi calls for research based arguments on the benefits of sustainable transport. Given the bias against non-motorised transport and its infrastructure, a holistic appraisal tool for NMT projects may shed some light on the potential benefits of prioritising NMT infrastructure in Nairobi.

3.1 NMT-PAT and the Data requirements

The Non-Motorised Transport Project Assessment Tool (NMT-PAT) is a spreadsheet based tool that evaluates the costs and benefits associated with walking and cycling projects. NMT-PAT has four key categories of benefits and disbenefits that are considered relevant to non-motorised transport projects: *environmental, health, economic and social*. To effectively utilise the quantitative and monetary functionality of NMT-PAT, a certain number of the necessary data indicators in Table 5 are required.

Based on a literature review of several policy documents in Kenya, World Bank databases and university studies that have been carried out, there is a clearer view of what data is available. Additionally, direct collaboration was formed with officials from the Nairobi City County Government and the University of Nairobi.

3.2 Data collection challenges

Non-motorised transport research is a topical issue especially in the current dialogues on sustainability and climate change. However, the availability of NMT related data is still very limited in African cities. In Nairobi, procuring the necessary data was even more difficult than expected and may be linked to a bias that still exists toward motorised transport modes. Table 5, shows the data that was found to be available during the three months of data collection. Some of the indicators had to be approximated using relevant data. The biggest challenge was acquiring credible data about the nature of Nairobi in the future. Without effective metropolitan transport or urban growth models, the data for many of the indicators could only be found for the present context. The discrepancies that exist with regards to data availability presented huge limitations to the scope of the study. However, several options were explored to source the remaining data needed to comprehensively appraise NMT projects in the context of Nairobi.

3.3 Opportunities to fill the gaps

Within the academic institutions of Kenya, a lot of research has gone into understanding non-motorised transport and the opportunities available to increase its modal share. Several academics were identified that have experience in NMT research within Nairobi. These key personnel provided local insight and expert opinion on the status of NMT in Nairobi, which proved to be invaluable to the research. Furthermore, an experts' opinion poll was created, see section B.14, that requested local NMT experts to provide estimates for the unavailable data related to the future of Nairobi.

Table 5: Data Availability for NMT-PAT for Appraisal in Nairobi

Necessary data indicators	Availability
Total number of trips per day	✓
Base year prices	✓
Scheme costs	✓
Discount rate	✓
GDP/capita	✓
Currency	✓
Average inflation rate	✓
Economic growth rate	✓
Metropolitan Population	✓
Modal Split	✓
Current Value of Transport Injury	?
Share of trips affected by scheme	✓
Estimated time saving due to scheme	✓
Fuel Levy	✓
Petrol Price per litre	✓
Diesel Price per litre	✓
Value Added Tax (VAT)	✓
Money Saved per person per year	?
Percentage of money saved spent on taxed consumables	?
Number of NMT injuries	✓
Number of NMT fatalities	✓
Average number of trips per day	✓
All-cause mortality rate	✓
Reference year for VSL data	✓
Value of a statistical life (VSL)	✓
Noise level at 50 metre intervals	?
Average occupancy per mode	?
Dominant fuel type per mode	✓
Average trip length	✓

3.4 Potential to widen the scope of NMT-PAT

The improvement or provision of NMT facilities provides benefits to different road users who may directly use the facilities or benefit indirectly from its use. Benefits can also be derived from knowing that there is an alternative option in case it is ever needed. Many studies that evaluate the societal contribution of NMT infrastructure, fail to sufficiently include the indirect positive impacts. The scope of NMT-PAT could be extended such that it fully captures the holistic contribution of NMT to the city.

A major group of indirect positive impacts related to NMT infrastructure fall under the concept of 'non-user benefits'. These benefits are derived from the use of NMT infrastructure but are experienced by the users of motorised transport. Examples of non-user benefits include reduced levels of congestion and lower air pollution. These benefits are due to the modal shift of trips away from motorised travel and toward NMT as a result of new or improved NMT infrastructure. Subtle benefits, like the security that a car user feels when they know that a pedestrian or cyclist is not going to suddenly enter the road, allow motorised users to travel faster and with a higher journey quality.

A number of survey methods have been employed to try gather non-user benefit data in the developed cities. The most common method is the application of stated preference surveys, often using contingent valuation and choice experiments. By quantifying the value that individuals place on certain attributes or experiences, these methods provide an avenue to monetise the benefits of an asset that the individuals do not actually use. Litman, 2011 provides a comprehensive guide on possible NMT survey methods.

4 Case study scenarios

The primary aim of this project is to test the applicability of the Non-Motorised Transport Project Appraisal Tool (NMT-PAT) in the context of an African city. A secondary aim was to determine the magnitude of benefits that is likely to be derived from NMT infrastructure in Nairobi, Kenya. Four case study scenarios were chosen - two smaller scale, newly constructed projects and two larger, theoretical networks - in order to test NMT-PAT on projects with varying scale and context. . It is hoped that the analysis of these scenarios will encourage investment in NMT infrastructure and generate meaningful insight about potential associated benefits. The four case study scenarios tested are:

1. Thika Highway
2. Haile Selassie Avenue
3. Nairobi NMT Policy Network
4. Metropolitan NMT network

The study examines the likely environmental, health, economic and social costs or benefits of each case study scenario. NMT-PAT simulates and compares a future in which each project is constructed with a business-as-usual case. The period of analysis is from a set pre-construction year, 2015, to the year 2030, allowing 15 years for the benefits to accrue and before major rehabilitation would be required.

Chapter 3 outlines the many challenges faced in the data collection phase of this project. Many of the indicators that are essential for a detailed analysis of each project were unavailable and needed to be estimated by local NMT experts in the opinion poll or approximated using supplementary data. Accordingly, the results of the analyses contained within this chapter are still useful for testing the applicability of NMT-PAT but should not be construed as accurate predictions. It is believed that the orders of magnitude of the benefits and costs related to each project are realistic but are based on incomplete and uncertain sets of data.

4.1 Thika Highway

Thika Highway is a dual-carriageway that begins in the northeast of the Nairobi CBD and extends out radially for 45km, to Thika town (African Development Bank, 2007). The highway is a main artery to the CBD for the various satellite towns surrounding Nairobi and also serves the economic hubs of Kiambu, Ruaraka and Juja. The corridor hosts several economic activities, that is manufacturing and entrepreneurial ventures which mostly employ the low income groups. There is also a large informal sector along the corridor. Thika Road is one of the most travelled corridors as it allows people to access employment, education among other services in the Nairobi CBD and also areas around Parklands and Westland's. However despite the vast opportunities that the corridor provides, the corridor is also plagued with congestion, poor air quality and high accident and fatality rates involving non-motorised users (KARA & CSUD, 2012).

Road safety issues along the corridor have been linked to the inadequacy of pedestrian or non-motorised transport infrastructure which has led to high non-motorized transport user fatalities. One of the criticisms made about the Thika highway is the demolition of the Githurai market without an accompanying plan to rehabilitate the traders. Some traders continued selling their commodities along the road side and some of these traders have become road fatality statistics (Klopp, 2011). Further, the poor design of the highway and poorly located pedestrian footbridges has exacerbated pedestrian fatalities.

The Thika Highway non-motorised infrastructure scenario will comprise of cycling facilities and pedestrian walkways on the full length of the highway including foot bridges where appropriate. The construction of the infrastructure does not only benefit pedestrians but also motorised transport users as there is a high probability of reducing non-motorised transport user fatalities and casualties especially where pedestrians insist on crossing at busy sections of the road.

Table 6: Modal split of Thika Highway

Modal split	Base - 2015	Business as usual - 2030	With project - 2030
Walking	21%	21%	25%
Cycling	4%	4%	5%
Bus	22%	22%	20%
BRT	0%	0%	0%
Minibus taxi	37%	38%	35%
LRT & rail	0%	0%	0%
Cars	14%	14%	14%
Motorcycles	1%	0%	1%
Taxi	0%	0%	0%
Other	1%	1%	1%

4.1.1 Environmental benefits

In NMT-PAT, the environmental benefits of an NMT project are derived from the shift in trips away from motorised modes. According to the experts that were polled, the Thika Highway project is likely to increase the proportion of trips completed by walking and cycling by 2030, rather than the natural decrease that would be expected without the project, see Table 6. It has been projected that the majority of the NMT trips will be shifted away from cars and minibus taxis, and the project will also increase the usage of the Bus Rapid Transit (BRT) infrastructure that is currently in the planning phase.

Table 7: Emissions of trips along Thika Highway

Emissions (tons)	Business as usual	With project	Savings
	tons	tons	tons
CO2	593 415,43	573 503,93	19 911,50
PM	216,78	209,89	6,89
NOx	3 182,03	3 063,48	118,56

The modal shift of the trips, due to the Thika Highway project, results in Carbon Dioxide (CO_2), Particulate Matter (PM) and Nitrous Oxides (NO_x) savings of 3%, 3% and 4% respectively by 2030, see Table 7. Additionally, Table 8 shows that energy usage of the trips along Thika Highway would decrease 3% and 4% with the project by 2030, for Petrol and Diesel respectively.

Table 8: Energy usage of trips along Thika Highway

Energy usage	Business as usual	With project	Savings
	Gj	Gj	Gj
Petrol	6 369 651,99	6 176 204,18	193 447,81
Diesel	1 605 818,90	1 530 780,58	75 038,32

4.1.2 Health Benefits

The potential modal shift in trips along Thika Highway, due to the NMT infrastructure, also affects the average health of the users. The 15 613 new NMT users by 2030 will have a lower risk of mortality due to their healthier transport mode. Table 9 illustrates that the physical activity benefits for these new users will prevent 150 of them from dying prematurely due to non-communicable diseases (NCDs).

Table 9: Physical activity benefits of the Thika Highway NMT infrastructure

Indicator	No. of new users	Physical activity per week	Relative risk of mortality	Premature deaths prevented
	#	Minutes	#	#
Walking	11 170	205,29	0,8656	122
Cycling	4 442	223,95	0,7537	28

The safety improvements associated with the Thika Highway NMT infrastructure is expected to save 150 lives and prevent 1406 NMT injuries over the 15 year analysis period.

