# Cost Benefit Analysis of Non-Motorised Transport Infrastructure Investments

A South African case study

CENTRE FOR TRANSPORT STUDIES

Faculty of Engineering and the Built Environment

# Cost Benefit Analysis of Non-Motorised Transport Infrastructure Investments

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Project funding: South African Road Federation

Date January 2017

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## Acknowledgements

Project partner: Share the Road Programme, United Nations Environment Programme

Editorial review: Cheryl Wright, University of Cape Town

Cover photos:
Image 1: youtube.com/user/adrian8carver
Image 2: myloveaffairwithcapetown.files.wordpress.com

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# ABSTRACT

That Non-Motorised Transport (NMT) is the most sustainable mode of transport, which is well recognised in the academic literature. In practise, many governments have also started to appreciate the need for more NMT planning and implementation. In the developing world, however, the planning and implementation of NMT facilities is not following this world trend, or at a much slower speed.

To make sure that all countries around the world are able to fast-track their NMT planning and implementation, the Centre for Transport Studies (CfTS) at the University of Cape Town, funded by the UN Environmental Programme (UNEP), developed an NMT appraisal tool. The aim of the tool was to develop a scientifically sound calculation method in situations where data is scarce and unreliable. The tool was tested in developing countries in South America and Africa. This report summarises some of the findings generated through the application of the Non-Motorised Transport Project Assessment Tool (NMT-PAT) in the South African context. This study was made possible by the generous funding of the South African Road Federation (SARF).

The tool includes the estimation of various NMT benefits. Benefits for the individual include: health, time, financial and equity improvements. The community benefits through reduced automobile dependency, reduced road injuries and fatalities, economic benefits, such as the effects on commercial areas and residential areas, and improved social cohesion. Environmental benefits include less fossil fuel consumptions, air- and noise pollution.

The aim of this research project was the advancement of the Mon-Motorised Transport Project Appraisal Tool (NMT-PAT) through the application in the city of Cape Town. For the Cape Town area, two case studies were developed, i.e. an analysis of the Central Business District (CBD) only and an assessment of the whole Metropolitan area.

The magnitude of benefits derived from a project can be inherently linked to the scale of the project and its cost. The potential R3 billion price tag, estimated in this research, for a comprehensive metropolitan NMT network, would be one of the largest investments in transport infrastructure in Cape Town but could produce an estimated R24 billion of value to the city, just in health benefits.

It was proven that the tool generates useful outcomes on a city level. Cape Town, for example, has a great need for substantial NMT infrastructure investment, in the near future, due to its ever growing population. However, the perceived benefits of NMT infrastructure are still that it is of lesser importance than the needs of other modes of transport. NMT-PAT was able to show considerable positive impact if the perceived misconception can be corrected.

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.

Major challenges were faced collecting the necessary data to utilise NMT-PAT effectively, even though it is less data intensive than many other assessment tools utilised around the world. Without adequate data, transport authorities are not able to equitably compare prospective transport projects or monitor and evaluate existing infrastructure.

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# 1 INTRODUCTION

Non-Motorised Transport (NMT) is a sustainable mode of transport that has various benefits for urban societies. However, there is no recommended method for appraising NMT projects, particularly in developing countries. In order for the full impact of NMT projects to be evaluated, numerous factors and indicators need to be taken into account in order for a comprehensive and holistic understanding of NMT initiatives to be generated.

Through the recent work done by the United Nations Environment Program (UNEP) and the University of Cape Town (UCT), a tool to appraise NMT projects in developing countries has been developed. This study reports on some of the findings of that work and aims to investigate whether the Non-Motorised Transport Project Assessment Tool (NMT-PAT) is applicable in the South African context. This research was made possible by the generous funding of the South African Road Federation (SARF).

To test the suitability of NMT-PAT for the South African context, two varied case studies were analysed: the NMT infrastructure upgrades in Cape Town's Central Business District (CBD) and a hypothetical metropolitan-wide NMT network. The two case studies were chosen based on their differing geographic scale and the availability of necessary data.

The report starts with a brief overview of the many benefits of NMT, for the individual user, the community, and the environment. The third chapter reviews the use of evaluation tools on NMT projects in previous studies and their substantive problems. The fourth chapter illustrates why a comprehensive tool is necessary to assess NMT projects, especially in the context of a developing country. Chapter Five explores the essential components that need to be incorporated into the tool, and how these components have been expressed in the past. The sixth chapter reveals the challenges for NMT projects and the use of the NMT-PAT in the Cape Town context. Chapter Seven discusses the results of the analysis into the two case studies and the eighth chapter concludes on the lessons learned from these results, as well as the suitability of NMT-PAT for appraising NMT projects in South African cities.

# 2 Non-Motorised Transport: A Potential Solution to Urban Challenges

Traditional engineering practices are primarily concerned with ensuring the efficient and optimal flow of motorised vehicles, especially the flows of privately owned motor vehicles. Modelling efforts typically aim at ensuring that the flow of vehicles occurs with as little resistance as possible, at the highest speed possible. This traditional approach to transport evaluation focuses on the movement of vehicles, rather than the movement of people, and has a very narrow scope regarding costs and benefits (Litman, 2007). This approach continues, in spite of the fact that the increasing of facilities to alleviate congestion is proving to be largely unsuccessful and unsustainable (Macmillan, 2014).

> As the externalities of motorised transport hinder economic and social development and equality, more sustainable solutions to transportation challenges are being emphasized by both public decision-makers and private stakeholders.

In order to change how people choose to travel, high-quality alternative modes need to be made available, while the current transportation modes that have the highest negative externalities need to be discouraged (Sinnett et al., 2011). NMT has few negative externalities and many positive ones, which are rarely considered or quantified. In order for cities to create sustainable transport systems, they need to be aware of all the effects that each mode has on its society.

## 2.1 Benefits for the individual

### 2.1.1 Health benefits for individuals

On the individual level, there are several benefits of shifting towards non-motorised modes, such as walking and cycling. One of the most valuable is the health benefits that individuals gain due to a more active means of transportation (Sinnett et al., 2011). Associated benefits include: increased cardiovascular fitness, decreased stress levels, and lower risk of obesity. Macmillan et al. (2014) found that the greatest component of the benefits of NMT is the overall reduction in mortality from physical inactivity. It contributes to up to half of the total beneficial value in case studies conducted in European cities (Sælensminde, 2004).

> As more individuals shift to NMT trips, the benefits of their actions impact on the community/city as an entity.

### 2.1.2 Time-savings for individuals

Depending on the type of NMT facilities, individuals that shift to NMT trips in urban areas can save time, due to reduced time spent in traffic, as well as travelling on routes that are more direct, due to the more flexible nature of NMT (Litman, 2007).

### 2.1.3 Financial savings for individuals

Individuals can, potentially reduce travelling costs significantly. These include fuel costs, vehicular expenses, license, registration and related taxes, as well as savings on public transport fares.

### 2.1.4 Increased equity for individuals

NMT is often the only means by which the most vulnerable members in society can gain access to opportunities and social services, limiting their high levels of social exclusion (Teunissen et al., 2015). It gives independence and mobility to those that that have little else, decreasing income inequality and social exclusion (Bogotá Declaration, 2011).

## 2.2 Benefits for the community

### 2.2.1 Reducing automobile dependence

NMT trips help reduce congestion, while efficient NMT infrastructure also improves the attractiveness of public transport modes. Hence, NMT helps to further reduce the burden of traffic on the motorised transportation network (Sinnett et al., 2011; Pucher and Buehler, 2010; Sælensminde, 2004; Litman, 2007).

Reducing the need for motorised transport facilities has several co-benefits, including lower public expenditure on maintaining the motorised transport facilities (Litman, 2007). Additionally, cities that are fully dependent on motorised transport are more vulnerable to fuel price volatility and other external price shocks (Kenworthy, 2003).

### 2.2.2 Improved road safety

There is a strong correlation between higher NMT usage and an improvement in road traffic safety (Macmillian, 2014; Mohan, 2002; Litman, 2007). Sælensminde (2004) notes that traffic accidents are likely to be reduced with increased levels of NMT infrastructure. This may be due to motorists becoming more sensitive to the needs of NMT users, or the NMT users becoming more visible and accepted as a viable mode of transportation (Pucher and Buehler, 2010; Litman, 2007).

Road safety can be viewed in terms of the actual road fatality and injury levels, as well as in terms of the perceived levels of road safety felt by the users. Perceived road safety can often have a more significant effect on travel behaviour than actual road traffic safety improvements (Sælensminde, 2004).

### 2.2.3 Economic benefits for residential and commercial areas

In terms of economic benefits, commercial areas and residential areas have shown to increase in value after measures have been put in place to increase the usability of NMT modes within the area. For residential areas this often means that property values increase as the demand increases. Local businesses often benefit greatly, due to the increased footfall past their location. Evidence in Canada and the USA suggest that bike lanes are beneficial to urban businesses and communities (Buehler and Pucher, 2012).

> INDIVIDUALS AND COMMUNITIES THAT INCORPORATE NMT AS A VIABLE MODE OF TRANSPORT WITHIN THEIR URBAN ENVIRONMENTS CONTRIBUTE SIGNIFICANTLY TO IMPROVING THE QUALITY OF THE ENVIRONMENT, BOTH LOCALLY AND GLOBALLY.

### 2.2.4 Societal benefits

Communities that have higher levels of NMT have better levels of cohesion, equity and liveability (Shumi et al., 2014). This hypothesis was found to be true by Appleyard et al. (1981), who measured the differences in liveability along three residential streets in San Francisco that vary in levels of traffic volume and are physically similar. Cervero (2002), shows how the built environment influences traffic, mobility choices, accessibility, liveability and quality-of-life. He, amongst others, presents evidence that a compact, mixed-use, and walking-friendly environment influences mode choice in favour of non-motorised and public transport modes.

## 2.3 Benefits for the environment

Reducing the number and lengths of motorised trips has several benefits for the environment in both the local and global context. Globally, a reduction in motorised trips and the related dependence on fossil fuels means a more sustainable use of resources. When comparing NMT to motorised transport, it has significantly lower uses of non-renewable resources (Litman, 2007). Due to the fundamental nature of NMT, it does not depend on non-renewable fuels for trips but rather energy from the individual. Cycling, in particular, is the most effective means of travel, in terms of energy efficiency (Massink et al., 2011).

# 3 Ex-ante Evaluation Tools for NMT Assessment

## 3.1 Cost-benefit analysis (CBA)

CBA is a common tool to evaluate the impacts of road infrastructure investments in many countries (Sælensminde, 2004). It's based on the monetisation of all costs and benefits related to an investment or policy (Beria, Maltese and Mariotti, 2012). The primary costs, time and environmental externalities, can be converted to monetary values through direct opportunity cost methods such as Willingness To Pay (WTP) or through substitute markets such as the 'hedonic prices' method (Beria, Maltese and Mariotti, 2012). The costs and benefits are relatively well known, with the ability to utilise a vast theoretical backing and empirical data from previous projects (van Wee, 2011). The availability of this data, as well as a perceived neutrality of CBA in comparison with Multi Criteria Analysis (MCA), contributes significantly to its popularity (van Wee, 2011). Although, the costs and benefits often do not coincide along a project's timeline, which means that an inter-temporal discount is used to compare future and present costs and benefits. The choice of this discount rate is rather subjective. A large discount rate means that costs and benefits in the present are valued much more than any that will occur in the future.

