FINANCIAL VIABILITY OF SUSTAINABLE INFRASTRUCTURAL DEVELOPMENT AT THE NELSON MANDELA METROPOLITAN UNIVERSITY

Gregory Justin Ducie

Student Number 212444697

Submitted in fulfilment of the requirements for the degree of Masters in Commerce in
Business Management
of the Faculty of Business and Economic Sciences

AT

The Nelson Mandela Metropolitan University
Port Elizabeth

SUPERVISOR: Prof Miemie Struwig

October 2013

DECLARATION
MCOM CANDIDATE

I, Gregory Justin Ducie, student number 212444697 hereby declare that the dissertation, *Financial viability of sustainable infrastructural development at the NMMU,* for the *Master of Commerce,* is my own work and that it is has not previously been submitted for assessment or completion of any postgraduate qualification to another university or for another qualification.

Gregory Justin Ducie
PORT ELIZABETH
JUNE 2013

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to the following people and institutions for their contributions to making this study possible:

- My supervisor, Professor Miemie Struwig, for her encouragement and support prior to and during the course of the study. Her expertise and guidance added value to the learning experience which stretched beyond the scope of the thesis. Her commitment towards her students, enthusiasm towards the topic and passion for research made it a privilege to have her as a supervisor.
- The Nelson Mandela Metropolitan University (NMMU) for the financial support that has made this study possible.
- All the participants in this study for their valuable contributions and time sacrificed.
- Dr Marcelle Harran for language editing of the dissertation and her thorough attention to detail and assistance with editorial aspects.
- Mrs Chantell Vogts for the assistance with the final formatting of the dissertation.
- Last, but not least, my wife Yvonne for her moral support and sacrifices during the period of my study.

TABLE OF CONTENTS

CHAPTER TWO
RESEARCH DESIGN AND METHODOLOGY

CHAPTER THREE
CONVENTIONAL AND ALTERNATIVE INFRASTRUCTURAL INTERVENTIONS

CHAPTER FOUR
RELATIONAL COST FACTORS AND RELATIONAL SUSTAINABILITY INDICATORS

CHAPTER FIVE
A FINANCIAL VIABILITY FRAMEWORK OF SUSTAINABLE INFRASTRUCTURE AT A UNIVERSITY

CHAPTER SIX
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Sustainable environmental practices need to be integrated into a university's infrastructural operations. Universities are entities that function within financial constraints with varying priorities across both administrative and educational functions. Unfortunately, these financial constraints often imply that a university's potential leadership role can only be realised should the viability (business case) of a proposed intervention be determined. This study focuses on the determination of a relational sustainable indicator and a relational cost factor. A relational sustainable indicator demonstrates how a university can collectively determine the contribution made to sustainability by various sectors of infrastructure. This is developed by means of a secondary study. Two components are important for calculating the relational sustainability indicator, namely, green infrastructure attributes and the basic elements of sustainability systems, namely, the environmental, economic and social dimensions of sustainability.

The determination of a relational cost factor involves the quantification of the costs associated with alternative infrastructure provision. In particular, attention is paid to demand-side management costs, rationalising spatial growth costs, green building development costs, operation and maintenance of existing buildings costs, wastewater infrastructure costs, water infrastructure costs, energy infrastructure costs and transport infrastructure costs. Once the actual costs of each intervention category are determined, a relational sustainable cost factor can be calculated. Utilising the costs in the eight categories identified, a relational sustainable cost factor is determined. A resultant relational cost benefit as per the eight defined categories of sustainable infrastructure provision is derived from the relevant costs of sustainable infrastructure provision, the resultant relational cost factors and, finally, the relational sustainability indicators.

It is proposed that that the determination of a budget split between the various interventions based on the resultant relational cost factor occur as follows:

- Demand side management interventions: 15.97%
- Rationalising spatial growth: 6.72%
- Construction of green buildings: 24.37%

- Operations and maintenance: 21.85%
- Wastewater: 7.56%
- Water: 1.68%
- Energy: 12.61%
- Transport: 9.24%

This study provides a platform to guide how and where to invest in sustainable infrastructure and provide direction in determining a budget split between various categories of sustainable infrastructure development.