Table 10: NMT fatalities and injuries along Thika Highway

Indicator	*Base - 2015*	*Business as usual - 2030*	*With project - 2030*
NMT Fatalities per year	89	100	80
NMT Injuries per year	334	438	250

4.1.3 Economic Benefits

The dominant economic benefit of most transport projects is the decrease in travel time experienced by the users, as travel is conventionally classified as a disutility. Table 11 highlights that the NMT infrastructure on Thika Highway could result in over 14 000 years of travel time saved. Due to the spatial segregation of motorised and non-motorised transport along the highway, no impedance is expected for the motorised transport users by the NMT infrastructure.

Table 11: Travel time years saved due to the Thika Highway NMT infrastructure

Indicator	Total amount of time saving
	Person years
Walking	10 594,29
Cycling	3 883,94
Total	14 478,23

The modal shift of trips from motorised to NMT modes will also have economic effects. The 3 - 4% saving in petrol and diesel use could result in a reduction in fuel tax revenue of approximately 207 million shillings over the 15 year analysis period. This tax reduction could be counteracted by the increase in Value Added Tax (VAT) and income tax revenue due to the much lower operating and transport costs borne by new NMT users. However, the data required to estimate this increase to the tax base could not be sourced.

4.1.4 Qualitative Analysis

A qualitative assessment of Thika Highway's NMT infrastructure, in Table 12, highlights the perceived state of NMT along the corridor, and the state in 2030 with and without the new infrastructure. It is the perception of the experts polled that the state of NMT along Thika Highway would have remained the same (2.3/10) up to 2030 if no NMT infrastructure was constructed. Whereas, an average improvement of 121% on the current qualitative scores is expected due to the NMT infrastructure. In particular, the qualitative score for the road traffic accidents is expected to 400% higher in 2030. These improvements are relatively substantial due to the very low ratings given to NMT conditions along the pre-construction Thika Highway.

Table 12: Qualitative analysis of the Thika Highway NMT infrastructure

Qualitative indicator	Base - 2015	Business as usual - 2030	With project - 2030
Energy usage	2	2	3
Emissions	2	2	3
Noise pollution	1	1	3
Physical activity	2	2	4
Accidents/injuries	1	1	5
Time saving	4	4	4
Journey quality	4	4	5
Security	3	3	5
Liveability	2	2	6

Table 13 illustrates the average qualitative scores when the indicators are weighted by importance by the polled experts. The weighted average improvement is lower, at 67%, as the weighting given to 'time saving' was very high and no improvement is expected. However, an improvement of this magnitude is still very significant and describes the optimism with which people view the future effects of Thika Highway's NMT infrastructure.

Table 13: Qualitative improvement due to the Thika Highway NMT infrastructure

Weighted average			
Current - 2015	BAU - 2030	WP - 2030	Improvement
2,5	2,5	4,2	1,7

4.1.5 Monetary Analysis

The potential monetary benefits of the Thika Highway NMT infrastructure, summarised in Table 14, show that the health benefits to the NMT users

Table 14: Potential monetary benefit of the Thika Highway NMT infrastructure

Impacts		Monetary (NPV)	
Health	Physical activity	Sh	4 572 423 543,37
	Accidents/injuries	Sh	4 565 292 283,09
Economic	Time saving	Sh	2 997 198 365,96
	Tax revenue	Sh	-902 929 845,78

make up 75% of the total benefit to the Kenyan economy. The decrease in travel time – often the predominant measure for the value of transport infrastructure – represents the remaining 25% of benefits and the lower tax revenue resulting in a minor disbenefit.

The Benefit-Cost analysis of the Thika Highway NMT infrastructure, seen in Table 15, highlights that the benefits derived outweigh the immense costs of the project and results in a Benefit-Cost Ratio (BCR) of 2,79. The BCR is higher than one and, therefore, the infrastructure is expected to be economically justified.

Table 15: Benefit-cost analysis of the Thika Highway NMT infrastructure

BCR	Net Present Benefit (NPB)	Sh	11 231 984 346,64
	Net Present Cost (NPC)	Sh	4 023 554 566,36
	Net Present Value (NPV)	Sh	7 208 429 780,28
	Benefit-Cost Ratio (BCR)*		2,79

***Note BCR is unreliable in data scarce contexts**

4.1.6 Strategic Recommendations

Despite favourable results from the NMT-PAT analysis and a positive perception from the NMT experts, Thika Highway's NMT infrastructure has received mixed reviews from the public.

Articles from Nairobi's major media sites suggest that Thika Highway was designed without due consideration given to NMT users and the NMT infrastructure, especially the footbridges, were post-design additions. Three of the exceptionally expensive footbridges are accused of conveying NMT users to a 'No-man's land' upon which they are then expected to cross feeder roads unprotected (Nation, 2014, p. 1). Another footbridge is claimed to be entirely superfluous, due to the close proximity of other footbridges. According to the cost breakdown for the NMT infrastructure, footbridges accounted for 48% of the total costs of the 45km route. It is recommended that the design and alignment of major transport infrastructure consider the needs of NMT users from inception to minimise the costs associated with footbridges and other corrective measures. It is also advised that the NMT infrastructure form part of a coherent NMT network, so that the benefits of the infrastructure is not confined to the corridor on which it is placed. Furthermore, NMT infrastructure should be implemented due to the popularity of the NMT route and not as an addition to an improvement of a popular motorised route.

Doubt has also been cast over the expected reduction in NMT fatalities and injuries due to the new NMT infrastructure. The predictions may not have accounted for the negative effects of the new motorised infrastructure that comprises the bulk of the Thika Highway project. A year after the NMT infrastructure was opened to the public, pedestrians constituted 84% of the fatalities along the corridor, an increase on pre-construction levels (Mwakilishi, 2013). It highlights the importance of monitoring and evaluation, so that ex-post analyses can produce more accurate predictions for the next projects. It also raises the issue of the perceived effects being different to the actual effects of a project. The opinions and perceptions of local experts in the NMT field can be very useful but are still fallible and inferior to credible data. It is recommended that further emphasis is placed on the collection of longitudinal data regarding the road traffic accidents on new and existing NMT infrastructure to identify trends and causality.

Finally, a problem that arose during the interviews with many of the local NMT experts and from observations of Thika Highway is the standardised size of the NMT infrastructure irrespective of demand. Figure 4 illustrates that as the highway nears the CBD, the pedestrian demand surpasses the standard width of the sidewalk and the users are forced into the road or onto the traffic island. It is proposed that NMT infrastructure is sized according to demand, which is the case with most motorised infrastructure.

Figure 4: The lack of adequate NMT infrastructure on Thika Highway

4.2 HAILE SELASSIE AVENUE

Haile Selassie Avenue links the Nairobi Central Business District with a new business district forming in the Upperhill neighbourhood (Gonzales, et al., 2009). It has a length of approximately 1.4 kilometres, and is abutted by a wide range of economic and recreational activities. Although it has heavy pedestrian traffic, mainly due to a large Matatu bus rank near the Nairobi Railway station, the avenue had narrow sidewalks before improvement. There is high competition for space in this economically significant area and pedestrians were being severely disadvantaged as a result (Association for Safe International Road, 2012).

Figure 5: New NMT infrastructure on Haile Selassie Avenue

The NMT infrastructure along Haile Selassie Avenue was improved by installing wide sidewalks for both pedestrian and cyclist use. The sidewalks were protected by small concrete bollards to prevent motorised vehicles from utilising the space. Figure 5 illustrates the width and space protection provided for NMT users by the new infrastructure.

Table 16: Modal split of Haile Selassie Avenue

Modal split	Base - 2015	Business as usual - 2030	With project - 2030
Walking	21%	20%	22%
Cycling	4%	3%	8%
Bus	21%	22%	17%
BRT	0%	0%	0%
Minibus taxi	38%	37%	38%
LRT & rail	0%	0%	0%
Cars	14%	18%	13%
Motorcycles	1%	0%	1%
Taxi	0%	0%	0%
Other	1%	0%	1%

4.2.1 Environmental benefits

The modal split of the trips along Haile Selassie Avenue is expected to be significantly impacted by the additional NMT infrastructure, according to the experts polled. Table 16 shows that the share of pedestrian trips is set to increase marginally and the proportion of cycling trips will have a substantial increase.

Table 17: Emissions of trips along Haile Selassie Avenue

Emissions (tons)	Business as usual	With project	Savings
	tons	tons	tons
CO2	123 562,82	110 653,28	12 909,54
PM	42,64	37,45	5,19
NOx	661,07	581,77	79,30

The shift in trips to NMT modes, especially cycling, will result in CO_2, PM and NO_x savings of 10%, 12% and 12% respectively by 2030, see Table 17. These are significantly larger proportional emissions savings than that of the Thika Highway NMT infrastructure. The same is true for the 9% and 15% lower Petrol and Diesel usage respectively, along Haile Selassie Avenue with the project. It appears that the popularity of this route means that the relatively small (1,4km), but strategic NMT infrastructure investment will have exponentially greater benefits.

Table 18: Energy usage of trips along Haile Selassie Avenue

Energy usage	Business as usual	With project	Savings
	Gj	Gj	Gj
Petrol	1 343 252,80	1 216 485,81	126 767,00
Diesel	316 692,32	269 445,55	47 246,77

4.2.2 Health benefits

The substantial modal shift toward cycling and walking expected due to the NMT infrastructure will generate a significant number of new users. Table 19 shows that this will lead to 67 less lives being prematurely cut short by unhealthy sedentary lives.

Table 19: Physical activity benefits of the Haile Selassie Avenue NMT infrastructure

Indicator	No. of new users	Physical activity per week	Relative risk of mortality	Premature deaths prevented
	#	Minutes	#	#
Walking	467	205,29	0,8656	12
Cycling	1 169	223,95	0,7537	55

The bollards and other space protection measures for the NMT users are expected to save 24 lives and prevent 222 NMT injuries over the 15 year analysis period.

Table 20: NMT fatalities and injuries along Haile Selassie Avenue

Indicator	*Base - 2015*	*Business as usual - 2030*	*With project - 2030*
NMT Fatalities	28	30	27
NMT Injuries	105	121	92

4.2.3 Economic benefits

The travel time savings are expected to be considerable, despite the short length of the infrastructure. The pedestrian users will benefit the most, accumulating close to 1 000 years of travel time savings over the analysis period, seen in Table 21. It is also predicted that the travel times of car, bus and minibus users will be negatively affected, resulting in an overall travel time saving of 441,64 years.