> COST-BENEFIT ANALYSIS (CBA) AND MULTI CRITERIA ANALYSIS (MCA) PROVIDE SYSTEMATIC APPROACHES TO ESTIMATE THE STRENGTHS AND WEAKNESSES OF TRANSPORT ALTERNATIVES AND DETERMINE A RANKING OF PREFERENCES AMONG THE AVAILABLE OPTIONS.

The core of a CBA is a comparison of trade-offs: the total value of the benefits, in both demand and social objectives met, must exceed the opportunity costs of the consumed resources (Beria, Maltese and Mariotti, 2012). If the benefits from NMT infrastructure to society do not exceed the opportunity cost of using those resources elsewhere, then it is likely that the project is not considered feasible. However, the use of CBA alone is less common when assessing NMT improvement measures (Sælensminde, 2004). The reason for this may be the difficulty of representing some important impacts, such as health benefits and insecurity, in monetary terms for the CBA to analyse (Sælensminde, 2004).

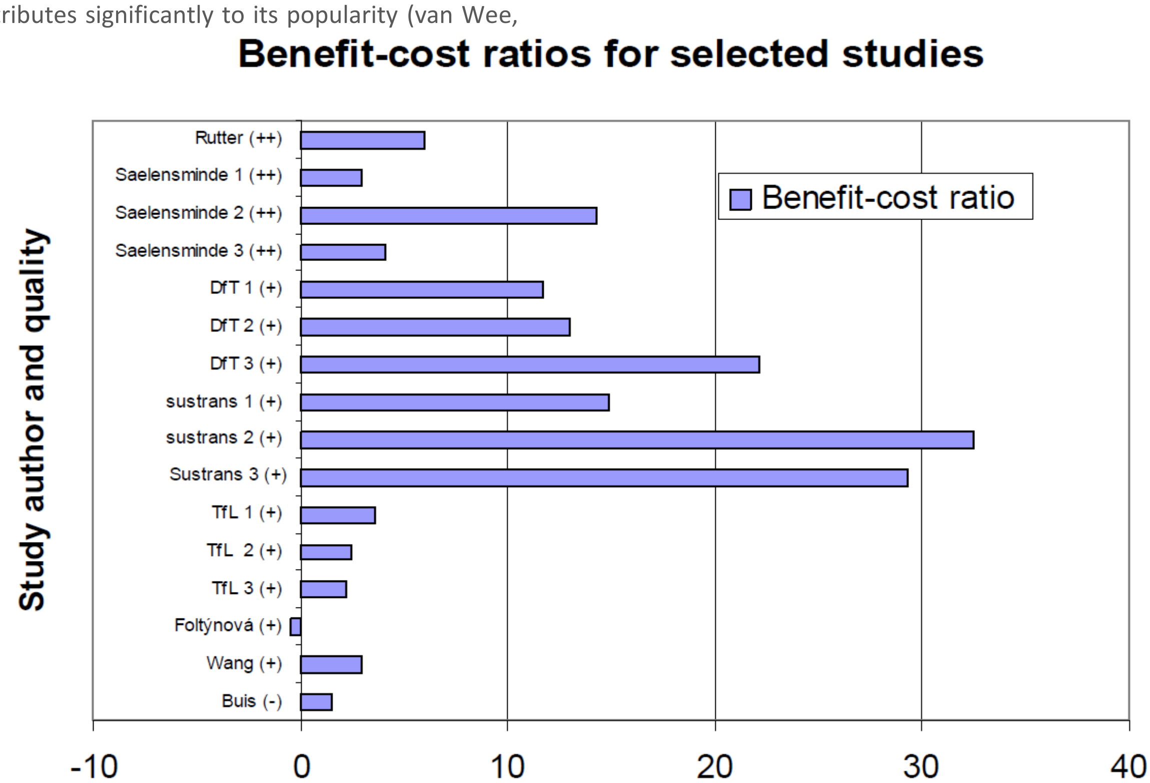


Figure 1: Benefit cost ratios for selected studies (Cavill et al., 2008)

### 3.1.1 Structure of a CBA

According to the Department for Transport of the United Kingdom, a Cost-Benefit Analysis is:

> *'analysis which quantifies in monetary terms as many of the costs and benefits of a proposal as feasible, including items for which the market does not provide a satisfactory measure of economic value.'* (UK Department for Transport, 2014b:1)

Van Wee (2011) notes three phases in a basic CBA, namely, 'before CBA', 'CBA' and 'after CBA'. Before the CBA process, a selection method is utilised to assemble a collection of relevant and feasible alternatives (van Wee, 2011). After the CBA is completed, the results are used, often in parallel with, or as addition input to, other evaluations, in the making of the final decision (van Wee, 2011).

All of the values used in the analysis are represented in monetary terms for a single point in time, expressed as the Net Present Value (NPV). The singular output of a CBA is the Benefit-Cost Ratio (BCR), which numerically demonstrates the unitary value of benefits accrued from the project per unit of cost. This output can be easily compared across very diverse alternative options for which a similar analysis is done. The discount rate, used to discount future benefits in order to compare against present costs, can range from zero to higher than 12% and even small alterations can have significant effects on the BCR (Thomopoulos, Grant-Muller and Tight, 2009).

### 3.1.2 Examples of CBA utilisation in NMT infrastructure evaluation

Cavill et al. (2008) have conducted a systematic review of the economic analyses regarding cycling and walking improvement that considered health effects. Of the studies included in the review, 13 were CBAs of walking and/or cycling infrastructure: (see Rutter, 2006; Krag, 2005; Lind, Hydén and Persson, 2005; Saari, Metsäranta and Tervonen, 2005; Wang et al., 2005; Foltýnová and Kohlová, 2002; Jones and Eaton, 1994).

Within the confines of the core CBA structure, the studies are very heterogeneous and based on many different assumptions. Cavill et al. (2008) summarised the Benefit-Cost Ratio (BCR) outputs of the relevant case studies within the literature into Figure 1. The BCR ranges from -0.4 to 32.5, with a median of 5.1; but note the duplication of some

**Table 1: Benefits and costs of investments in walking and cycling track networks in three Norwegian towns (Sælensminde, 2004)**

| Benefit and cost components | Hokksund | Hamar | Trondheim |
|---|---|---|---|
| **Benefits of walking and cycling tracks (present value)** | | | |
| Accidents (assume no change) | 0 | 0 | 0 |
| Travel time (assume no change) | 0 | 0 | 0 |
| Reduced insecurity for current pedestrians | 4.2 | 2.7 | 107.6 |
| Reduced insecurity for current cyclists | 9.5 | 6.1 | 398.2 |
| Reduced insecurity for new future pedestrians | 0.5 | 0.4 | 13.7 |
| Reduced insecurity for new future cyclists | 3.5 | 2.3 | 100.7 |
| Reduced costs for transporting children | 2.6 | 1.1 | 3.6 |
| Reduced costs related to less severe diseases and ailments and less short-term absence | 16.7 | 35.4 | 269.2 |
| Reduced costs related to severe disease and ailments | 97.7 | 206.6 | 1572.4 |
| Reduced external costs of motorised road transport | 9.4 | 20.0 | 124.4 |
| Reduced parking costs for employers | 9.5 | 34.6 | 433.4 |
| Total Benefit | **153.7** | **309.1** | **3023.3** |
| **Costs of walking and cycle tracks (present value)** | | | |
| Capital costs | 23.6 | 15.8 | 600 |
| Maintenance costs | 1.6 | 1.0 | 39.5 |
| Tax-cost factor, 20% of budget costs | 5.0 | 3.4 | 127.9 |
| Total Costs | **30.2** | **20.1** | **767.4** |
| Net benefit / cost ratio | **4.09** | **14.34** | **2.94** |

**Unit: NOK million (NOK 1 = USD 0.14)**

studies representing multiple cases within the same study (Cavill et al., 2008). The sign next to the study author expresses the perceived quality of the study by Cavill et al. (2008), ranging from high quality (++) to low quality (-). Overall, it can be concluded that the benefit-cost ratio for NMT projects is generally greater than one.

One of the most detailed studies, Sælensminde (2004), utilised a CBA to evaluate walking and cycling track networks in three Norwegian towns. The CBA was deliberately conservative, as to avoid over-estimation and double-counting, and took into account the reduced insecurity and health benefits associated with improved NMT infrastructure. Table 1 summarises the results of the CBA, which used detailed data to monetise the social and environmental impacts. The unit values of the different benefits were derived from an extensive archive of governmental and academic studies related to the Norwegian context. Despite the credibility of the data, a sensitivity analysis was still performed with the extreme values in each range to gauge the boundaries of possibility for the return on these investments (Sælensminde, 2004).

### 3.1.3 Criticism of CBA use for evaluation of NMT infrastructure

There are concerns regarding the ethical and practical issues regarding CBA which are discussed in Chapter *Ex-ante* Evaluation of NMT: The Need for a Comprehensive Tool There has also been significant criticism of the CBA process and its use in evaluating transport related spatial-infrastructure projects. A very extensive and detailed review of this literature can be found in the Ph.D. Thesis of Mouter (2014:25), summarised in Table 2, which categorises the articles according to the element of the CBA that is being criticised. Additionally, Mouter, (2014) outlines and ranks the substantive problems within the CBA process based upon Dutch best practice and case studies.

In France, the CBA process has been accused of failing to account for the knowledge produced through the participation process of various stakeholders (Damart and Roy, 2009). Damart and Roy (2009) determined that CBA, alone, is not compatible with public participation or constructive discourse; two key elements in the acceptance of publically-funded projects. They suggest that

**Table 2: Overview of literature on substantive problems with CBA in transport, categorised by element of criticism (Mouter, 2014)**

| Substantive problem categories | Example papers that study (solutions for) substantive problems |
|---|---|
| Reference case | Damart and Roy (2009); Mackie and Preston (1998); Quinet (2000) |
| Estimating non-monetised effects in | Damart and Roy (2009); Grant-Muller et al. (2001) |
| Estimating non-monetised transport effects | Damart and Roy (2009); Flyvbjerg (2005); Flyvbjerg et al. (2005); Grant-Muller et al. (2001); Hayashi and Morisugi (2000); Holz-Rau and Scheiner (2011); Lee (2000); Mackie and Preston (1998); Morisugi (2000); Salling and Banister (2009); Ševcíková et al. (2011); Vickerman (2000); Van Wee (2007) |
| Estimating costs | Salling and Banister (2009); Van Wee (2007) |
| Indirect effects | Annema et al. (2007); Bristow and Nellthorp (2000); Grant-Muller et al. (2001); Morisugi (2000); Quinet (2000); Rothengatter (2000); Vickerman (2007) |
| External benefits | Brahten and Hervik (1997); Grant-Muller et al. (2001); Hayashi and Morisugi (2000); Quinet (2000); Rietveld (1994); Vickerman (2000); Vickerman (2007) |
| External costs | Forkenbrock (2001); Grant-Muller et al. (2001); Mandell (2011); Morisugi (2000); Quinet (2000); Rothengather (2000); Verhoef (1994); Vickerman (2007); Willis et al. (1998) |
| Monetising in general | Annema et al. (2007); Damart and Roy (2009); Grant-Muller et al. (2001); Hyard (2012) |
| Value of time | Borjesson (2012); Brahten and Hervik (1997); Fosgerau (2007); Grant-Muller et al. (2001); Hayashi and Morisugi (2000); Hensher (2006) Holz-Rau and Scheiner (2011); Mackie and Preston (1998); Morisugi (2000); Lee (2000) |
| Value of statistical life | Grant-Muller et al. (2001); Hauer (1994); Holz-Rau and Scheiner (2011); Verhoef (1994) |
| Value of reliability | Hollander (2006); Peer et al. (2012) |
| Presentation | Annema et al. (2007); Damart and Roy (2009); Grant-Muller et al. (2001); Quinet (2000); Van Wee (2007) |
| Discounting | Annema et al. (2007); Grant-Muller et al. (2001); Weitzman (1998) |
| Distribution | Annema et al. (2007); Bristow and Nellthorp (2000); Hyard (2012); Lee (2000); Quinet (2000); Rothengather (2000) |
| Uncertainty in CBA | Annema et al. (2007); Damert and Toy (2009); Flyvbjerg et al. (2005); Grant-Muller et al. (2001); Holz-Rau and Scheiner (2011); Salling and Banister (2009); Ševcíková et al. (2011); |

changes in the CBA structure are needed to accrue the legitimacy derived from collaborative public debate while maintaining the rationality of the original decision-making process (Damart and Roy, 2009).