CHAPTER 1

INTRODUCTION TO THE STUDY

1.1 INTRODUCTION

The leadership role that South African universities possess within society dictates that sustainable environmental practices and interventions need to be integrated into a university's operations thereby allowing universities to become learning institutions rather than just teaching institutions. Universities are, however, entities that function within financial constraints with varying priorities across both administrative and educational functions. Unfortunately, these financial constraints often imply that a university's potential leadership role can only be truly realised should the financial viability of a proposed intervention or programme be proven. In the case of innovation / sustainability in construction, the client or the university, can, in fact, act as a champion of innovation by taking the leadership role in construction innovation (Kulatunga, Amaratunga & Haigh, 2011).

Owing to the complex structure of universities, broad institutional goals and objectives are often diluted through the establishment of varying institutional committees tasked with driving the identified goals and objectives. This is particularly true within the context of environmental sustainability. It has been further suggested that there are a number of universities worldwide that use initiatives such as recycling, energy efficient lighting, water conserving fittings, composting toilets, passive solar design, green building design, car-pooling programmes, public transportation initiatives and environmental procurement programmes. Very few universities have, however, managed to institutionalise a systematic commitment to environmental sustainability (Sharp, 2002).

This study seeks to quantify the financial implication of sustainable infrastructural interventions in relation to one another and in turn provide a basis for the determination of budget split between the various interventions.

The background and importance of the study is first provided, followed by a literature review. Thereafter, the study's research design and methodology are outlined and the main results discussed.

1.2 BACKGROUND TO THE STUDY

The importance of undertaking a study of this nature is primarily based on the following factors:

- Strengthening the resolve of tertiary institutions to commit financially to environmental imperatives
- Assisting in quantifying and promoting various sustainability initiatives
- Demonstrating how the cost benefits of localised sustainability interventions can be financially beneficial to local governmental structures

Environmental sustainability as portrayed in financial terms may strengthen the resolve of a tertiary institution to more appropriately commit to the environmental imperatives that exist.

In addition to strengthening the resolve of a tertiary institution to commit to existing environmental imperatives, the financial argument may further support and authenticate sustainability initiatives. For example, the Association for the Advancement of Sustainability in Higher Education (AASHE) (2006), which was established in the United States in January 2006, seeks to promote sustainable campus communities for higher education by means of a Sustainability Tracking, Assessment and Rating System™ (STARS). STARS seeks to measure university progress towards sustainability in all sectors of higher education from education and research through to operations and administration (Association for the Advancement of Sustainability in Higher Education, 2012). Progress towards sustainability is enhanced if it can demonstrate the financial benefits of doing so particularly with regards to a university's non-core or support activities. Walton and Galea (2005), in applying business sustainability practices to university campus environments, state that universities would do well to emulate sustainability practices as practiced by business as business views support services such as facilities management as inefficient expenditure. Inefficient expenditure is thus curtailed should support activities such as energy, water and facilities management be as waste-free as possible.

In addition, universities contribute to their host communities and cities by means of creating economic clusters that generate employment. The development of the university campus is, however, changing with respect to planning processes and campus management. Heijer (2008), in reviewing the management of university campuses, states that campus management has changed from monitoring the technical condition of campus buildings to adding value to university goals. In the case of Nelson Mandela Metropolitan University, the university's values include Respect for the Environment and Ubuntu (Nelson Mandela Metropolitan University, 2010). As such, any sustainable infrastructural intervention undertaken on a university campus has a direct relation to how Nelson Mandela Metropolitan University can practice its values through the development and management of its infrastructure. Furthermore, the nature of sustainable infrastructure provision has direct benefit flows to that of the surrounding community along with the respective local government structure. As a result, the university becomes more than an economic cluster within the city but a significant contributor to city-wide sustainability.

Given these benefits/factors, the informants to sustainable infrastructural provision on a university campus relate to defining:

- a university campus
- sustainable urban planning
- sustainable infrastructure development
- financial viability
- operational management

1.2.1 Definition of a university campus

Universities may be viewed as economic engines in which the university, as a business, produces a service, employs employees that are highly-educated and is respectful of the environment and supportive of green initiatives (Scott, 2010).

For the purposes of this study, a university campus is defined as a community reminiscent of a small town with the requisite population that require appropriate infrastructural services, social facilities and where the activity generated within contributes to the broader economy within the region. The planning, delivery and inter-relatedness of the various sectors of infrastructure is thus critical to the overall governance of the university. Price, Matzdorf, Smith and Agahi (2003) suggest that the impact of university facilities and infrastructure is critical to the business of the university and is dependent on the positioning and strategic goals of the institution.