Table 21: Travel time years saved due to the Haile Selassie Avenue NMT infrastructure

Indicator	Total amount of time saving
	Person years
Walking	955,04
Cycling	58,09
Bus	-162,51
Minibus taxi	-335,32
Cars	-82,49
Motorcycles	8,82
Total	441,64

4.2.4 Qualitative analysis

The qualitative assessment of Haile Selassie Avenue's NMT infrastructure, found in Table 22, shows that the pre-construction state of NMT is better than Thika Highway but still only just over 3/10 on average. The experts polled believe that the level of physical activity and chance of being involved in a road traffic accident are very bad for the current NMT users along the corridor. Marginal improvements are expected in the Business-as-usual case for the environmental indicators and the level of security. This may be due to the growth of the high-income business district in the suburb that Haile Selassie Avenue leads to, which could lead to newer, less polluting cars utilising the corridor. The small, but strategic NMT infrastructure is expected to have a positive impact through each of the four benefit categories by 2030. Most significant will be the effect on the travel time for the NMT users, which were hindered by their large volumes overwhelming the previous infrastructure.

Table 23: Qualitative analysis of the Haile Selassie Avenue NMT infrastructure

Qualitative indicator	Base - 2015	Business as usual - 2030	With project - 2030
Energy usage	3	6	7
Emissions	4	6	8
Noise pollution	3	5	6
Physical activity	1	2	3
Accidents/injuries	1	1	1
Time saving	1	1	3
Journey quality	4	2	4
Security	6	7	8
Liveability	5	3	5

The analysis of the weighted qualitative improvement due to the project is shown in Table 23. Despite having a higher absolute improvement over the current value, compared to Thika Highway, the perceived inherent improvement in the BAU case means that it scores a lower net weighted improvement. It is important to determine what benefits are directly attributable to the project under appraisal and what are attributable to the natural gentrification of an area.

Table 24: Qualitative improvement due to the Haile Selassie Avenue NMT infrastructure

Weighted average			
Current - 2015	BAU - 2030	WP - 2030	Improvement
2,5	3,0	4,4	1,4

4.2.5 Monetary Analysis

The monetary benefits of the NMT infrastructure along Haile Selassie Avenue, summarised in Table 24, are immense relative to the diminutive size of the project. This is predominantly due to the potential health benefits that can be derived from persuading users to shift to NMT modes along this short corridor. The health benefits make up 96% of the total monetary benefits of the project and would not have been included in a conventional appraisal. The travel time savings account for only 4% of the monetary benefits and are outweighed by the loss in fuel tax revenue.

The diminutive size of the project is reflected in the small budget required for construction, seen in Table 25. The potential Net Present Benefit (NPB) is far larger than Net Present Cost (NPC) and leads to a

Table 22: Potential monetary benefit of the Haile Selassie Avenue NMT infrastructure

Impacts		Monetary (NPV)	
Health	**Physical activity**	Sh	1 181 970 754,32
	Accidents/injuries	Sh	416 190 927,48
Economic	**Time saving**	Sh	61 899 398,36
	Tax revenue	Sh	-339 655 740,68

BCR of 31,44. The magnitude of this BCR is rare for an infrastructure project. It shows the immense opportunity to start with the small, strategic projects that will have an exponential positive impact on the NMT users and the local government.

Table 25: Benefit-cost analysis of the Haile Selassie Avenue NMT infrastructure

BCR	**Net Present Benefit (NPB)**	Sh	1 320 405 339,49
	Net Present Cost (NPC)	Sh	42 000 000,00
	Net Present Value (NPV)	Sh	1 278 405 339,49
	Benefit-Cost Ratio (BCR)*	31,44	

***Note BCR is unreliable in data scarce contexts**

4.2.6 Strategic Recommendations

The small scale of the project means that its success has not been widely debated, as was the case for Thika Highway. Informal interviews with users of the new NMT infrastructure expressed very positive sentiment. The strategic position of the route, between the offices of the Government of Nairobi and the new service-based economic node in the Upperhill suburb, attracted a much higher proportion of new NMT users that were utilising private vehicles for the short trip.

The only suggestion reiterated by users was the separation of cyclists and pedestrians, which currently share the protected space. The steep grade of the terrain accelerates cyclists to much higher speeds than the other NMT users, increasing the chance of inter-NMT accidents. A dedicated cycle lane on each side of the road would allow the cyclists to safely achieve the much higher speeds and not consume much width of the NMT infrastructure.

The immediate perceived success of the Haile Selassie Avenue NMT infrastructure has led it to be termed a 'quick win' by many of the experts polled. It would be advisable to examine all of the currently popular NMT routes in the city to identify other quick wins that could also achieve such high Benefit-Cost Ratios.

Finally, it is recommended that the NMT infrastructure incorporate the natural gentrification that is occurring in the area and its proximity to a large urban park. The infrastructure is very pragmatic but also stark and still scores low with regard to journey quality. The high income companies in the area could be approached to co-fund street furniture, vegetation, cleaning services and other improvements. Privately funded Community Improvement Districts have functioned well in other developing cities to increase the quality and liveability of the urban environment in certain popular areas whose cost cannot be justified by the local government. The Upper Hill District Association, although still small in mandate, is expected to have an increasingly important role in the provision of NMT infrastructure in the area in the future.

4.3 Nairobi NMT Policy network

The approach taken in this scenario would be an implementation of NMT infrastructure that allows for easy integration with already existing public transport networks. Further the scenario considers links where a large number of non-motorised user fatalities or casualties have been recorded. With that in mind, the three infrastructure packages mentioned within the Nairobi NMT Policy will be explored, where the central focus is on Nairobi's Mass Rapid Transit and the pedestrianisation of the CBD. The following MRT corridors were identified:

- Nairobi Railway Station (NRS) – Ruiru – Thika
- NRS – Juja Road – Kangundo
- NRS – Jogoo Road – Komorock
- NRS – Jomo Kenyatta International Airport – Athi River
- NRS – Langata Road – Karen
- NRS – Upper Hill – Ngong
- NRS – Kabete – Kikuyu
- NRS – Gigiri – Limuru
- Outer Ring Road

The selected MRT links include two road links, Jogoo and Juja road, which have been at the top of discussions with regards to NMT fatalities and casualties. A study by Mitullah et al. (2013) on the traffic accidents occurring on the two roads indicated that 71.7% of the accidents involved pedestrians, 10.7 % involved cyclists and 6.9 % involved handcarts. Most of these accidents are attributed to poor crossing behaviour by pedestrians, and recklessness and speeding by motorists. Furthermore, the limited space given to the NMT modes on the available infrastructure also contributes to NMT user accidents. Implementation or improvement of NMT facilities on the road links will go a long way in addressing some of these issues.

Based on the MRT links above, NMT networks comprising of 36km in the east; 55km in the west of Nairobi and the partial pedestrianisation of the Nairobi central CBD will be tested in this scenario.

4.3.1 Scenario 2(A): Road Links for the East NMT Network

The NMT network in the east of Nairobi would comprise the following road links:

- Jogoo road corridor to the CBD (10km) from Outer Ring - Jogoo-Landhies and goes through Haile Selassie. There will be bicycle parking at the Kenya Railway (KR) station
- Juja Road corridor to the CBD from Outer Ring-Ring Road Ngara-Races course and terminates at Landhies round –about (10km)
- Mumias South road, through Rabai road, across, KR lines to Tanga Road to Lunga road (6km)
- First Avenue Eastleigh from Juja across KR across Jogoo road to Likoni up to enterprise road (6km)
- Lunga Lunga road from Likoni to Outer Ring Road (4km)

4.3.2 Scenario 2 (B): Road Links for the West NMT Network

The NMT network in the west of Nairobi would comprise the following road links:

- Kibera to Industrial area: Mbagathi – Langata – Lusaka – Jogoo road round-about (7 km)
- Enterprise from Lusaka to Likoni road intersection (3 km)
- Kibera – Kilimani – Westlands: Kibera drive – KR crossing – James Kangethe – NMT-only route – Ring Road Kilimani – Kitale lane – Githunguri (15 km)
- Kawangware – Kilimani – CBD: Gitanga – Ole Dume – Argwings Kodhek – Valley road – Kenyatta Avenue (15 km)
- Kawangware – Westlands/Waiyaki Way: (1) Chalbi drive – Isaac Gathanju – Mugumo – Olenguruone – Ring road Kileleshwa – Ring road Westlands (15 km)

A key point to note in this scenario is the strategic location of the network route relative to where marginalised non-motorised transport users live and work. These corridors are the main arteries that link the low and middle income residential areas with major employment hubs and have a large number of pedestrian and cyclist traffic. It is possible to move from the east to the west towards the CBD and to the industrial area. This may immensely contribute to addressing some of the issues with regards to accessibility and safe mobility.

4.3.3 Scenario 2 (C): Pedestrianisation of the CBD

Walking has a large modal split share in Nairobi, and as such pedestrianisation of the central business district may make walking more attractive within the CBD. Based on the Nairobi NMT Policy, the pedestrianisation of the CBD scenario will have two routes with a length of approximately 25 km. These will be comprised of the following road links:

- Route 1 - Harry Thuku – Muindi Mbingu – Mama Ngina – Wabera – Taifa – Harambee – Tumbo – City Square Post Office – Workshop – Industrial area
- Route 2 - Upper Hill (community) – Uhuru Park – City Hall way – Luthuli/Ronald Ngala – River Road – Landhies – Jogoo. Aga Khan Walk, part of Harambee Avenue, Parliament road, and around the Holy family Basilica

The targeted routes house several economic and recreational activities and hence high volumes of both pedestrian and cyclist traffic. With proper pedestrian infrastructure on the above mentioned links, there is a possibility of reducing the share of motorised transport and improving both the liveability and the productivity of the CBD.

4.3.4 Environmental benefits

The potential effect of the Nairobi NMT Policy network on modal splits is difficult to measure as each segment of the network has a unique modal split. Therefore, the experts polled were questioned over the possible effect of the network to the overall modal split of the Nairobi Metropolitan area. Table 26, shows that the potential modal shift due to the network is likely to be small at the metropolitan scale, but could be significant at the scale of the project. The network is perceived to potentially shift 2% of what would have been the mode share of pedestrian and motorcycle users to become cycling and bus users. The increase in bus usage may be due to the increased access of the multiple bus stations connected by the Nairobi NMT Policy network.

The environmental effect of the Nairobi NMT Policy network could be mixed, if the potentially conservative modal shifts expected by the experts occur. Table 27 shows that due to the increase in bus usage, the PM and NO_x emissions of the overall transport system could increase, while the CO_2 emissions would see a marginal saving.