## 3.2 Multi Criteria Analysis (MCA)

MCA, in the framework of transport project appraisal, is "*capable of eliciting the trade-offs between objectives (e.g. transportation efficiency, improved equity, and reduced environmental externalities) in ways that enable decision makers to make rational and systematic choices regarding the preferred project*" (Berechman, 2009, p. 306). MCA allows a multi-objective decision-making approach to be taken in contexts for which a single criterion or measurement is unable to effectively assess the merits of each project (Berechman, 2009; Thomopoulos, Grant-Muller and Tight, 2009). Additionally, MCA encourages decision-makers to become acquainted with the details of the project as their participation in the assessment process is integral to its approach (Thomopoulos, Grant-Muller and Tight, 2009). Therefore, it can also account for the opinions of the stakeholders and the contextual knowledge of the decision-maker (Berechman, 2009).

MCA is typically non-monetary but could include criteria based on monetary attributes. The typical phases of an MCA, according to Berechman (2009); Thomopoulos, Grant-Muller and Tight (2009) and Tsamboulas (2007), are:

1. Definition of the projects or actions to be judged;
2. Definition of judgment criteria;
3. Analysis of the impacts of the actions;
4. Judgement of the effects of the actions in terms of each of the selected criteria;
5. Aggregation of judgements.

## 3.3 Integrated CBA-MCA

A comparison between the features of the two methods discussed before has been summarised in Table 3. These different features sometimes lead to opposing results, even on uncomplicated, urban scale road infrastructure projects (Tudela, Akiki and Cisternas, 2006). In that specific case, the alternative suggested by the MCA was chosen, however, a combination of CBA and MCA was proposed (Tudela, Akiki and Cisternas, 2006). There have been several combinations of CBA and MCA utilised in the evaluation of transport alternatives due to the inherent flaws in each individual process (Beria, Maltese and Mariotti, 2012).

## 3.4 Examples of CBA-MCA utilisation in NMT infrastructure evaluation

An advanced and complex system has been built by the United Kingdom's Department for Transport; specifically the Transport Analysis Guidance (TAG) unit (UK Department for Transport, 2014c). The system is comprised of transport appraisal guidelines and a set of spreadsheet based tools. Viable alternatives are developed through a screening process, the Early Assessment and Sifting Tool (EAST), using minimum standards to remove options that may be economically favourable but are too socially or environmentally detrimental. Where possible, the impacts of implementing the alternatives are quantified and monetised. These

**Table 3: Summary of CBA and MCDA features (Browne & Ryan, 2011)**

| | CBA | MCDA |
|---|---|---|
| **Application** | Predominantly road project evaluation but has been applied to demand management and technology policy options | Predominantly project-level |
| **Trends in use** | Widely used, firmly embedded in project appraisal | Not widely used in practice but qualitative elements of MCDA increasingly used in project appraisal |
| **Indicator** | Benefit-cost ratio | Decision ranking |
| **Positive impacts considered** | Predominantly travel time savings and reduction in accidents and fatalities | Potentially all benefits |
| **Stakeholder participation** | Possible but not required | Formal part of process |
| **Ease of communication** | Simple – single value | Difficult to interpret |
| **Transparency** | Not clear – assumptions hidden behind single result | Clearer since multiple facets presented |
| **Ease of use** | Difficult to monetise all impacts | Lengthy consensus necessary to value impacts and impute weightings |
| **Other comments** | May not quantify all impacts correctly | Criteria weighting may be subjective |

feed into a Cost-Benefit Analysis (CBA) tool and a Benefit-Cost Ratio (BCR) is calculated. An accompanying 'Data Book' supplies vast amounts of geographically specific data for use in this process. However, the detail and extent of this data is unlikely to be found in most developing cities.

For impacts that are difficult to monetise, or for which the required data is not available, the more qualitative MCA technique can be used. The distribution of the impacts, due to transport interventions across different social groups, are also taken into account. A Distributional Impact (DI) appraisal is conducted for each of the Key Performance Indicators (KPIs) to determine if any particular group is being unfairly affected or if significant impacts are affecting any of the vulnerable groups within society. The quantitative and qualitative results from the evaluation of each of the KPIs are summarised into the 'Appraisal Summary Table' (AST), which is the final output that assists with the decision-making process. An AST is created for each alternative and no specific alternative is suggested or recommended. Within the WebTAG system is an appraisal tool designed for appraising 'Active Travel' (NMT) infrastructure and promotion schemes (UK Department for Transport, 2014a).

Hüging (2014) is developing a simplified approach to the holistic assessment of urban mobility measures. The approach is primarily based on the MCA methodology, but accounts for the integration of CBA features when the required data is available. The steps in the process for this new approach have been summarised in Table 4. These steps have also been adopted in the modelling approach in this project.

In this process, a CBA is optional, but can be performed in parallel to the overall analysis of the KPIs. If the amount of data available for each alternative is equal then the Cost-Benefit Ratio (CBR) is still valuable for comparative evaluation. Step 4 of the process describes the normalisation of all performance figures: monetary, quantitative (non-monetary) and qualitative. The normalisation occurs using a maximum score approach. As an example, the score for Alternative A for Criterion 1 (C1) is based upon its original performance figure ($x_{C1(A)}$), the largest performance figure for C1 ($x_{C1(max)}$) and a scaling factor ($F_{scale}$) of 10 for ease of calculation (Hüging, 2014). These values are used in Equation 1:

$$Score\ C1(A) = \frac{x_{C1(A)}}{|x_{C1(max)}|} \times F_{scale}$$

**Equation 1: Normalisation of performance figures (Hüging, 2014)**

Step 5, criterion weighting, is performed according to the conventional procedure associated with an Analytical Hierarchy Process (AHP) MCA. The MCA will calculate an overall score for each alternative which is then communicated to the decision-makers. Hüging (2014) posits that the single output from an MCA or CBA often does not effectively communicate the true impacts of each alternative to the decision-makers. Hüging (2014) suggest that the MCA score should be accompanied by the optional BCR and a description of the absolute impacts in an impact-summary table similar to the Appraisal Summary Table (AST) produced by the WebTAG system.

**Table 4: Steps for the simplified, holistic approach to transport intervention assessment (Hüging, 2014)**

| Step | Description |
|---|---|
| **1. Describe project and alternatives** | The planned project and alternatives, including the reference (BAU) case are described. The assessment details (e.g. appraisal period) are determined. |
| **2. Identify effects and indicators** | The effects, by which measures should be assessed, along with the indicators by which the performance should be measured, are identified. |
| **3. Impact Assessment** | For BAU and the proposed project (and any alternatives), the magnitude of each of the effects selected in step 2 is determined. |
| **4. Normalisation** | The performance figures are converted to unit-less relative numbers. |
| **5. Criterion weighting** | The criteria are assigned a weight value reflecting their relative importance |
| **6. Visualisation and interpretation** | Final scores for each measure are calculated from the normalised performance and weighting value, which can be displayed in graphs. |
| **7. Sensitivity analysis** | The significance of individual effects is assessed to test the effect of less-reliable assumptions / values. |
| **8. Communicate results** | The results and key information about the assessment procedure are communicated to the decision makers. |

# 4 Ex-ante Evaluation of NMT: The Need for a Comprehensive Tool

The implementation of NMT infrastructure and facilities, generally, depends on the approval thereof by either a national or local authority. NMT projects or measures are normally in competition with other transport projects for 'political' and financial support (Hüging et al., 2014).

In order for transport infrastructure investment decisions to be of a high standard, the decision-maker needs to be fully informed about the potential benefits and costs of the NMT project, to be able to compare with the benefits and costs of investment in other projects. The ability to predict the value of NMT infrastructure projects before they are implemented is an important part of prioritising and motivating for these projects (Hüging et al., 2014).

> Capturing the more comprehensive benefits of NMT projects is required to improve the quality of decisions.

However, the current lack of adequate tools that can be used by decision-makers to evaluate projects that aim to improve NMT is a hindering factor for these kinds of projects, as there is a lack of information regarding the potential costs, benefits and the total impacts of the possible projects. Hence, for the true value of NMT infrastructure to be appraised, more holistic appraisal tools need to be developed that have the ability to evaluate various benefits, which are typically difficult to monetise and usually omitted from traditional CBA models (van Wee, 2011; Hüging et al., 2014).

Specifically, a tool that is able to do a holistic assessment of the potential social, environmental and economic benefits of improvements to the NMT infrastructure is needed to support decision-making regarding investment returns, both quantitative and qualitative, when investing in NMT infrastructure.

## 4.1 Cost-Benefit Analysis: Ethical considerations

The various manners in which the evaluation of projects is conducted can be subjective to the method that is used and the structure of the tool, as well as the indicators that are selected or not selected. Evaluation of projects should guide authorities in making decisions that result in the most benefits for the society as a whole; i.e. value in monetary terms through economic, social and environmental parameters. Ideally, the decision taken by a decision-maker should be aligned with that of the public (van Wee, 2011).

In order for this to happen, the fundamental approach of the evaluation needs to be ethically sound. The inclusion of consideration for vulnerable members of society, whom are susceptible to being excluded from the evaluation process, should be ensured from the project's outset (van Wee, 2011).

## 4.2 Ethical concerns regarding CBA

In a CBA, costs and benefits of a project or programme are calculated and compared. CBAs are often assumed to be neutral in nature, as the costs and benefits are monetised and are not weighted, in contrast to the MCA approach. However, the CBA approach has been criticised by some, with regards to ethics.

Equity issues are often alleged to be ignored within a CBA approach. Certain benefits and costs that are monetised, such as time-savings, can have a bias toward the higher income groups within the society. In many cases, CBAs are not considered to be democratic. Road users have different "willingness to pay" (WTP) and "value of time" (VOT), which fundamentally skews the results of the CBA in favour of those that have more financial means than those that do not (van Wee, 2011).

CBAs are also criticised for focussing exclusively on the benefits and costs for humans, without including the costs to the environment, the climate or to endangered species. Benchmark levels are not adequately accounted for in the CBA approach while comparing projects and only the changes due to the project implementation are considered. This is a critical aspect of CBA, as it does not alert the decision-maker to an indicator that is below a level considered to be a human right or ethical (van Wee, 2011).