Table 26: Modal split of Nairobi

Modal split	Base - 2015	Business as usual - 2030	With project - 2030
Walking	40%	34%	33%
Cycling	2%	2%	3%
Bus	12%	14%	15%
BRT	0%	0%	0%
Minibus taxi	28%	30%	30%
LRT & rail	0%	0%	0%
Cars	14%	15%	15%
Motorcycles	3%	4%	3%
Taxi	0%	0%	0%
Other	1%	1%	1%

Table 27: Emissions of trips in Nairobi

Emissions (tons)	Business as usual	With project	Savings
	tons	tons	tons
CO2	11 892 098,62	11 887 626,51	4 472,10
PM	3 647,31	3 669,60	-22,29
NOx	60 003,88	60 572,42	-568,55

The same is true for the energy usage of the system, seen in Table 28. The Petrol savings due to fewer motorcycles being used is approximately equal to the increase in Diesel usage due to more bus trips. However, this scenario assumes that the buses used in 2030 are no cleaner or more efficient than the buses used currently. If advances are made in the fuel efficiency of the bus fleet or if some buses are converted to biofuel, the impact to the environment could become definitively positive.

Table 28: Energy usage of trips in Nairobi

Energy usage	Business as usual	With project	Savings
	Gj	Gj	Gj
Petrol	137 355 733	136 274 128	1 081 604
Diesel	22 053 791	23 119 971	-1 066 180

4.3.5 Health benefits

The environmental impact of the Nairobi NMT network could be debatable, whereas the health impact would not be. As there is expected to be both a positive and negative mode shift of 1% between the two NMT modes, there will potentially be no net increase in NMT users. However, due to the further distances that a cyclist can travel and the longer average time that a cyclist spends exercising, Table

Table 29: Physical activity benefits of the Nairobi NMT Policy infrastructure

Indicator	No. of new users	Physical activity per week	Relative risk of mortality	Premature deaths prevented
	#	Minutes	#	#
Walking	-26 381	205,29	0,8656	-677
Cycling	26 381	223,95	0,7537	1241

29 shows that there is still a positive net number of premature deaths prevented: 564.

The overall safety of the NMT users is also set to improve substantially. Table 30, shows that the number NMT fatalities and injuries could be 9% and 18% lower respectively, by 2030 due to the Nairobi NMT Policy network.

Table 30: NMT fatalities and injuries in Nairobi

Indicator	*Base - 2015*	*Business as usual - 2030*	*With project - 2030*
NMT Fatalities	507	556	506
NMT Injuries	1001	1117	918

4.3.6 Economic Benefits

The Nairobi NMT Policy network could have a significant positive impact on the travel times of pedestrians in Nairobi, shown in Table 31. There could be a cumulative travel time saving of more than 18 000 years by 2030 as a result of the spatially protected NMT network. Surprisingly, cyclists are likely to only see modest improvements in travel time, as are cars due to less NMT users in the roadway.

Table 31: Travel time years saved due to the Nairobi NMT Policy infrastructure

Indicator	*Total amount of time saving*
	Person years
Walking	17 612,43
Cycling	395,15
Cars	144,13
Total	18 151,72

4.3.7 Qualitative Analysis

The qualitative assessment of Nairobi regarding the NMT Policy network, in Table 32, shows that the overall state of NMT is perceived to be better than that of the major NMT routes. Table 33 illustrates that the weighted average qualitative score for Nairobi is 3.8/10 and is predicted to decrease to 3.1/10 by 2030 without the implementation of a major NMT network. In particular, NMT road traffic injuries and fatalities are expected to get much worse as more vehicles and NMT users compete for the same space. Despite small changes to the modal split of Nairobi being predicted, the rapidly increasing population means that the number of vehicles on the roads will still increase significantly, making the safe navigation of streets by NMT users ever more difficult. The Nairobi NMT Policy network would maintain a significant amount of protected space for NMT use, leading to the stabilisation of NMT safety around current levels. It is likely to also have substantial impacts on the security that the users feel and the liveability of the surrounding areas.

Table 32: Qualitative analysis of the Nairobi NMT Policy infrastructure

Qualitative indicator	Base – 2015	Business as usual – 2030	With project – 2030
Energy usage	3	3	7
Emissions	4	4,5	6
Noise pollution	5,5	4,5	4
Physical activity	5	4,5	7
Accidents/injuries	5,5	2	5
Time saving	3	2,5	6
Journey quality	2,5	1,5	5
Security	3	2,5	7
Liveability	3	2,5	6

The weighted average qualitative score for the Nairobi NMT Policy network is 5,9 in 2030, almost double the relative score for the Business-as-usual case. A 54% qualitative improvement in NMT at the metropolitan scale shows the optimism around the expected effects that can be derived from a dedicated NMT network.

Table 33: Qualitative improvement due to the Nairobi NMT Policy infrastructure

Weighted average			
Current - 2015	BAU - 2030	WP - 2030	Improvement
3,8	3,1	5,9	2,8

4.3.8 Monetary Analysis

In contrast to the potentially small metropolitan mode shift due to the implementation of the Nairobi NMT Policy network resulting in meagre environmental benefits, its health and economic benefits are expected to be far from meagre. Table 34 summarises the monetisation of the health and economic benefits that could arise due to the network by 2030. The immense health and economic benefits are likely due to the highly popular, congested and accident prone corridors that have been chosen for inclusion in the NMT Policy network. The health benefits make up 88% of the total monetary benefits of the project and the travel time savings account for the remaining 12%.

Table 34: Potential monetary benefit of Nairobi NMT Policy infrastructure

Impacts		Monetary (NPV)	
Health	Physical activity	Sh	9 947 921 260,74
	Accidents/injuries	Sh	6 658 559 374,31
Economic	Time saving	Sh	2 177 729 047,65
	Tax revenue	Sh	-414 196 815,06

An estimate of the budget for the construction of the NMT network has been included in the Nairobi NMT Policy, seen in Table 35. The Net Present Cost (NPC) is far outweighed by the Net Present Benefit (NPB) of the project, even if the cost estimate is conservative. A BCR of 35,50 is exceptionally high for a transport infrastructure project, although the network is made up of the most necessary and auspicious NMT routes. Therefore, the vast magnitude of the Return on Investment (ROI) expected from the NMT network in the Nairobi NMT Policy is not representative of the ROI for a larger metropolitan-wide NMT network.

Table 35: Benefit-cost analysis of the Nairobi NMT Policy infrastructure

BCR	Net Present Benefit (NPB)	Sh	18 370 012 867,65
	Net Present Cost (NPC)	Sh	517 500 000,00
	Net Present Value (NPV)	Sh	17 852 512 867,65
	Benefit-Cost Ratio (BCR)*	35,50	

***Note CBR is unreliable in data scarce contexts**

4.4 Nairobi Metropolitan NMT Network

The metropolitan NMT network scenario explores the effects of having an extensive walking and cycling network throughout the Nairobi metropolitan area. The network would provide dedicated NMT infrastructure on major NMT routes and allow safe, expedient access to most activities. This scenario is based on the CicloRuta NMT network in Bogota, Colombia, which has already been tested using NMT-PAT and is beloved by the citizens of the city. The size of the network was estimated using the route density of CicloRuta, then adjusted for Nairobi's lower population size and density. The network in this scenario is not extensive but would form the backbone of a comprehensive, hierarchical NMT structure. An estimation that 350km of dedicated, inter-connected NMT infrastructure could form a cohesive NMT network for the metropolitan area of Nairobi, roughly three times the size of the network prescribed by the NMT Policy.

Table 36: Modal split of Nairobi

Modal split	Base - 2015	Business as usual - 2030	With project - 2030
Walking	40%	34%	43%
Cycling	2%	2%	3%
Bus	12%	14%	13%
BRT	0%	0%	0%
Minibus taxi	28%	30%	22%
LRT & rail	0%	0%	0%
Cars	14%	15%	12%
Motorcycles	3%	4%	3%
Taxi	0%	0%	3%
Other	1%	1%	1%

4.4.1 Environmental Benefits

A metropolitan-wide NMT network would have a far greater effect on the modal split of Nairobi than the NMT Policy network, shown in Table 36. The metropolitan NMT network is expected to have a substantial effect on the number of pedestrians in Nairobi in 2030. This may be due to the fact that the places a pedestrian would be able to access, without having to leave the spatially protected routes, increases exponentially with the scale of the NMT network. The additional NMT users would predominantly come from those currently using the minibus taxi mode, which would increase their level of physical activity. Interestingly, the proportion of car trips are expected to decrease and that of metered taxis will increase. This prediction may suggest that cars will be more optional and technologically integrated on-demand taxi services would meet the need, as is observed in many developed cities currently.

The shift in trips toward NMT modes would result in CO_2, PM and NO_x savings of 5%, 7% and 4%

Table 37: Emissions of trips in Nairobi

Emissions (tons)	Business as usual	With project	Savings
	tons	tons	tons
CO2	11 892 098,62	11 267 230,96	624 867,65
PM	3 647,31	3 396,82	250,49
NOx	60 003,88	57 412,29	2 591,59

respectively by 2030 across the whole of Nairobi, see Table 37. The savings in emissions are significant, but won't considerably change carbon footprint of the transport sector in Nairobi. The provision of NMT infrastructure is clearly of high environmental importance but won't have major effects by itself. However, if measures are utilised to promote NMT use and to pass the environmental cost of motorised transport on to the users, a much larger modal shift could be seen that could be accommodated by the metropolitan NMT network. The decrease in motorised transport use could result in Petrol and Diesel savings of approximately 5% each due to the NMT infrastructure, visible in Table 38.

Table 38: Energy usage of trips in Nairobi

Energy usage	Business as usual	With project	Savings
	Gj	Gj	Gj
Petrol	137 355 733	130 049 614	7 306 119
Diesel	22 053 791	20 987 611	1 066 180

4.4.2 Health Benefits

The health benefits of a metropolitan-wide NMT network for Nairobi could be substantial through the safety improvements for the existing NMT users and the increased physical activity of the new NMT users. It is predicted that Nairobi could have 263 816 new NMT users due to having a conducive network to travel on, seen in Table 39. Of these new users, 7 337 will be prevented from early death due to their previously sedentary lifestyles.

Table 39: Physical activity benefits of a Nairobi Metropolitan NMT network

Indicator	No. of new users	Physical activity per week	Relative risk of mortality	Premature deaths prevented
	#	Minutes	#	#
Walking	237 433	205,29	0,8656	5 141
Cycling	26 381	223,95	0,7537	1 046

Table 40 shows that the increased safety of the dedicated NMT network is expected to reduce NMT fatalities and injuries by 20% and 43% respectively across the whole of Nairobi by 2030.

Table 40: NMT fatalities and injuries in Nairobi

Indicator	*Base - 2015*	*Business as usual - 2030*	*With project - 2030*
NMT Fatalities	507	654	503
NMT Injuries	1001	1350	751

4.4.3 Economic Benefits

The impact of a Nairobi metropolitan NMT network on travel times would have a significant positive influence on the local economy. Table 41 illustrates that a combined 126 000 years of travel time could be saved by NMT users over the 15 year analysis period.

Table 41: Travel time years saved due to a Nairobi Metropolitan NMT network

Indicator	*Total amount of time saving*
	Person years
Walking	124 966,10
Cycling	1 053,74
Total	126 019,84

4.4.4 Qualitative Analysis

It was mentioned in section 4.3.7, the qualitative analysis of the Nairobi NMT Policy network, that the state of NMT in Nairobi is expected to decline significantly by 2030 without major intervention. This decline is visible in Table 42 and 43, especially for the health and well-being of the NMT users. However, if a metropolitan NMT network was implemented, similar to the scenario tested here, the state of NMT is perceived to drastically improve by 2030. The ability for NMT users to access a large proportion of Nairobi without leaving the protected network would contribute to the high safety and security ratings given by the polled experts. The social indicators scored especially high, which could become more important as Nairobi becomes larger and denser. These indicators could also be key in persuading the burgeoning middle class of Nairobi to maintain their current NMT routines and forgo the purchase of motorise vehicles. The avoidance of a middle class dependent on automobiles would have very favourable effects on the modal split and levels of congestion in the city.

Table 42: Qualitative analysis of a Nairobi Metropolitan NMT network

Qualitative indicator	Base - 2015	Business as usual - 2030	With project - 2030
Energy usage	3	3	6
Emissions	4	4,5	5,5
Noise pollution	5,5	4,5	6
Physical activity	5	4,5	6,5
Accidents/injuries	5,5	2	7,5
Time saving	3	2,5	6,5
Journey quality	2,5	1,5	7,5
Security	3	2,5	7,5
Liveability	3	2,5	7,5

When the scores are weighted, a metropolitan NMT network for Nairobi scores around 6,7/10, according to the polled experts. This constitutes a 75% improvement and could make NMT a 'car-competitive' transport mode. NMT would then become a transport mode of choice rather than one consigned to captive users.

Table 43: Qualitative improvement due to a Nairobi Metropolitan NMT network

Weighted average			
Current - 2015	BAU - 2030	WP - 2030	Improvement
3,8	3,1	6,7	3,6

4.4.5 Monetary Analysis

The monetary benefits of a metropolitan NMT network for Nairobi as it would involve a vast amount of infrastructure and a significant proportion of the transportation budget. Table 44 outlines the magnitude of monetary benefits that could be expected from a 350km NMT network. Again, the majority of the economic benefit for Nairobi would come from the improved health of its citizens. The health benefits account for 91% of the total monetary benefits accrued over the 15 year analysis period.

Table 44: Potential monetary benefit of a metropolitan Nairobi NMT network

Impacts		Monetary (NPV)	
Health	Physical activity	Sh	223 296 218 156,61
	Accidents/injuries	Sh	34 467 956 737,31
Economic	Time saving	Sh	26 087 894 650,84
	Tax revenue	Sh	-28 945 071 367,02

The Net Present Cost (NPC) for the project was derived from the cost of the similar sized metropolitan NMT network in Bogota, Colombia. A decision was taken to not scale up the proposed cost of the network in the Nairobi NMT Policy as those routes were chosen, in part, due to the ease with which construction of NMT infrastructure could occur. Scaling up the price of the NMT Policy network would under-appraise the true cost of a metropolitan network and the additional costs associated with a project of this size. However, the costs of constructing NMT infrastructure does seem to be more expensive in Colombia than Kenya, which means that the cost estimate may be inflated and the Benefit-Cost Ratio (BCR), conservative. Despite the cost uncertainty, the likely benefits of the network still outweigh the NPC and suggest a BCR of 8,52. Even if only the most common benefits are included, travel time savings and road traffic accidents, the BCR is still 2,02. The implementation of a metropolitan-wide NMT network in Nairobi appears to be more than feasible, it could be a very prosperous economic investment, based on this preliminary investigation.

Table 45: Benefit-cost analysis of a metropolitan Nairobi NMT network

BCR	Net Present Benefit (NPB)	Sh	254 906 998 177,74
	Net Present Cost (NPC)	Sh	29 935 245 973,72
	Net Present Value (NPV)	Sh	224 971 752 204,02
	Benefit-Cost Ratio (BCR)*		8,52

***Note CBR is unreliable in data scarce contexts**

4.5 Case Study Scenario Comparison

The four case studies scenarios analysed using NMT-PAT in Nairobi are very diverse and, therefore, their comparison is difficult. The magnitude of benefits derived from a project can be linked to the scale of the project and its cost. Hence, the chosen medium for the comparison of benefits is magnitude per monetary unit of project cost. Due to the varied magnitude of the benefit measurements for each criterion and indicator, the magnitude of the monetary unit changes between indicators but not between scenarios.

The chosen method is demonstrated in Figure 6, a comparison of the emission savings per monetary cost unit for the four scenarios. The graph shows the CO_2 savings in grams per Kenyan Shilling invested in the project. Haile Selassie Avenue (HSA) is a clear winner with more than 300g/Sh saved, due to its low overall cost and high probability of promoting a mode shift toward NMT. The remaining projects – the Metropolitan NMT (MNMT) network; the NMT Policy (NMTP) network and Thika Highway (TH) – saved 21 g/Sh, 9 g/Sh and 5 g/Sh respectively. The same is true for Particulate Matter (PM) savings, where HSA is the clear leader when the scale is normalised, with 124g/Sh1000 invested. Due to the NMTP network's positive influence on Bus ridership, PM is set to increase by 43g/Sh1000 invested as a result of the increased diesel usage. Finally, the Nitrous Oxides' savings follow the same trend, with TH expected to return mediocre emissions savings for all three measurements.

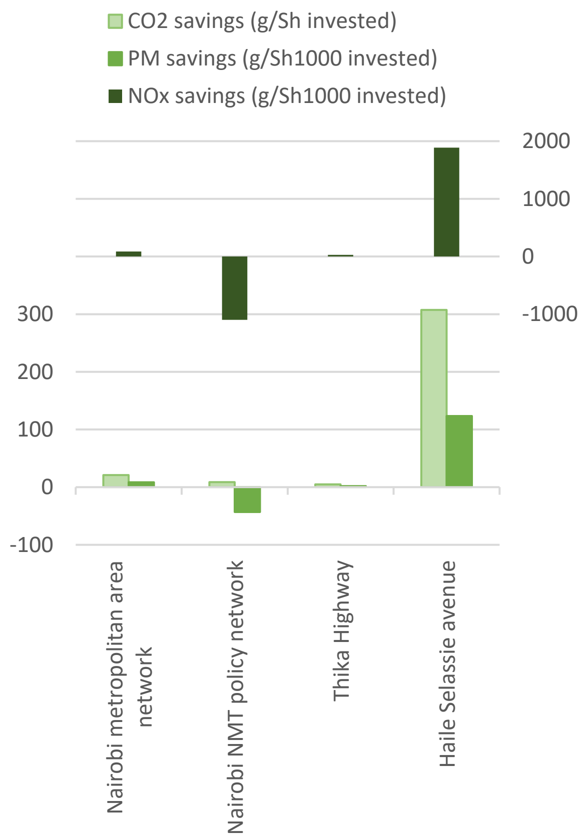


Figure 6: Comparison of potential emissions savings in Nairobi per monetary cost unit

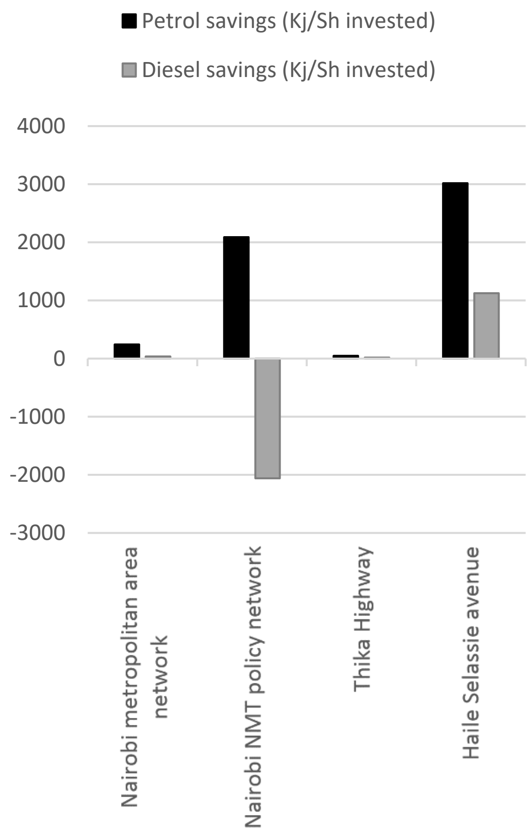


Figure 7: Comparison of potential fuel savings in Nairobi per monetary cost unit

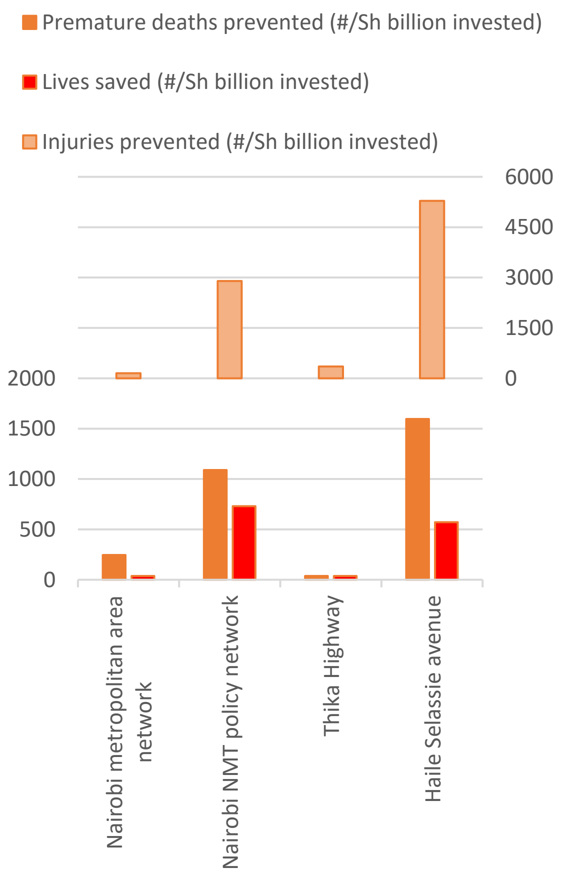


Figure 8: Comparison of potential health improvement in Nairobi per monetary cost unit