In terms of understanding the needs and wants of the public, CBA is not a good substitute for stakeholder input; rather it should be utilised with adequate consideration for where the data originates from. CBA is an inadequate approach in terms of addressing equitable participation, distribution justice and the inclusion of non-quantifiable factors (van Wee, 2011).

Yet, a CBA can be valuable if the user is aware of its shortcomings. The CBA can, for example, be amended to include non-quantifiable factors alongside the monetary outcomes. By qualitatively evaluating the monetarily quantifiable and non-quantifiable factors in the same manner, the non-quantifiable factors can be included in the CBA in relative terms.

## 4.3 Data in a developing world context

The availability of data, and the reliability thereof, is one of the biggest concerns with conducting ex-ante evaluations of projects. This is a common issue facing decision-makers as pre-implementation and post-implementation transport data is rarely collected. In terms of data analysis, NMT is a particularly challenging form of transport to be evaluated, as many of the highly beneficial aspects are considered to be “soft” or are difficult to monetise within the structure of a CBA.

The various benefits of increasing NMT use are also ignored or overlooked due to the difficulties in accurately reporting or benchmarking them (Sælensminde, 2004). This problem is less significant in developed countries as more data is available. Developing countries have more constrained budgets that can be made available to address data shortages, which may lead to a bias in favour of modes for which data is, or can be, collected.

Therefore, considering that the data conventionally required to conduct a comprehensive evaluation of NMT may not be available, care should be taken to develop a tool that is not heavily dependent on specific data inputs. Similarly, a tool that depends on assumptions from developed countries should be used with caution when in a very different context. The assumptions should be supplemented with qualitative judgement or institutional knowledge when local data is not available.

Cultural and social influences could be considered as well. Pucher and Buehler (2010) indicate that, though cultural and social elements are important in transport behaviour, policies and changes in facilities have shown to be more significant elements in explaining trends in NMT. Therefore, one should endeavour to account for the potential benefits of addressing equity and social issues, especially in areas with great social challenges.

# 5 Defining an Appropriate Tool

## 5.1 Tool components

In order to develop a tool that will be understood and accepted by multiple national and local authorities, the inclusion of evaluation approaches, that are currently used, is important in bridging the gap between how NMT projects are evaluated and how other forms of transport are evaluated (Elvik, 1999). This will encourage NMT investments to be considered on a more equal footing than is currently the case (Hüging et al., 2014).

IN ORDER FOR ETHICAL AND JUSTIFIABLE DECISIONS TO BE MADE, THE TOOLS USED TO MAKE THESE DECISIONS NEED TO INCORPORATE APPROPRIATE ETHICS TO ENSURE THAT THE OUTPUTS ARE SOCIALLY FAIR IN NATURE.

## 5.2 Potential key performance indicators for tool

The selection of Key Performance Indicators (KPIs) from the literature is crucial to the success of the tool and will be tailored to reflect what data can be expected to be available in a developing countries' context. The KPIs will also be selected to best reflect the different key benefits of NMT infrastructure and will, as much as possible, do justice to the ethical issues discussed in Chapter 4.

Some of the indicators will be altered, mainly due to differences in NMT usage, while others will change due to the alterations in motorised trip frequencies (cross-elastic impacts, for example). Table 5 and 6 show a selection of impacts that could be linked to indicators that evaluate the potential benefits of NMT projects.

## 5.3 Methodological best practice

Some of the tools and guidelines in the literature only appraise certain aspects of a transport intervention. This section reviews the current best practice for the valuation of different types of impacts and indicators.

### 5.3.1 Economic: Value of time

The Value of Time (VOT) represents the monetary value of shorter commuting times. The VOT equation, Equation 2, uses half of the number of induced users, i.e. those who have been added to the system due to the intervention, as their travel time savings are not consistent, ranging between zero and the predicted time saving (van Wee, 2011). It is assumed that the

$$VOT = \left(Existing\ users + \frac{Induced\ users}{2}\right) * predicted\ time\ saving * monetary\ value\ per\ time\ unit$$

**Equation 2: Benefit calculation for value of time (van Wee, 2011)**

**Table 5: List of potential impacts of measures to improve safety and/or mobility for pedestrians and cyclists (Elvik, 1999)**

| Impact | Relevant economic valuation | Cost estimates available |
|---|---|---|
| **Impacts for pedestrians and cyclists** | | |
| Changes in number and severity of accidents | Accident costs | Yes |
| Changes in travel time or waiting time | Costs of travel time | Only highly preliminary |
| Changes in route choice (accessibility) | Value of accessibility | No |
| Changes in traffic volume (number of trips) | Generalised costs of travel | No |
| Changes in health state | Cost of illness | Yes, partly |
| Changes in security (the feeling of safety) | Costs of insecurity | No |
| **Impacts on motorised traffic** | | |
| Changes in number and severity of accidents | Accident costs | Yes |
| Changes in speed / travel time | Costs of travel time | Yes |
| **Impacts of transfer of trips from motorised transport** | | |
| Changes in need for bus transport of school children | Cost of school bus transport | Yes |
| Changes in noise and pollution emission | Cost of noise and pollution | Yes |

**Table 6: Various indicators for the different criteria given with the applicable unit/measure**

| Criterion | Indicator | Unit / Measure |
|---|---|---|
| Health | Traffic accident fatalities / injuries (Sælensminde, 2004) | Fatalities per 100,000 persons<br>Serious injuries per 100,000 persons Value of Life [$ ] |
| | Short-term absence (assumed a reduction of 1%)(Sælensminde, 2004) | Lost days of productivity |
| | Premature mortality (include risk reductions of four types of severe diseases: cancer (five specific types), high blood pressure, type-2 diabetes, musculoskeletal ailments)) (Sælensminde, 2004) | Fatalities per 100,000 persons<br>Value of Life [$] |
| | Cost to welfare due to identified diseases and road traffic accidents (Sælensminde, 2004) | Fatalities per 100,000 persons<br>Value of Life [$] |
| | Cost of insecurity(Sælensminde, 2004) | Cost per person per km [$]<br>(assumed motorised trip taken instead of Non-Motorised trip) |
| Environmental | CO2-emissions (Sælensminde, 2004) | Tons of CO2 saved |
| | Local emissions to air (Sælensminde, 2004) | Price per km per type of vehicle (car vs. heavy vehicle) |
| | Noise pollution (Sælensminde, 2004) | Price per km per type of vehicle (car vs. heavy vehicle) |
| | Air / water pollution (TAG, 2014) | Price per km per type of vehicle (car vs. heavy vehicle) |
| | Barrier costs related to motorised traffic (Sælensminde, 2004) | Cost per person per km (US Dollars) |
| Social | Percentage of income spent on transport (Teunissen et al., 2014) | [%] |
| | Passenger comfort(TAG, 2014) | [Likert scale][1] |
| | Accessibility(TAG, 2014) | [Likert scale] |
| | Affordability(TAG, 2014) | [Likert scale] |
| Economic | Costs of infrastructure(Sælensminde, 2004) | [$/km] |
| | Cost of trip(Sælensminde, 2004) | [$/trip] |
| | Cost of parking(Sælensminde, 2004) | [$/hour parking] |
| | Cost of fuel(Sælensminde, 2004) | [$/litre petrol] |
| | Congestion(Sælensminde, 2004) | [$/minute] |
| | Modal split of NMT trips(Kenworthy, 2003) | [%] |

users are distributed equally along this linear time saving curve, meaning the average time saving is half of the predicted value (van Wee, 2011).

### 5.3.2 Health benefits: Reduced risk of mortality

There has been a significant amount of research into the relationship between increased physical activity, through NMT mode choice, and increased health benefits (see Rutter et al., 2013; Boarnet, Greenwald and McMillan, 2008; Cavill et al., 2008; Sælensminde, 2004). According to the literature, the Health Economic Assessment Tools (HEAT) for walking and cycling, created by the World Health Organisation, is the most detailed and extensively used tool for appraising the health benefits of NMT infrastructure (World Health Organisation, 2014).

HEAT uses the relative risk of mortality of regular cyclists and pedestrians, in comparison to the average citizen, in order to estimate health benefits (World Health Organisation, 2014). For example, if a cyclist spends 100 minutes per week cycling, for 52 weeks, they have a relative risk of 0.89. This means that the cyclist is 11% less likely to die from any cause than the average commuter, in any given year. A cyclist that spends 200 minutes per week cycling is 22% less likely to die, given a linear relationship. However, the perceived benefits of this physical activity are capped to avoid inflated values at the upper end of the range. Table 7 summarises the basic values that are used for the

**Table 7: Summary of basic values used for HEAT (World Health Organisation, 2014)**

| Mode | Applicable Age Range | Relative Risk | Volume | Benefits Capped At |
|---|---|---|---|---|
| Walking | 20 – 74 years | 0.89 (CI 0.83-0.96) | 168 minutes/week | 30% (458 minutes) |
| Cycling | 20 – 64 years | 0.9 (CI 0.87-0.94) | 100 minutes/week | 45% (450 minutes) |

monetary evaluation of health benefits related to increased walking and cycling.

This change in relative risk of mortality is then factored by the size of the population that stands to benefit, the Value of a Statistical Life (VSL) and other general parameters. These parameters include the intervention effect; the build-up period; the mortality rate; the discount rate and a time frame over which the benefits are to be calculated. The output of HEAT is the net present value of mean annual benefit, which can be used as an input for a CBA or integrated CB-MCA.

### 5.3.3 Environmental: Climate change mitigation

The Transportation Emissions Evaluation Model for Projects (TEEMP) has been developed by the Clean Air Initiative for Asian Cities (CAI-Asia) and the Institute for Transportation and Development Policy (ITDP, 2011). The tool estimates the reduction in Greenhouse Gas (GHG) emissions resulting from a transport intervention project. TEEMP includes direct, direct post-project and indirect GHG reductions due to the intervention. Direct reductions in GHG emissions are an output of the specific investments and activities related to the project, and contained within its scope of reference. Direct post-project reductions result from on-going mechanisms related to the project and indirect reductions are achieved through the positive perception of the project and justification for replication (ITDP, 2011).

For NMT projects, a baseline is set assuming 'Business As Usual' (BAU) and will typically be compared against the improvement scenario. For cities in which data is available, the full model is applied and all possible emissions savings are calculated. These savings are predominantly dependent on the modal shift achieved, trip length and the stream speeds. The key emissions used as indicators for comparison are Carbon Dioxide ($CO_2$), Particulate Matter (PM) and Nitrous Oxides ($NO_x$). For cities in which data is not available, an alternative 'Sketch Analysis Tool' uses data from projects in Rio de Janeiro and Bogotá to estimate possible GHG reductions (ITDP, 2011). The output of the model, GHG reductions, can be monetised and fed into a CBA analysis or presented in quantitative form within an impact-summary table, as is done by the WebTAG system (UK Department for Transport, 2014a).

Massink et al. (2011) use the fact that cycling is a zero-emission transport mode to estimate the $CO_2$ that would have been created had it not been an option. The opportunity cost of the avoided $CO_2$ emissions is calculated by substituting the cycling trips with those of the most likely alternative mode. This accumulation of avoided emissions is based on current modal splits, cycling's inter-modal competition and $CO_2$ emissions factors. Under the assumption that these avoided emissions are transferable for carbon tax credits, Massink et al. (2011) suggest that a monetary value can be placed on the environmental benefits of cycling. In a case study of Bogotá, Colombia, the 3.3% mode share of cycling is calculated to have a climate value of 55,115 avoided tons of $CO_2$ per year and an economic value of between 1 and 7 million US dollars' worth of carbon credits.

### 5.3.4 Social: Security, severance and journey quality impacts

With access to sufficient amounts of data, many social impacts of an NMT project can be monetised for use in a CBA (UK Department for Transport, 2014a). However, even using the data rich WebTAG system, the security, severance and journey quality impacts are not monetised and, instead, analysed qualitatively. The security impacts relate to the vulnerability that the user has to encountering crime during a trip. The severance impacts describe the effects that an NMT project might have on separating residents from facilities and services. The measure for severance is hindrance to pedestrian movement, which means that, apart from isolated cycling infrastructure, NMT projects would have very few or no severance effects. Journey quality is an indicator of the real or perceived social and physical environment that is experienced while making a trip. It is an often under-valued impact of transport projects as travel is an induced demand, although, it is exceptionally important to users when notably absent.

The WebTAG system uses a seven point Likert-style grading scale to evaluate the overall significance of each of these three impacts. Analysis is done for each one based on specific criteria to first determine if the effect is 'Beneficial', 'Neutral' or 'Adverse'. The Beneficial and adverse impacts are then further categorised as either 'Slight', 'Moderate' or 'Large'. These evaluations are done for scenarios including and excluding the project to determine relative effects. Furthermore, each indicator within the impact assessment is given a 'High', 'Medium' or 'Low' value of importance. Finally, the number of users affected is estimated and the overall impact assessment score is approximated (UK Department for Transport, 2014a).

# 6 Cape Town Context

Cape Town is one of the largest cities in South Africa and is the legislative capital of South Africa. The local population was estimated to be 3 740 025 in 2011 (City of Cape Town, 2011). This is likely to grow significantly in the coming years, as consistent urbanisation continues to shape the way the city develops.

## 6.1 Cape Town's transportation challenges

While Cape Town has a significant NMT mode share, it is struggling to provide adequate facilities for its pedestrians and other NMT users (City of Cape Town, 2005; NDoT, 2014; STATSSA, 2014). NMT is battling for priority with an increasing demand for motorised transport infrastructure, due to a rapid increase in the number of vehicles on the roads (Lombard, et al., 2007; Merven et al., 2012). As a result, Cape Town suffers from high levels of congestion, as well as high levels of road fatalities and injuries (Arrive Alive, 2005; City of Cape Town, 2006; Mabunda et al., 2008; Peden, M, Kobusingye and Monono, 2013).

Unfortunately, pedestrians and other NMT users are bearing the brunt of these deaths and injuries at the moment (Ribbens, H., et al., 2008; Statistics South Africa, 2014). This is compounding the negative effects to accessibility, social inclusion and equity. Some of the other concerns include the decreasing air quality and reduced productivity, due to time spent commuting (Merven et al., 2012).

Cape Town has, for the past several years, been going through a rapid process of urbanisation leading to increased population growth, car ownership and travel times (Lombard, et al., 2007). However, the densities in Cape Town are still relatively low compared to other developing cities (Lombard, et al., 2007). Urbanisation goes hand in hand with increasing traffic demand, and the negative externalities that are associated with high levels of motorised transportation. The low

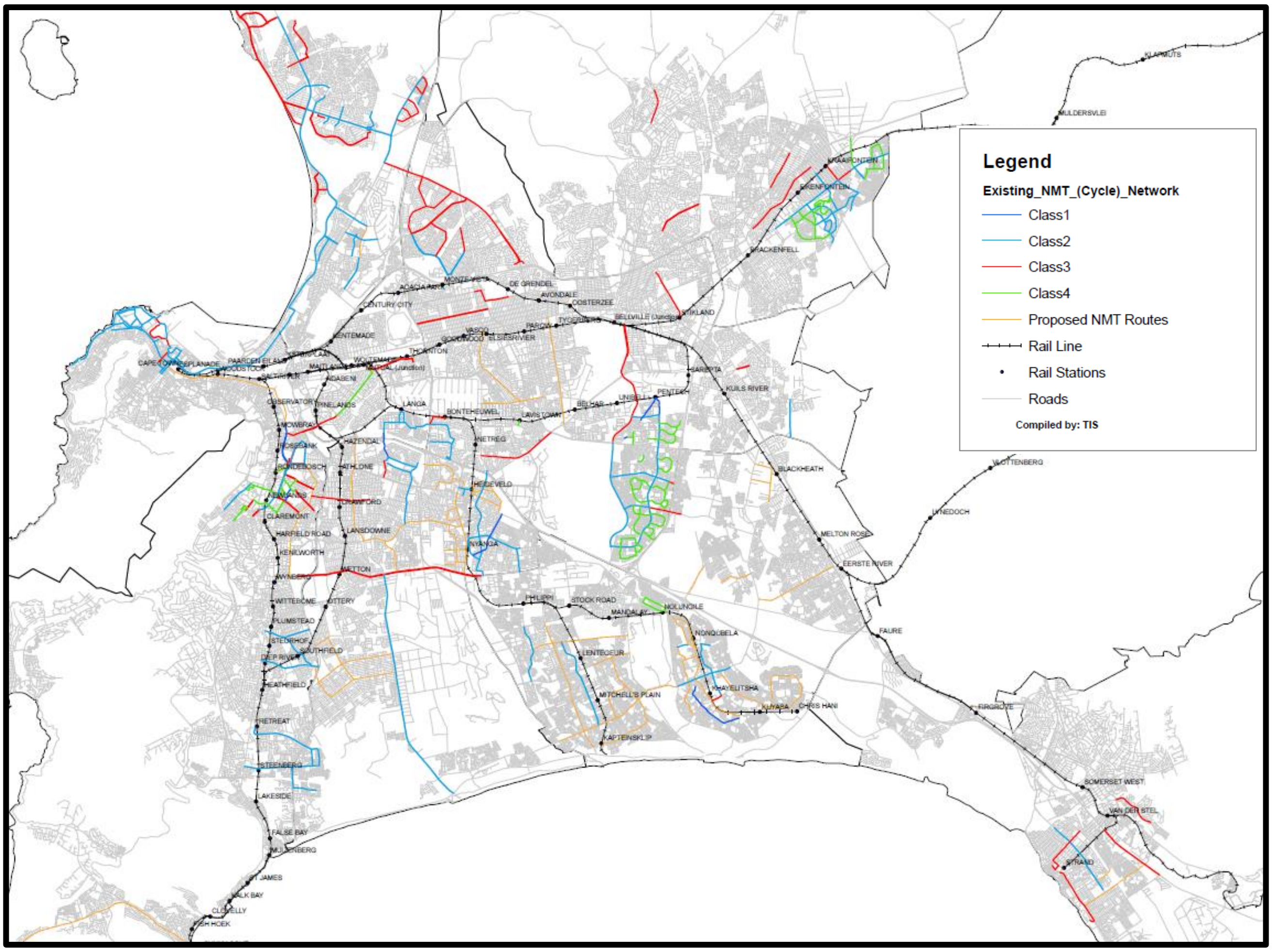


**Figure 2: Map of existing and proposed NMT (cycle) projects in Cape Town (Transport for Cape Town, 2012)**

densities and long trip lengths are likely to exacerbate these negative consequences (Lombard, et al., 2007).

In order to address these challenges, the City of Cape Town identified several strategies:

1. Increase the modal split of public transportation overall;
2. Implement a Bus Rapid Transport system, called MyCiti;
3. Reduce the number of fatalities and injuries on the roads;
4. Promotion of non-motorised transport, as a mode of transportation.

The City of Cape Town acknowledges the urgent need for adequate NMT facilities. At the metropolitan level, it has resulted in a number of NMT projects being rolled out in three year phases, under the *NMT City Wide Plan* for the periods 2009-2013 and 2013-2015. On a national level, the need to address the inadequate levels of facilities for NMT users has also received attention, with the drafting of the new NMT Facility Guidelines (NDoT, 2014).

## 6.2 Data availability

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 dis-benefits 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 8 are required. Based on a literature review of several South African policy documents, World Bank databases and university studies that have been carried out, Table 8 illustrates for which indicators data could be sourced. As NMT-PAT is designed for data scarce and institutionally under-developed contexts, the ease of which the data was sourced is not an accurate representation of NMT data availability, generally.

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 most African cities. In the case of Cape Town, South Africa the area for which data was unable to be sourced was in the prediction of future scenarios. Adequate predictions could not be found for the expected state of NMT in the future and how this status quo might be affected by significant investment in NMT projects. To fill these gaps in the data, an experts' opinion poll was created that requested local experts to provide estimates for the unavailable data related to the future of NMT in Cape Town.

**Table 8: Data availability for NMT-PAT for appraisal in Cape Town**

| Necessary data indicators | Availability |
|---|---|
| Scheme costs | ✓ |
| Discount rate | ✓ |
| GDP/capita | ✓ |
| Currency | ✓ |
| Average inflation rate | ✓ |
| Economic growth rate | ✓ |
| Metropolitan Population | ✓ |
| Modal Split | ✓ |
| Total number of trips per day | ✓ |
| 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 | ✓ |

## 6.3 Potential to widen the scope of NMT-PAT

The improvement or provision of NMT facilities provides benefits to different road users, including those who use the facilities and those that benefit indirectly from its use. Benefits can also be derived from knowing that there is a viable alternative option, in case the need for it ever arises. 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 and its residents.

A major category 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 in an attempt to 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 (2013) provides a comprehensive guide on possible NMT survey methods.

# 7 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 a South African city. A secondary aim was to determine the magnitude of benefits that is likely to be derived from NMT infrastructure in Cape Town, South Africa. Two case study scenarios were chosen - one smaller scale, newly constructed project and one larger, theoretical network - 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 into potential associated benefits. The two case study scenarios tested are:

1. NMT facility upgrades in the Cape Town CBD
2. Cape Town 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 six outlines the challenges faced in sourcing data about the future of NMT in Cape Town. A few of the indicators 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 primarily for testing the applicability of NMT-PAT and 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.