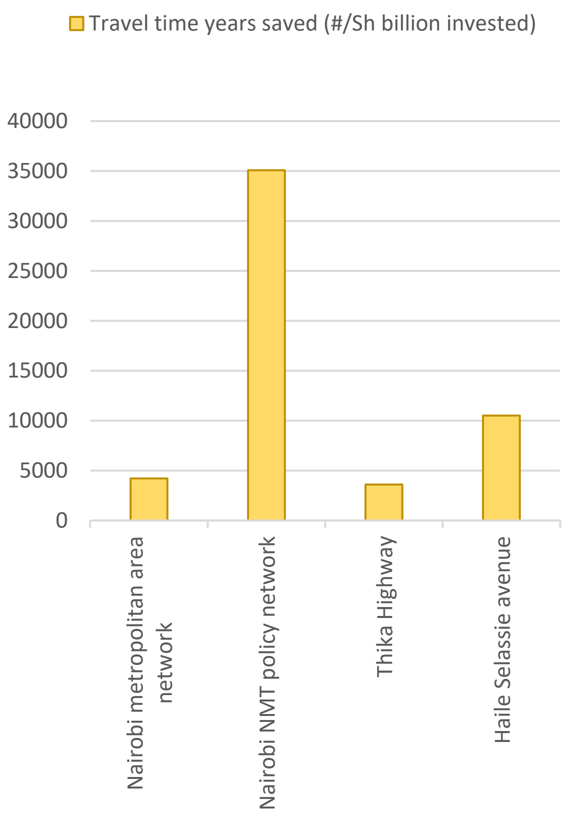


Figure 9: Comparison of potential travel time savings in Nairobi per monetary cost unit

The aforementioned increase in Diesel usage attributed to the NMTP network can be seen in Figure 7 and accumulates to more than 2000 Kilojoules per Shilling invested of the 15 year analysis period. However, the higher level of Diesel usage is almost completely counteracted by the expected decrease in motorcycle use and associated lower level of Petrol consumed. The larger modal shift to NMT due to the infrastructure on HSA, seen in the significantly larger proportional emissions savings, is observed again through the immense fuel savings. The MNMT network could expect an average of 244 Kj/Sh invested by 2030.

The health benefits have shown to be exceedingly important in the appraisal of these NMT projects due to their ability to improve the general health of Nairobian citizens and reduce the high number of NMT-related road traffic injuries. Figure 8 illustrates the potential positive effects of the four scenarios, per billion shilling invested in each project. Again HSA and the NMTP network are expected to prevent the most premature deaths due to unhealthy lifestyles through the higher proportion of users willing to become new NMT users along those routes. HSA could prevent more than 40 times as many deaths as TH, relative to their budgets, due to the much higher efficiency of the infrastructure. The same is true for decreasing NMT injuries and fatalities. This means that it may be advantageous for the local government to focus on constructing NMT facilities along existing, popular at-grade routes rather than along the new popular, grade-separated highways.

The final quantifiable benefit of the four scenarios is the net savings in travel time by the users over the analysis period, found in Figure 9. The NMTP network could save more than 35 000 years of travel time per billion shilling invested, seven times that of an MNMT network. Travel time is also the only criterion for which TH is near to the productivity of another of the scenarios. HSA would have displayed a much greater number of travel time years saved, but the total was discounted for the negative effect it is expected to have on the travel time of motorised vehicles. Conversely, the NMTP network is predicted to decrease the travel time of car users, which would be an example of a non-user benefit.

The Benefit-Cost Ratio (BCR) is a useful measure for comparing the magnitude of monetisable benefits in relation to the scale of the invested required. Figure 10 illustrates the Holistic BCR (all the monetisable components of the NMT-PAT tool) as well as the Conventional BCR (only the travel time benefits) for each of the four scenarios. Based upon the estimations of the polled experts, HSA is expected to accrue eleven times the value of benefits per monetary cost unit that TH will in next 15 years. However, its BCR is only twice as high when focussing exclusively on the projected travel time savings. It also illustrates the fallibility of focussing purely on transport as the movement between two places rather than a core portion of a user's lifestyle and wellbeing. The NMTP network shows that under

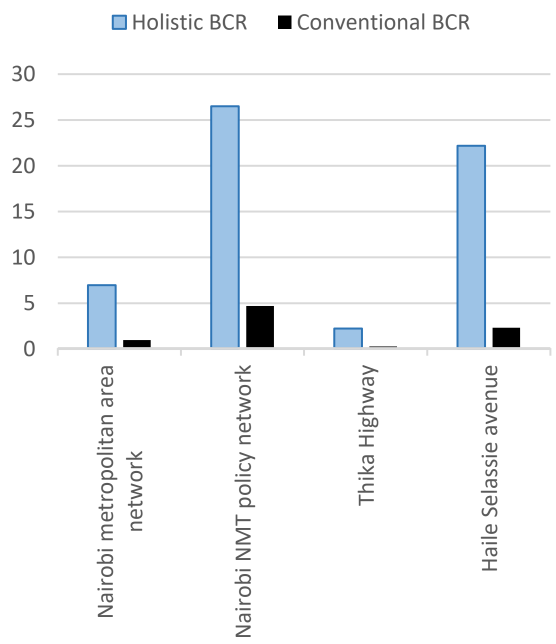


Figure 11: Comparison of Benefit-Cost Ratios (BCR)

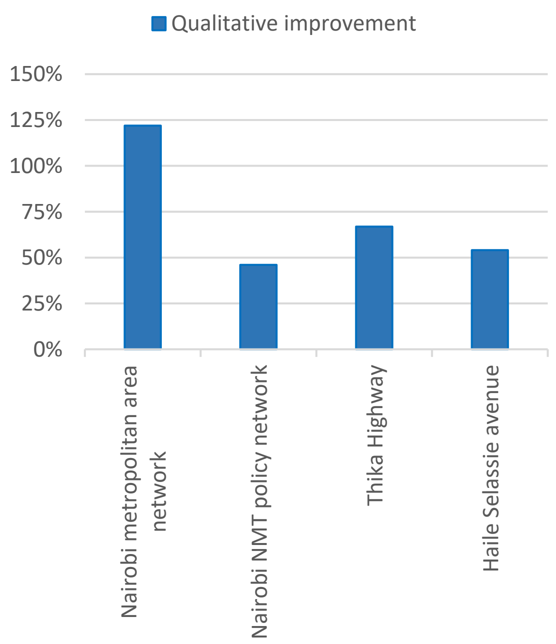


Figure 11: Comparison of potential qualitative improvement due to the projects

the conducive conditions provided by the Nairobi central city, NMT infrastructure is likely to generate significantly higher returns than any comparable motorised transport project.

A metropolitan NMT network would likely be one of the largest investments in transport infrastructure that has been made in Nairobi but could produce eight shillings of value to the city for each shilling invested. However, if the environmental, health and social improvements are not accounted for, the network will be perceived to return marginally less value than was invested. If the narrow view of transport infrastructure, purely as a conduit for the movement of people, then a metropolitan NMT network for Nairobi would appear to be a poor investment when the opposite is true.

The economic analysis of these four case study scenarios can be very insightful but the uncertainty and scarcity of the data, as well as the dependence on the opinions of the polled experts, means that the results are purely speculative. Therefore, the qualitative assessment of the scenarios is of equal value and can outline the differences between the expected success of these projects and the perception of their success. Figure 11 highlights the perceived qualitative improvement on the current situation in reference to a score out of ten. The qualitative improvement is in direct contrast to the quantitative and monetary analyses of the four case study scenarios. This is due to the fact that HSA and the NMTP network are in the Nairobi central city, a heavily congested area but with some existing NMT infrastructure. Therefore, improvements along the popular routes, even slight, can have disproportionately large associated benefits due to the vast number of users. This means that the sheer existence of NMT infrastructure in this area already places it above average in a qualitative rating of NMT. Whereas, in the case of TH and the MNMT, very little NMT infrastructure is in existence, hence any new infrastructure is a vast improvement over the current scenario. This analysis is important, as it highlights the danger of prioritising transport infrastructure only on potential returns, without considering the equality of access to decent NMT infrastructure.

5 NMT-PAT Training Workshop

The immense interest in NMT-PAT, shown by local stakeholders in Nairobi, led to the decision to host a training workshop for the tool on the 10th of December 2015. Relevant local experts were invited, including NMT activists; transport engineers; government personnel and development bank economists. Of the 20 relevant partners that were shortlisted, 14 arrived for the full-day workshop. The schedule of the training workshop, found in Table 46, shows that the first few sessions were composed of lectures to introduce the participants to the concept of transport project appraisal and the unique benefits that NMT projects have. This was followed by an introduction to NMT-PAT and a tutorial in its use.

Figure 12: NMT-PAT Training Workshop

5.1 Appraising the benefits of NMT

A lecture introducing the appraisal techniques of transport projects, and NMT projects specifically, started the workshop and outlined the importance of being able to fairly compare different scenarios. Some of the participants did not have a background or base knowledge of transport economics, so the fundamentals of Cost-Benefit analyses (CBA) and Multi-criteria analyses were discussed in full. The advantages and disadvantages of each were debated among the participants, with an overall agreement that a hybrid analysis would be most useful in the context of Nairobi.

Examples were used to explain the concepts of benefit and cost discounting, leading to a discussion around the use of Net Present Value and Benefit-Cost Ratio (BCR) as measure for transport infrastructure performance. One concept of much interest to participants was that of Land Value Capture (LVC). The idea that transport infrastructure imparts additional value to surrounding properties, and that value can be estimated before the implementation of the project. A conversation began around the associated future increase in property rates and taxes collected by the government due to an NMT project and how it could be used as collateral to secure funding for the project's construction.

A further point of contention among the participants was the measure of Value of Time (VoT) and whether it is equal across different transport modes, when considering the different socio-economic characteristics of the users and different levels of Willingness-to-pay (WTP).

Table 46: NMT-PAT Training workshop schedule

Duration	Session
08:30 – 09:00	Registration, networking and refreshment
09:00 – 09:15	Welcome address – UNEP/UCT
09:15 – 10:00	Appraising the benefits of NMT: an introduction
10:00 – 10:45	Quantifying the benefits of NMT: technical concept
10:45 – 11:00	Q&A session
11:00 – 11:30	Break and refreshments
11:30 – 12:30	Non-user benefits and NMT survey methodology
12:30 – 13:30	Lunch
13:30 – 14:15	NMT – PAT tool: introduction
14:15 – 16:00	NMT – PAT tool: tutorial
16:00 – 16:15	Q&A and evaluation
16:15 – 16:30	Closing remarks and certificate awarding

5.2 Quantifying the benefits of NMT

The second lecture featured the different methods of quantifying and monetising the benefits of NMT infrastructure used around the world and the purported international best-practices. The quantification of environmental benefits, and specifically emissions saved due to NMT projects, was widely discussed as the Training Workshop was hosted at the same time as the 21st Conference of the Parties (COP). The participants were very worried about the health effects of pollution in Nairobi and saw an opportunity to use this as a point of advocacy for local NMT infrastructure projects.

Quantifying the health benefits of NMT through increased physical activity was seen as less important in the context of Nairobi as Non-Communicable Diseases (NCDs) such as obesity is not as common as in the developed world.

5.3 Non-user benefits and NMT survey methodology

The final lecture in the workshop discussed the benefits that motorised transport users can derive from NMT infrastructure and the options available to improve NMT data availability. The non-user benefits include the positive environmental effects, having healthier employees, and reductions in congestion among others. Currently, non-user benefits are not usually included in the appraisal of NMT projects but efforts are being made to create methods of quantification. The participants were intrigued about trying to source co-funding for NMT projects from those parties that are likely to experience the greatest non-user benefits.

The lecture then began a discussion on the methods for conducting NMT surveys, and the differences between revealed preferences and stated preferences. The proliferation of mobile phones in Nairobi was seen as an opportunity to study revealed preferences and use big data to more precisely set transport routes to meet travel patterns. The platform of the mobile phone, specifically apps, was also debated as a cheap method of collecting stated preference data and testing scenarios.

5.4 NMT – PAT Introduction and Tutorial

The second half of the training workshop consisted of a brief explanation of NMT-PAT and a tutorial in its use. The tutorial involved collectively utilising the tool to test one of the four Nairobi Case studies in a step-by-step process. The data was provided and the participants were tasked with entering each data point correctly as the utility of each aspect was explained. The first problem arose due to the varied versions of spreadsheet software using either a comma or a period to denote a decimal point.

An interesting development was also the debate that surrounded some of the assumptions that were made regarding the data collected for Nairobi and the incorrectness of certain data points. It brought into view the advantage of utilising the tool as a group and making collective decisions or having to reason assumptions made to a colleague. An effort should be made to explore the options for syncing NMT-PAT across multiple devices in order to test scenarios cooperatively.

6 Conclusion

The aim of this project is the advancement of the non-motorised transport project appraisal tool (NMT-PAT) through added functionality and the testing of its applicability in the context of an African city. Four case study scenarios were chosen within the city of Nairobi, Kenya and tested to determine the potential magnitude of their associated benefits.

Nairobi has a rapidly increasing population and very limited transport infrastructure. Car ownership is rising sharply, eroding its large share of NMT users and contributing to its status as the fourth most congested city in the world (Klopp, 2015). Nairobi has a great need for substantial NMT infrastructure investment in the near future, but it is perceived to be of lesser importance than other transport needs. NMT-PAT could have a considerable positive impact if it can change that perception, as long as it is applicable in this context.

In congruence with the challenges faced by NMT users in Nairobi, major challenges were faced collecting the necessary data to utilise NMT-PAT effectively. Without adequate data, the transport authority would not be able to equitably compare prospective transport projects or monitor and evaluate existing infrastructure. To overcome the dearth of NMT data, an opinion poll was disseminated to local experts within the field. The poll requested estimations for data based on a description of the future scenario being tested. The poll allowed more detailed analysis of each case study scenario, but the variance in the responses did increase the level of uncertainty in the predictions. However, when coupled with the ability of NMT-PAT to test the sensitivity of the results to the uncertain estimates, the opinion poll became a significant and useful tool for the substitution of unavailable data.

NMT-PAT was able to analyse the many benefit and cost indicators for each of the four case study scenarios. Based on the results, trends could be identified and causality was suggested. The results could be critically and equitably compared despite the varied scale and nature of the projects. It is suggested that NMT-PAT is applicable to the context of Nairobi and meaningful insight into the viability of each of the four projects can be derived from the results and analyses. NMT-PAT's applicability is supported by the successful training workshop for local NMT stakeholders hosted in Nairobi. The participants showed immense interest in NMT-PAT and conveyed optimism around its potential use to advocate for NMT infrastructure investments. Every participant was capable of performing a project appraisal example in a few hours, when the relevant data was supplied in advance. It is believed that NMT-PAT has great potential to accurately and equitably appraise NMT investments in the urban African context.

7 REFERENCES

Angira, O. C. A., 2001. Challenges and Opportunities for Sustainable Urban Mobility (Non-Motorized Transport): A Case Study of 'Nyamakima, Area', Nairobi County, Kenya.. *Unplublished thesis University of Nairobi.*

African Development Bank, 2007. *Nairobi -Thika Highway Improvement Project,* Nairobi: African Development Bank.

Anon., n.d. Multimodal Transport Modeling for Nairobi, Kenya: Insights and Recommendations with Recommendations with an Evidence based model.

Association for Safe International Road, 2012. *Road Travel Report: Kenya,* Rockville: ASIRT.

CSE & APEC, 2012. *Feasibility Study & Technical Assistance for Mass Rapid Transit System for the Nairobi Metropolitan Region,* Nairobi: Ministry of Transport Republic of Kenya.

Gachanja, J., 2015. *Mitigating Road Traffic Congestion in the Nairobi Metropolitan Region: Policy Brief No 2,* Nairobi: The Kenyan Institute of Public Policy and Research and Analysis.

Gonzales, E. J., Chavis, C., Li, Y. & Daganzo, C. F., 2009. Multimodal transport modeling for Nairobi, Kenya: insights and recommendations with an evidence-based model. *UC Berkeley Center for Future Urban Transport: A Volvo Center of Excellence..*

I-ce, 2000. *The significance of Non-Motorised Transport for Developing Countries: Strategies for Policy Development,* Utretcht: Interface for Cycling Expertise.

International Road Assessment Programme, 2009. *A World Free of High Risk Roads: Kenya Results,* England: iRAP.

JICA , 2006. *The Study on the Master Plan for Urban Transport in Nairobi Metropolitan Area,* Nairobi: JICA.

JICA, 2014. *The project on Integrated Urban Development Master Plan for the City of Nairobi in the Republic of Kenya,* Nairobi: Nairobi City County.

KARA & CSUD, 2012. *THIKA HIGHWAY IMPROVEMENT PROJECT: The Social/Comunity Component of the Analysis of the Thika Highway Improvement Project,* Nairobi: Kenya Alliance of Residenet Associations.

Kayi, C., 2007. *Exploring Policy Options and Strategies in Enhancing the Safety of Non-Motorized Transport Modes in African Cities: The Case of Nairobi City.* California, World Conference in Transport Research.

KIPPRA, 2006. *Organizing urban road public transport in Nairobi City,* Nairobi: KIPPRA.

Klopp, J., 2011. Towards a Political Economy of Transportation Policy and Practice in Nairobi. *Urban Forum,* pp. 1-21.

Klopp, J., 2015. *Nairobi Planning Innovations.* [Online]
Available at: http://nairobiplanninginnovations.com/2015/04/10/nairobis-traffic-congestion-confusion-where-are-the-citizens/
[Accessed 7 August 2015].

Litman, T., 2011. *Evaluating Non-Motorized Transportation Benefits and Costs,* Victoria: Victoria Transport PolicY Institute.

McGregor, S. & Doya, D. M., 2014. *Bloomberg Busines.* [Online]
Available at: http://www.bloomberg.com/news/articles/2014-03-25/nairobi-traffic-loses-570-000-a-day-as-no-2-africa-hub
[Accessed 8 August 2015].

Mitullah, W. V., Opiyo , . R. & Asingo, P., 2013. Planning, Infrastructure and Travel Patterns among Pedestrians, Cyclists and Handcart pushers in Nairobi City County , Kenya.

Mwakilishi, 2013. *Mwakilishi.* [Online]
Available at: http://www.mwakilishi.com/content/articles/2013/10/05/kenya-national-highways-authority-at-loss-as-thika-superhighway-turns-into-trap.html
[Accessed 10 09 2015].

Nairobi County Government, 2015. *Non-Motorised Transport Policy: towards NMT as the mode of choice,* Nairobi: Nairobi County Government .

Nation, D., 2014. [Online]
Available at: http://mobile.nation.co.ke/blogs/Thika-superhighway-design-a-threat--to-lives/-/1949942/2405632/-/format/xhtml/-/14j4pxa/-/index.html
[Accessed 10 09 2015].

NCCG, 2014. *Integrated Urban Development Master plan for the city of Nairobi,* Nairobi: NCCG.

Omwenga, M., 2007. *Integrated Transport System for Liveable City Environment: A Case Study of Nairobi, Kenya.* Wuhan, China, 47th ISOCARP Congress 2011.

Omwenga, M., 2011. *Integrated Transport System for Liveable City Environment: A Case Study of Nairobi, Kenya.* Nairobi, 47th ISOCARP Congress 2011.

RAC Foundtion, 2012. *RAC Foundation.* [Online] Available at: http://www.racfoundation.org/media-centre/transport-poverty
[Accessed 12 August 2015].

Salon, D. & Aligula, E. M., 2012. Urban Travel in Nairobi, Kenya, insights, and opportunities. *Journal of Transport Geography,* Volume 22, pp. 65-76.

Tibaijuka, A., 2007. Nairobi and its Environment.. In: J. Barr & C. Shisanya, eds. *Nairobi City Development Strategy top priority for 21st Century future of the Kenyan capital..* Nairobi: UNEP.

Tibaijuka, A., 2007. *Nairobi and its Environment. Nairobi city development strategy top priority for 21st Century future of the Kenyan Capital , Nairobi: United Nations Environment Programme,* Nairobi: UNEP.