## 7.1 NMT facility upgrades in the Cape Town CBD

The various NMT projects that have been implemented in the City of Cape Town's CBD during 2012 were chosen as the small-scale case study. The total length of the various upgrades that happened in the 2011/2012 period was 4.53 km. The upgrades included both bicycle and pedestrian infrastructure, as well as Universal Access (UA) improvements, landscaping of NMT facilities and the provision of street furniture. Examples of the infrastructure include:

- A segregated, bi-directional cycle lane in Adderley Street from Strand Street to Wale Street
- A Class 3 cycle lane on both sides of Bree Street from Short Market Street to Hans Strijdom Avenue

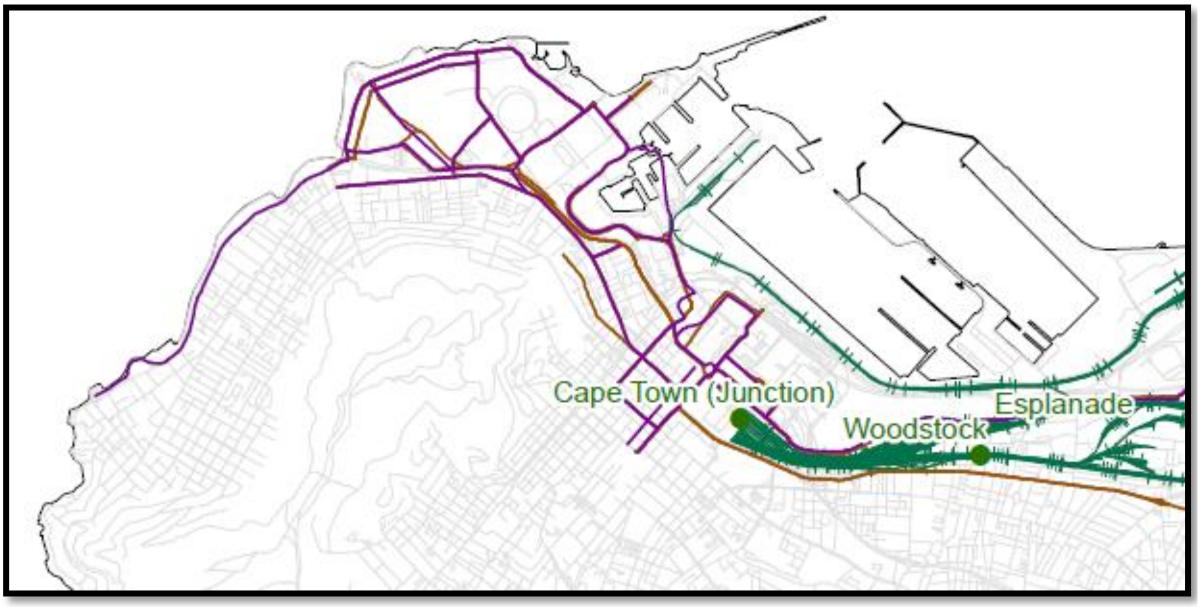


**Figure 3: Map of NMT facilities, existing and proposed, as of March 2015 (Transport for Cape Town, 2015)**

- A shared, Class 2 facility on Short Market Street from Bree Street to Adderley Street.

The existing NMT facilities can be seen in Figure 3, indicated by the purple lines, while the proposed NMT facilities are indicated by the brown lines. The grey lines represent the road network, while the rail network is indicated by green lines (Transport for Cape Town, 2015).

Figure 3 illustrates that the NMT network is limited to a small percentage of the CBD area. However, it does provide significant opportunities for the effective distribution of the pedestrians arriving at Cape Town Station, the primary ingress point to the central city.

**Table 9: Modal split of the Cape Town CBD**

| Modal split | Base - 2015 | Business as usual - 2030 | With project - 2030 |
|---|---|---|---|
| Walking | 2% | 3% | 5% |
| Cycling | 0% | 0% | 3% |
| Bus | 6% | 6% | 7% |
| BRT | 1% | 1% | 1% |
| Minibus taxi | 10% | 7% | 11% |
| LRT & rail | 19% | 16% | 19% |
| Cars | 61% | 65% | 51% |
| Motorcycles | 0% | 0% | 1% |
| Taxi | 1% | 1% | 1% |
| Other | 0% | 1% | 1% |

### 7.1.1 Environmental impacts of the NMT upgrades

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 NMT improvements around the CBD are expected to result in a small but significant increase the proportion of trips completed by walking and cycling by 2030, see Table 9. It has been projected that the majority of the new NMT trips will be shifted away from cars, currently the dominant transport mode in the area, and the project will also increase the usage of the both the Bus and Minibus modes.

**Table 10: Emissions of trips in the Cape Town CBD**

| Emissions (tons) | Business as usual | With project | Savings |
|---|---|---|---|
| | tons | tons | tons |
| CO2 | 1 714 167 | 1 550 154 | 164 012 |
| PM | 175 | 186 | -10 |
| NOx | 8 625 | 7 805 | 820 |

The potential modal shift of the trips, due to the CBD NMT upgrades, would result in Carbon Dioxide ($CO_2$) and Nitrous Oxides ($NO_x$) savings of 10% each by 2030, see Table 10. Whereas, Particulate Matter (PM) is expected to increase by 6% due to the higher proportion of trips utilising the more PM-intensive diesel buses. 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 electric, as has been proposed for the MyCiti BRT vehicles, significant PM savings are likely (MyCiti, 2016).

**Table 11: Energy usage of trips in the Cape Town CBD**

| Energy usage | Business as usual | With project | Savings |
|---|---|---|---|
| | Gj | Gj | Gj |
| Petrol | 21 989 315 | 19 730 898 | 2 258 416 |
| Diesel | 893 822 | 969 441 | -75 619 |

Table 11 shows the 8% increase in diesel usage due to the potential modal shift in favour of the bus modes, as well as a 10% decrease in petrol usage by 2030, due to the NMT upgrades in the CBD.

### 7.1.2 Health impacts of the NMT upgrades

The health impacts of the NMT project to the average employee or resident of the CBD have been categorised into two primary groups: those that affect their average level of physical activity and those that affect their level of safety.

**Table 12: Physical activity benefits of the Cape Town CBD NMT infrastructure**

| Indicator | No. of new users | Physical activity per week | Relative risk of mortality | Premature deaths prevented |
|---|---|---|---|---|
| | # | Minutes | # | # |
| Walking | 2 187 | 426 | 0.72 | 58 |
| Cycling | 3 171 | 292 | 0.68 | 96 |

The dominant cause of death in Cape Town, over the past ten years, has been cardiovascular and metabolic diseases (City of Cape Town, 2014). Non-Communicable Diseases (NCDs), such as these, are often linked to a poor quality of lifestyle and a lack of physical activity (Mayosi et al., 2009). Particularly in the CBD, where workers often occupy more sedentary employment positions, the promotion of NMT would decrease the risk of citizens succumbing to these NCDs. The expected modal shift to NMT, due to the infrastructure improvements, will have a significant positive impact on the lives of the new users. Table 12 shows that the approximately 2000 new pedestrians and 3000 new cyclists could enjoy 7 and 5 hours more physical activity per week, respectively, due to their new commuting mode. The combined decrease in their relative risk of mortality means that a total of 154 premature deaths are likely to be prevented.

**Table 13: NMT fatalities and injuries in the Cape Town CBD**

| *Indicator* | *Base - 2015* | *Business as usual - 2030* | *With project - 2030* |
|---|---|---|---|
| NMT Fatalities per year | 0 | 10 | 0 |
| NMT Injuries per year | 25 | 200 | 25 |

The safety of NMT users is of the utmost importance due the fact that they constitute more than 40% of all road traffic fatalities in South Africa (Statistics South Africa, 2014). Though the number of NMT fatalities and injuries in the CBD is not considered high, the NMT upgrades will ensure that the movements of NMT users are not constricted by the increasingly congested motorised traffic. The improvements will help prioritise and encourage NMT trips, through a greater sense of safety and journey quality for the users. Based on the estimates given in Table 13, 75 lives could be saved and 1300 injuries prevented due to the NMT upgrades in the Cape Town CBD.

### 7.1.3 Economic Impacts of the NMT upgrades

Improving the access and mobility of individuals to social and economic activities is an important function of the NMT upgrades. They will also protect NMT users' movements from conflicting with the growing intensity of car use in the Cape Town CBD (Merven et al., 2012). Consequently, improving the ease of movement for NMT users will also increase the access and appeal of the various public transport modes, such as the Bus Rapid Transport system, and congestion in the CBD. Each of these effects have impacts on the regional economy within the CBD and the metropolitan economy as a whole.

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. However, Table 14 highlights that the NMT upgrades could result in a marginal overall travel time increase. The NMT users could experience total travel time savings of 55 years over the analysis period. Similarly, the public transport modes are predicted to enjoy similar travel savings, possibly due to their increased accessibility and support. The travel time increases will be borne by the car users as a result of NMT now being prioritised at many of the intersections.

### 7.1.4 Qualitative analysis

A qualitative assessment of the NMT upgrades, in Table 16, highlights the perceived state of NMT in the Cape Town CBD, and the state in 2030, with and

**Table 14: Travel time years saved due to the Cape Town CBD NMT infrastructure**

| Indicator | Total amount of time saving |
|---|---|
| | Person years |
| Walking | 25.37 |
| Cycling | 29.26 |
| Bus | 35.81 |
| BRT | 3.11 |
| Minibus taxi | 18.98 |
| LRT & rail | 8.50 |
| Cars | -125.08 |
| Motorcycles | 0.48 |
| Taxi | 0.41 |
| Total | -3.18 |

without the new infrastructure. It is the perception of the experts polled that the state of NMT would decrease from an average rating of 4.8 (out of 10) to 3.8 in 2030 if the NMT infrastructure was not constructed. Whereas, an average improvement of 33% on the current qualitative scores is expected, up to a rating of 6.3, due to the NMT infrastructure. In particular, the qualitative score for the road traffic accidents is expected to be 200% higher in 2030. These improvements are substantial as they describe the possible change in perception toward NMT safety and the other barriers to its use.

**Table 16: Qualitative analysis of the Cape Town CBD NMT infrastructure**

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

Table 17 illustrates the average qualitative scores when the indicators are weighted according to importance by the polled experts. The weighted average rating is lower in each case as the weighting given to 'time saving' was relatively high. However, the improvement is still of the same magnitude and describes the optimism with which people view the future effects of the NMT upgrades.

**Table 17: Qualitative improvement due to the Cape Town CBD NMT infrastructure**

| Weighted average | | | |
|---|---|---|---|
| Current - 2015 | BAU - 2030 | WP - 2030 | Improvement |
| 4.6 | 3.6 | 6.1 | 2.5 |

### 7.1.5 Monetary Analysis

Of the potential monetary benefits of the CBD NMT upgrades, Table 15 shows that only the health and travel time benefits are able to be effectively monetised with the available data. One can see that the potential monetary gain, through the improved health of the CBD's inhabitants, is substantial. It vastly outweighs the expected monetary dis-benefit of longer travel times for the CBD's car users.

The Benefit-Cost analysis of the Cape Town CBD NMT upgrades, seen in Table 18, highlights that the anticipated benefits derived also outweigh the costs of the project and results in a Benefit-Cost Ratio (BCR) of 8.63. The BCR is higher than one and, therefore, the infrastructure is expected to be economically justified.

**Table 15: Potential monetary benefit of the Cape Town CBD NMT infrastructure**

| Impacts | | Monetary (NPV) | |
|---|---|---|---|
| Health | Physical activity | R | 263 498 366 |
| Health | Accidents/injuries | R | 56 685 562 |
| Economic | Travel time saving | R | -1 028 965 |

**Table 18: Benefit-cost analysis of the Cape Town CBD NMT infrastructure**

| | | | |
|---|---|---|---|
| BCR | Net Present Benefit (NPB) | R | 319 154 963 |
| | Net Present Cost (NPC) | R | 37 000 000 |
| | Net Present Value (NPV) | R | 282 154 963 |
| | Benefit-Cost Ratio (BCR)* | 8.63 | |

*Note BCR is unreliable in data scarce contexts

## 7.2 Metropolitan Cape Town NMT Network Scenario

The metropolitan NMT network scenario explores the effects of having an extensive walking and cycling network throughout the Cape Town 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 Cape Town'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 350 km of dedicated, inter-connected NMT infrastructure could form a cohesive NMT network for the metropolitan area of Cape Town.

### 7.2.1 Environmental Impacts of a Metropolitan NMT Network

The potential effect of the Cape Town Metropolitan NMT network on local modal splits is difficult to measure as each segment of the network would have a unique modal split. Therefore, the experts polled were questioned over the possible effect of

**Table 19: Modal split of Cape Town**

| Modal split | Base - 2015 | Business as usual - 2030 | With project - 2030 |
|---|---|---|---|
| Walking | 21% | 22% | 25% |
| Cycling | 0% | 0% | 10% |
| Bus | 13% | 10% | 15% |
| BRT | 0% | 0% | 1% |
| Minibus taxi | 15% | 10% | 16% |
| LRT & rail | 11% | 8% | 10% |
| Cars | 37% | 47% | 20% |
| Motorcycles | 1% | 1% | 1% |
| Taxi | 1% | 1% | 1% |
| Other | 1% | 1% | 1% |

the network to the overall modal split of the Cape Town Metropolitan area.

shows that the metropolitan NMT network is expected to have a significant effect on the number of pedestrians and a substantial effect on the number of cyclists in Cape Town in 2030. This may be due to the fact that the places an NMT user 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 private vehicles, which would increase their level of physical activity.

The shift in trips toward NMT modes would result in $CO_2$ and $NO_x$ savings of 26% and 24% respectively, by 2030, across the whole of Cape Town - see Table 20. The PM levels are expected to increase by 10% due to the higher proportion of trips utilising the more PM-intensive diesel buses, similar to the CBD NMT upgrades. Again, this scenario assumes that the buses used in 2030 are no cleaner or more efficient than the buses used currently. The $CO_2$ and $NO_x$ savings are significant, and would considerably change the carbon footprint of the transport sector in Cape Town. These emissions savings could be compounded if other measures are utilised to promote NMT use and to pass the environmental cost of motorised transport on to the users.

**Table 20: Emissions of trips in Cape Town**

| Emissions (tons) | Business as usual | With project | Savings |
|---|---|---|---|
| | tons | tons | tons |
| CO2 | 45 593 730 | 33 839 030 | 11 754 699 |
| PM | 6 714 | 7 383 | -668 |
| NOx | 231 355 | 175 655 | 55 700 |

The decrease in private motorised transport use would also result in petrol savings of approximately 29% due to the NMT infrastructure, visible in Table 22. However, the NMT network would increase diesel usage by 26% by 2030, as a result of the higher patronage of the bus-based transport modes.

**Table 22: Energy usage of trips in Cape Town**

| Energy usage | Business as usual | With project | Savings |
|---|---|---|---|
| | Gj | Gj | Gj |
| Petrol | 570 632 287 | 404 518 857 | 166 113 430 |
| Diesel | 38 633 337 | 48 490 770 | -9 857 433 |

### 7.2.2 Health impacts of a metropolitan NMT network

A large mode shift to NMT modes, due to a metropolitan-wide network, could produce considerable health benefits for the average Cape Town resident. It is predicted that Cape Town could have 235 877 new NMT users due to having a conducive network to travel on, seen in Table 21. Of these new users, 9 245 would be spared an early death due to their, previously, sedentary lifestyles.

**Table 21: Physical activity benefits of the Metropolitan Cape Town NMT network**

| Indicator | No. of new users | Physical activity per week | Relative risk of mortality | Premature deaths prevented |
|---|---|---|---|---|
| | # | Minutes | # | # |
| Walking | 55 284 | 476.70 | 0.70 | 1 567 |
| Cycling | 180 593 | 520.04 | 0.55 | 7 678 |

Similarly, the increased safety of the dedicated NMT network could result in fatalities and injuries being 77% and 83% lower, respectively, across Cape Town in 2030. This would mean that 8 625 lives would be saved in the 15 year analysis period (summed from Table 23).

**Table 23: NMT fatalities and injuries in Cape Town**

| *Indicator* | *Base – 2015* | *BAU - 2030* | *With project - 2030* |
|---|---|---|---|
| **NMT Fatalities per year** | 582 | 1500 | 350 |
| **NMT Injuries per year** | 7 000 | 21 000 | 3 500 |

### 7.2.3 Economic impacts of a metropolitan NMT network

The impact of a Cape Town metropolitan NMT network on travel times would have a significant positive influence on the local economy. Table 25 illustrates that a combined 3 106 years of travel time could be saved by both NMT and non-NMT users over the 15 year analysis period. The NMT network is expected to have no effect on the travel times of pedestrians but a significant improvement on the ease of movement for cyclists. Additionally, the bus-based public transport modes are predicted to also benefit from lower travel times; possibly as a result of their higher resultant mode share providing the impetus for the creation of their own prioritised road-space.

**Table 25: Travel time years saved due to the Metropolitan Cape Town NMT network**

| Indicator | Total amount of time saving |
|---|---|
| | Person years |
| Cycling | 1 669.12 |
| Bus | 1 942.85 |
| BRT | 61.13 |
| Minibus taxi | 474.79 |
| Cars | -1 056.70 |
| Motorcycles | 7.22 |
| Taxi | 7.57 |
| **Total** | 3 105.97 |

### 7.2.4 Qualitative analysis

Table 24 shows that, based on a qualitative analysis by the polled experts, the state of NMT in Cape Town is expected to decline significantly by 2030, without major intervention. This is especially true for the security and liveability in which NMT users will travel and reside. Additionally, NMT road traffic injuries and fatalities are expected to get worse as more vehicles and NMT users compete for the same space. Despite slowing population growth, the rise of a substantial middle could mean that the number of vehicles on the roads will still increase significantly, making the safe navigation of streets by NMT users ever more difficult. 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 Cape Town 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 Cape Town becomes increasingly denser. These indicators could also be key in persuading the future burgeoning middle class of Cape Town to maintain their current NMT routines and forgo the purchase of motorised vehicles. The avoidance of a middle class dependent on automobiles would have very favourable effects on the modal split and high, existing levels of congestion in the city.

**Table 24: Qualitative analysis of the Cape Town NMT network**

| *Qualitative indicator* | Base - 2015 | Business as usual - 2030 | With project - 2030 |
|---|---|---|---|
| **Energy usage** | 6 | 4 | 8 |
| **Emissions** | 4 | 3 | 7 |
| **Noise pollution** | 4 | 3 | 7 |
| ***Physical activity*** | 4 | 3 | 8 |
| ***Accidents/injuries*** | 3 | 2 | 6 |
| ***Time saving*** | 3 | 2 | 8 |
| ***Journey quality*** | 3 | 2 | 7 |
| ***Security*** | 4 | 2 | 8 |
| ***Liveability*** | 4 | 2 | 9 |

When the scores are weighted, in Table 26, a metropolitan NMT network for Cape Town scores around 7.6/10, according to the polled experts. This constitutes a 140% 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 26: Qualitative improvement due to the Metropolitan Cape Town NMT network**

| Weighted average | | | |
|---|---|---|---|
| Current - 2015 | BAU - 2030 | WP - 2030 | Improvement |
| 3.7 | 2.4 | 7.6 | 5.2 |

### 7.2.5 Monetary Analysis

The monetary benefits of a metropolitan NMT network for Cape Town are exceedingly important as it would involve a vast amount of infrastructure and a significant proportion of the transportation budget. Table 27 outlines the magnitude of monetary benefits that could be expected from a 350 km NMT network. In this scenario, the majority of the economic benefit for Cape Town would come from the improved health of its citizens. The health benefits account for 99% of the total monetary benefits accrued over the 15 year analysis period. This is primarily due to the health benefits being the only impact, apart from travel time, that can be effectively monetised using the available data.

The Net Present Cost (NPC) for the project was derived from the cost of the similar sized metropolitan NMT network in Bogota, Colombia. However, the costs of constructing NMT infrastructure does seem to be more expensive in Colombia than South Africa, 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 7.58. Even if only the two most common benefits are included, travel time savings and road traffic accidents, the BCR is still 2.26. The implementation of a metropolitan-wide NMT network in Cape Town appears to be more than feasible. It could be a very prosperous economic investment, based on this preliminary investigation.

**Table 28: Benefit-cost analysis of the Metropolitan Cape Town NMT network**

| | | | |
|---|---|---|---|
| BCR | Net Present Benefit (NPB) | R | 22 551 278 899 |
| | Net Present Cost (NPC) | R | 2 977 011 494 |
| | Net Present Value (NPV) | R | 19 574 267 405 |
| | Benefit-Cost Ratio (BCR)* | | 7.58 |

*Note BCR is unreliable in data scarce contexts

## 7.3 Case Study Scenario Comparison

The two case study scenarios analysed using NMT-PAT in Cape Town are very diverse in scale and, therefore, their comparison is difficult. The magnitude of benefits derived from a project can be inherently 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.

**Table 27: Potential monetary benefit of the Metropolitan Cape Town NMT network**

| Impacts | | Monetary (NPV) | |
|---|---|---|---|
| Health | Physical activity | R | 15 819 451 575 |
| | Accidents/injuries | R | 6 518 839 647 |
| Economic | Travel time saving | R | 212 987 676 |

The chosen method is demonstrated in Figure 5, a comparison of the emission savings per monetary cost unit for the two scenarios. The graph shows the $CO_2$ savings in grams per South African Rand invested in the project. The Cape Town CBD NMT upgrades have a marginally higher rate of $CO_2$ savings at approximately 4400g/R invested, potentially due to the higher average usage per kilometre of infrastructure than the metropolitan network. Regarding Particulate Matter (PM) savings, both projects are expected to result in higher PM levels due to their positive influence on the ridership of the diesel bus modes. The projects could lead to between 220 and 280 g/R1 000 invested, over the 15 year analysis period. Finally, the Nitrous Oxides' savings follow the same trend as the $CO_2$ savings with relatively comparable levels of approximately 20g/R invested.

The aforementioned increase in diesel usage, attributed to both NMT projects, can be seen in Figure 4 and accumulates to 2-3 Megajoules/R (Mj/R) invested over the 15 year analysis period. However, the higher level of diesel usage is completely counteracted by the expected decrease in petrol consumed. The effects of the modal shifts to NMT, due to the infrastructure, is observed again through the immense fuel savings. The CBD upgrades and metropolitan NMT network could expect an average saving of 61 Mj/R invested and 56 Mj/R invested by 2030, respectively.

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 Capetonian citizens and reduce the high number of NMT-related road traffic injuries. Figure 6 illustrates the potential positive effects of the two scenarios, per million Rand invested in each project. The CBD upgrades are expected to prevent more premature deaths due to unhealthy lifestyles per unit of cost, possibly because of the higher shift in the number of trips to NMT per kilometre of infrastructure. However, the opposite is true for the prevention of road traffic injuries and fatalities. The CBD has a relatively low number of injuries relative to the number of trips to and from the area. The metropolitan network could prevent 42% more lives from being lost and 24% more injuries from occurring, per unit of cost.

The final quantifiable benefit of the two scenarios is the net savings in travel time by the users over the analysis period, found in Figure 7. The metropolitan NMT network could save more than 3000 years in travel time by 2030. Conversely, the CBD NMT upgrades will have a negative effect on overall travel times due to the higher proportion of private car trips in the area.

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 8 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 the two scenarios. Based upon the estimations of the polled experts, the CBD upgrades would accrue marginally more value in benefits in relation to the associated costs. In absolute terms, the BCRs of 8.6 and 7.6, for the CBD upgrades and metropolitan network, respectively, are far greater than most comparable motorised transport projects, despite only the health and travel time benefits being accounted for.