UN-HABITAT, 2013. *Planning and Designing for Urban Mobility: Global Report on Urban Settlements,* Nairobi: UN-HABITAT.

World Bank, 2002. Scoping study: Urban mobility in three cities—Addis Ababa, Dar Es Salaam and Nairobi. *Working Paper, Sun-Saharan Africa Transport Policy Program,* Volume 70.

A Technical documentation

The NMT Project Assessment Tool (NMT-PAT) analyses four benefit criteria: *Environmental, Health, Economic* and *Social*. The criteria consist of ten indicators that are assessed qualitatively and, where possible, quantitatively.

A.1 Qualitative Assessment Process

The qualitative assessment methodology is typically used if quantitative data on a criterion is lacking or unreliable. It allows for a simple rating system between 1 and 10, with a higher value being positive. An importance factor (I) is given for the base year to set a status quo and the two future scenarios, *Business As Usual (BAU)* and *With Project (WP)*, to determine a qualitative representation of the effect of the project. The results of the qualitative assessment of each indicator are weighted to give a final value for the effect of the project. The weighting of criteria and indicators is optional. The weighting process is performed in a similar manner to the AHP (Analytic Hierarchical Process) method for multi-criteria analysis. The criteria *c* and indicators *i* are weighted separately, where the final weighting W_i given to an indicator is dependent upon the weighting of its criterion and the weighting of the other indicators within that criterion, as seen in Equation 2.

$$W_i = \frac{I_i}{\sum_{i \epsilon c_j} I_i} * \frac{I_{c_{j \ni i}}}{\sum_j I_{c_j}} \forall i$$

Equation 1: Weighting process for indicators *i*

A.2 Quantitative Assessment Process

Where it is possible, quantitative and monetary representation of the effects on each of the four benefit criteria of the project are calculated. The quantitative values are displayed within the Appraisal Summary Table (AST) for context, comparison and further analysis, whereas the monetary values are summed to generate a *Cost-Benefit Ratio (CBR)*. It must be acknowledged that the credibility of the *CBR* is directly dependent on the credibility of the data input. Therefore, the qualitative assessment is the preferable benchmark in all but the most data rich contexts. Using the inflation rate, the monetary values of cost are reduced to a *Net Present Cost (NPC)*, which represents all of the costs as one cost value in the base year. Similarly, the monetary values of benefits are reduced to a *Net Present Benefit (NPB)* using a discount rate. As the *NPC* and *NPB* are both monetary values in the same base year, they can be fairly compared. The difference between the two values is known as the *Net Present Value (NPV)* of the project, and the ratio of the values is the *CBR*.

A.3 Environmental Criterion

The *Environmental* criterion consists of three indicators: *Emissions; Energy usage* and *Noise pollution*. The quantitative assessment of the *Emissions* and *Energy usage* indicators is derived from the Transportation Emissions Evaluation Model for Projects (TEEMP) produced by Clean Air Asia (CAA), and is used with their permission.

$$VKT_m = \frac{MS_m * N * \bar{L}_m}{\overline{OCC}_m} \quad \forall m$$

Equation 2: Average number of *Vehicle Kilometres Travelled (VKT)* per day per mode

The modal split (MS_m), number of trips per day (*N*), the average trip length per mode ($\bar{L}_m$) and average occupancy ($\overline{OCC}_m$) are used to calculate the Vehicle Kilometres Travelled (VKT_m) per mode per day utilising Equation 2. Three options are given for the dominant fuel type, in order to utilise different default values for emissions produced per unit used. Three types of emissions are calculated: Carbon Dioxide (CO_2), Particulate Matter (PM) and Nitrous Oxides (NO_x). The amount of these emissions produced each day is calculated by multiplying the VKT per day with fuel efficiency (f_m^{ef}) and emission factors ($f_m^{CO_2}$), shown for CO2 emissions per day in Equation 4a.

$$E_{CO_2} = \sum_m \frac{f_m^{CO_2} * VKT_m}{f_m^{ef}}$$

Equation 3: Average amount of CO_2 produced per day per mode

$$E_e = \sum_m f_m^e * VKT_m \quad \forall e$$

Equation 4: Average amount of emissions (e={PM, NOx}) produced per day per mode

The mass of emissions produced per day is then predicted for the two future scenarios: *Business As Usual (BAU)* and *With Project (WP)*. The emissions produced for all modes are summed over the period of assessment and the difference between the *BAU* and *WP* scenarios are proposed to be potential emissions savings.

The amount of energy used per mode per day (ε) is similarly calculated in Equation 5 by multiplying the VKT_m by an energy density factor (f_m^{ed}). The *Energy usage* for all modes is also summed over the period of assessment and the difference between the *BAU* and *WP* scenarios are proposed to be potential energy savings.

$$\varepsilon = \sum_m \frac{f_m^{ed} * VKT_m}{f_m^{ef}}$$

Equation 5: Average amount of energy used per day per mode

The level of *Noise pollution* is determined by measuring the average level of in different classes in the base year and predicting the noise level for the two future scenarios. The average difference ($\Delta\overline{NP}_d$) in noise level over the distances and the period of assessment is then calculated as the quantitative measure of noise pollution effects.

$$\Delta\overline{NP}_d = \Delta\overline{NP}_{d_{WP}} - \Delta\overline{NP}_{d_{BAU}} \quad \forall d$$

A.4 Health Criterion

The health criterion is measured by two indicators, the new level of physical activity and the difference in number of NMT accidents. The quantitative assessment for the project's health benefits related to increased physical activity takes a simplified but similar approach to that of the Health Economic Assessment Tool (HEAT) created by the World Health Organisation (WHO), used with their knowledgeThe assessment calculates the monetary value of changing the Relative Risk of Mortality (RRM) of a new user (VPA) due to the change in physical activity.

The Person Kilometres Travelled (PKT_m) per mode per day is calculated using Equation 5. The average difference in PKT for cycling and walking per day, between the BAU and WS scenarios can then be determined.

$$PKT_m = MS_m * NU_m * \bar{L}_m \quad \forall m$$

Equation 6: Average number of Person Kilometres (PKT) per day per mode

The number of new NMT users (NU_m) is determined by dividing the average difference in NMT trips per day by the average number of trips per person per day. This is used to determine the amount of PKT per new user per day and then the amount of physical activity per week per new user ($PA_{user,m}^{week}$) in Equation 7. The average speed is set as *4.4 km/h* and *14 km/h* for walking and cycling respectively. These, and any other default values, can be replaced with context specific data when or if it is available.

$$PA_{user,m}^{week} = \frac{PKT_{user,m}^{week}}{\bar{\mu}_m} \quad \forall m$$

Equation 7: Average amount of physical activity performed per new user per week

The HEAT model utilised extensive studies to create an equation that translates this amount of physical activity into a factor that represents the Relative Risk of Mortality (*RRM*) for the new NMT users, shown as Equation 8. The equation uses a health factor (H_m) derived from these empirical studies, for each mode.

$$RRM_m = 1 - \frac{PA_{user,m}^{week} * H_m}{100} \quad \forall m$$

Equation 8: Average Relative Risk of Mortality (RRM) of a new user

The all-cause mortality rate (MR_m) is used to estimate the number of new NMT users that are expected to die in any given year and the relative risk factor (RRM_m) identifies how many lives are saved, due to increased physical activity. Equation 9 uses these two indicators, as well as the average *Value of a Statistical Life (VSL)*, to calculate the monetary value of the lives saved due to increased *Value of physical activity* (VPA). The *VSL* is a monetary approximation of the average of a *Value of Life* in a certain area or demographic group, based on earning potential and many health-related factors (Kahlmeier et al., 2011).

$$VPA = \sum_m (1 - RRM) * NU_m * VSL * MR_m$$

Equation 9: Average monetary value of physical activity per year

The health benefits related to safer streets are calculated based on the predicted reduction of NMT fatalities and injuries between the two future scenarios. The monetary value of this reduction is calculated by multiplying the total fatalities and injuries prevented by the *VSL* or the current value of a transport injury.

A.5 Economic Criterion

The economic criterion contains two indicators, the effect on the travel time of all trips within the city and the effect on the tax revenue collected by the government. The change in travel times, due to the project, is determined by estimating the share of trips that may be affected by the project and the time saving per trip for each mode. The monetary value of travel time (VOT_m) is calculated in Equation 10 using factors (f_{tt_m}) from the research of Todd Litman (2007).

$$VOT_m = \frac{f_{tt_m} * GDP_{capita}}{f_t}$$

Equation 10: Average monetary value of time per minute per mode

Equation 9 illustrates that the GDP per capita (GDP_{capita}) is multiplied by a specific coefficient value for each mode and factored (f_t) down to a monetary unit per minute. The monetary value of time saved (VOS) is the product of this value of time, the amount of time saved per trip and the average number of trips affected, see Equation 11.

$$VOS = \sum_m VOT_m * \Delta T_m * N_{t_m}$$

Equation 11: Average monetary value of time savings per year

The effect on the tax revenue has two facets: the lower fuel tax revenue, due to decreased motorised trips and the increased Value Added Tax (VAT) revenue, due to money saved that is spent on taxed consumables. The petrol price, diesel price (p_{fuel}) and fuel levy (f_{levy}) are required by Equation 11, along with amount of fuel saved (ΔF) that was calculated earlier, to determine the loss of fuel tax revenue (ΔR_{fuel}) to the city or national government.

$$\Delta R_{fuel} = p_{fuel} * f_{levy} * \Delta F$$

Equation 12: Average monetary value of fuel tax revenue lost through fuel savings per year

The increase in VAT revenue (ΔR_{VAT}) is calculated by Equation 13 using the $VAT\ levy\ (f_{VAT})$. The approximate monetary amount saved per person per year $(\Delta S_{person}^{year})$, due to the project, and the proportion of this amount that would be spent on taxed consumables (f_{taxed}) need to be estimated for the equation. The total tax revenue is calculated by subtracting the fuel tax losses from the VAT revenue gains.

$$\Delta R_{VAT} = \Delta S_{person}^{year} * Pop * f_{VAT} * f_{taxed}$$

Equation 13: Average monetary value of VAT revenue gained through money saved per year

A.6 Social Criterion

The social criterion uses the indicators of *journey quality, security* and *liveability*, and are only assessed qualitatively as their impacts are very difficult to quantify or monetise. This highlights the more holistic approach of the qualitative assessment and its importance in data-scarce context.