However, when focussing exclusively on the projected travel time savings, the BCR of the metropolitan NMT network would be 0.07 and the BCR of the CBD upgrades would be -0.03. If the only basis for appraisal was the travel time savings, as is the methodology preferred by many data deprived cities, these projects would likely be designated as uneconomical. It 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 potential R3 billion price tag of a comprehensive metropolitan NMT network would be one of the largest investments in transport infrastructure in Cape Town but could produce R24 billion of value to the city just in health benefits. However, if the environmental, health and social improvements are not accounted for, projects such as this one will be perceived to return significantly less value than invested. If the narrow view of transport infrastructure is taken, purely as a conduit for the movement of people, then a metropolitan NMT network for Cape Town would appear to be a poor investment when the opposite is true.

The economic analysis of these two 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 9 highlights the perceived qualitative improvement on the current situation in reference to a score out of ten. The qualitative analysis of the potential relative improvement is in contrast to the quantitative and monetary analyses of the two case study scenarios. This is due to the fact that the CBD upgrades are in a heavily congested area but some significant NMT infrastructure does already exist.

Therefore, these 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 the metropolitan NMT network, 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.

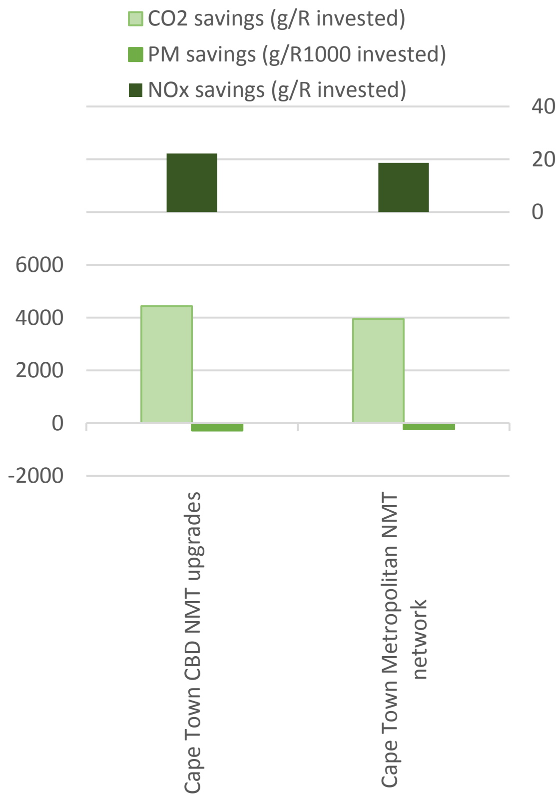


**Figure 5: Comparison of potential emissions savings in Cape Town per monetary cost unit**

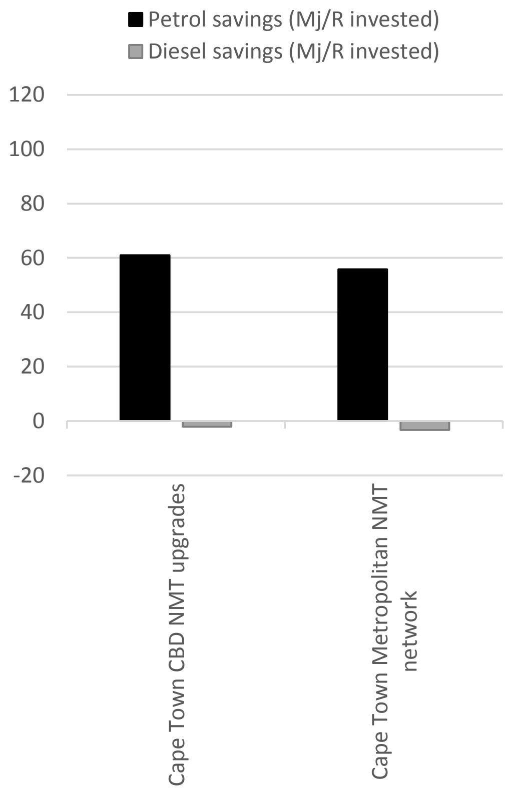


**Figure 4: Comparison of potential fuel savings in Cape Town per monetary cost unit**

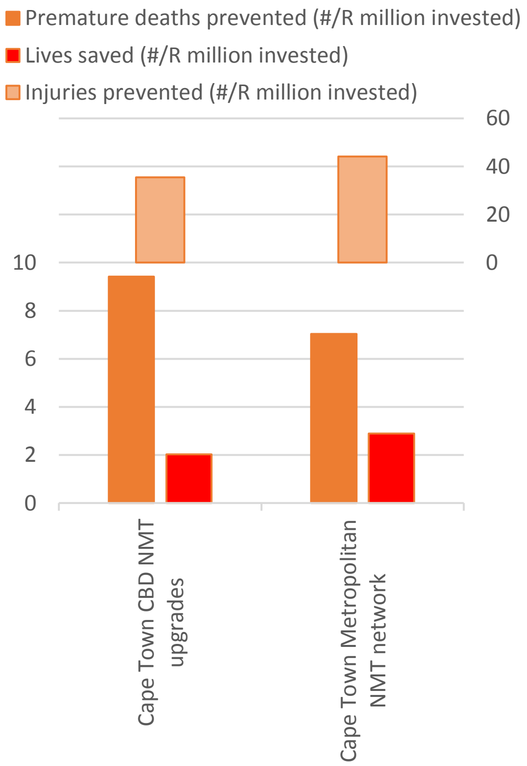


**Figure 6: Comparison of potential health improvement in Cape Town per monetary cost unit**

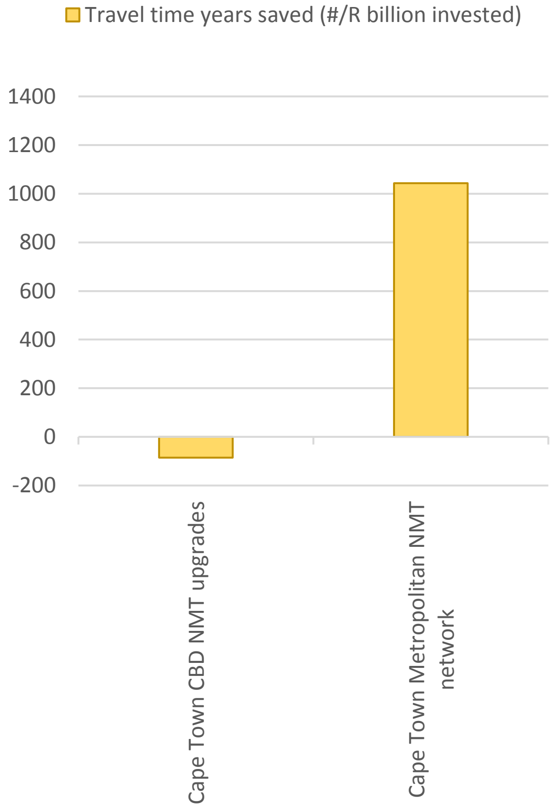


**Figure 7: Comparison of potential travel time savings in Cape Town per monetary cost unit**

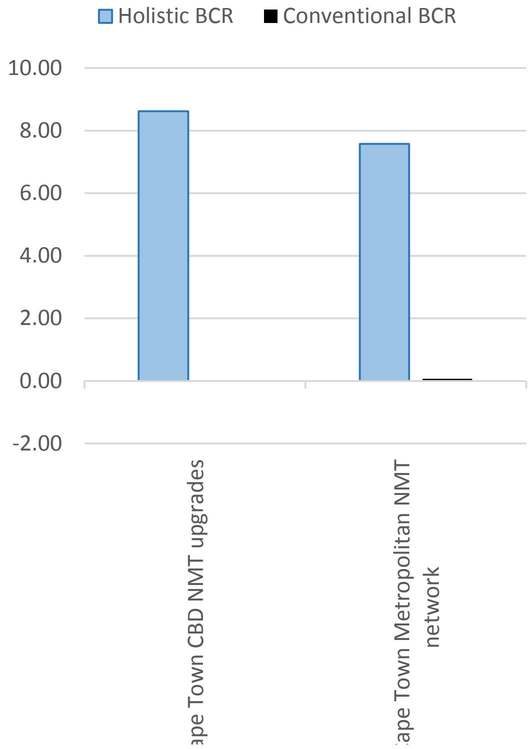


Figure 8: Comparison of Benefit-Cost Ratios (BCR)

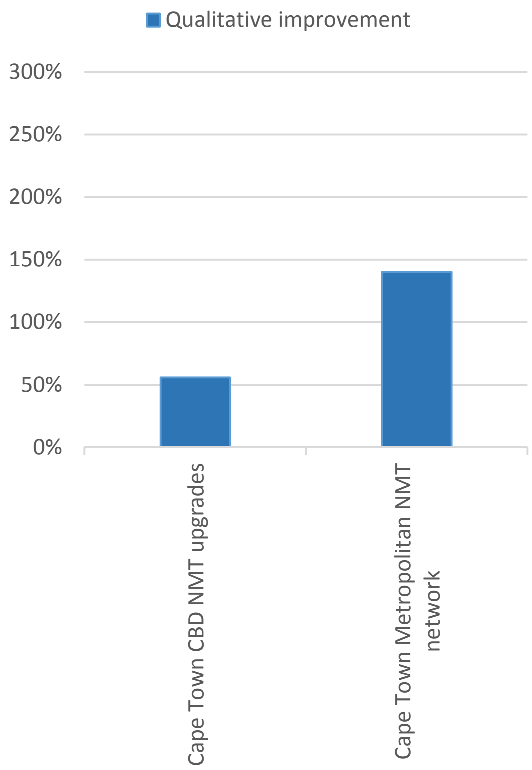


Figure 9: Comparison of potential qualitative improvement due to the projects

# 8 CONCLUSION

The aim of this project is the advancement of the Mon-Motorised Transport Project Appraisal Tool (NMT-PAT) through added functionality and the testing of its applicability in the context of a South African city. Two case study scenarios were chosen within the city of Cape Town, South Africa and tested to determine the potential magnitude of their associated benefits.

Cape Town has an increasing population and very limited NMT infrastructure. Car ownership is rising steadily, eroding its share of NMT users and contributing to its status as the most congested city in South Africa. Cape Town 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 Cape Town, 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 both of the 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 Cape Town and meaningful insight into the viability of both of the projects can be derived from the results and analyses. It is believed that NMT-PAT has great potential to accurately and equitably appraise NMT investments in the urban African context.

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# 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.

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

**Equation 2: 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 3: 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 $CO_2$ emissions per day in Equation 4a.

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

**Equation 4: Average amount of $CO_2$ produced per day per mode**

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

**Equation 5: 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 ($\varepsilon$) 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 6: Average amount of energy used per day per mode**

The level of *Noise pollution* is determined by measuring the average level 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 knowledge. The 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 7: 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 8: 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 9: 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 10: 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 11: 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 12: 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 the amount of fuel saved ($\Delta F$) that was calculated earlier, to determine the loss of fuel tax revenue ($\Delta R_{fuel}$) to the city or national government.

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

**Equation 13: Average monetary value of fuel tax revenue lost through fuel savings per year**

The increase in VAT revenue ($\Delta R_{VAT}$) 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 14: 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.