1.2.2 Definition of sustainable planning

Agudelo-Vera, Mels, Keesman and Rijnaarts (2011) define urban planning as a process which seeks to manage spatial development whilst considering sociological, economic, political, technological and environmental factors. This implies that the provision of any form of infrastructure cannot be deemed sustainable should appropriate prior urban planning not lay the foundation for, and ultimately compliment, the provision of infrastructure.

Roosa (2004) suggests that sustainable development is in effect the overarching guide for sustainable planning. By implication, this would suggest that the urban planning process needs to facilitate the eventual implementation of infrastructural provision that is deemed to be more sustainable.

Nelson Mandela Metropolitan University's Urban Design Framework (2011), the spatial management tool of the university, seeks to facilitate the eventual implementation of infrastructural provision that is deemed to be more sustainable through the identification of key desired performance qualities. The desired performance qualities relevant to infrastructure provision include:

- Equity of access
- Sustainability
- Integration
- Intensification

- Efficiency

The relationship between the implementation of sustainable infrastructure provision and the desired performance qualities are detailed as follows.

Equity of access implies that the entire university population has access to the opportunities and facilities of the university. As such, the focus should be on pedestrian and non-motorised transport along with public transport on major movement corridors. Furthermore, aggregate amounts of movement should be reduced by consolidating university activities which has a direct impact on the provision of infrastructure.

Sustainability within the context of Nelson Mandela Metropolitan University's Urban Design Framework (2011) implies that there are continuities of green spaces on the university campus that practice local water capture and apply the use of renewable energy sources as well as green building principles so that the university maximises the efficiencies of resource allocation.

The principle of integration entails integrating with broader urban systems within the Metropolitan in which the university is located along with the broader community.

Intensification relates to the more efficient and concentrated usage of land which has a direct impact on the provision of relevant infrastructure.

Efficiency refers to the optimisation of available resources in terms of land and service costs, energy, water, operational and maintenance costs.

Given the sustainable infrastructure provision and desired performance qualities relationships, for the purposes of this study, sustainable planning is defined as rationalising spatial linkages and associations while being economically, socially and ecologically aware so as to achieve the cumulative benefits of spatial logic along with the associated infrastructural provision thereof.

1.2.3 Definition of sustainable infrastructure

In quantifying the financial implication of sustainable infrastructural interventions, a clear definition must be provided as to what sustainable infrastructure provision means. Numerous definitions and interpretations exist, for example:

- The North West Green Infrastructure Think Tank, a group in the United Kingdom established as a partnership between Community Forests Northwest and Natural England defines green infrastructure as "*a collection of natural assets which provide multiple functions and services to people, the economy and the environment*" (Green Infrastructure Northwest, 2011).
- The Civil Engineering Department of the University of Toronto defines sustainable infrastructure engineering as "*the design of new infrastructure and the re-design, rehabilitation, re-use or optimisation of existing infrastructure, which is consistent with the principles of urban sustainability and global sustainable development*" (Sustainable Infrastructure, 2001).
- The Norwegian University of Science and Technology defines sustainable infrastructure as "*ensuring the smallest possible strain on resources and the environment which contributes to a sustainable society as a whole*" (Norwegian University of Science and Technology, 2012).
- The City of Seattle (2009) defines sustainable infrastructure as "*a decision-making framework for capital spending that links asset management to an interest in green outcomes and an understanding of the most effective capital investments may require us to explore some non-traditional alternatives and integrate efforts across department silos and lines of business*".

For the purposes of this study, the various sustainable infrastructure provision definitions need to be considered within the context of a university campus. These include the following:

- Demand side management with respect to end-user utilisation of infrastructure
- Rationalising university growth as per an approved university growth plans

- Construction of new Green Star rated buildings as per the Green Building Council of South Africa's (GBCSA) rating tool for public and educational buildings
- Operation and maintenance of existing buildings as per the United States Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system. Currently, no such rating system exists within South Africa hence the use of the United States Green Building Council’s operation and maintenance of existing buildings rating tool
- Application of green technologies in the treatment of sewerage
- Application of green technologies in the conservation of water
- Application of green technologies in the provision of energy
- Provision and utilisation of public transport facilities

Collectively, these sustainability practices broadly define the overall sustainability of a university campus.

1.2.4 Definition of financial viability

In defining financial viability, a distinction needs to be made between the financial viability of the institution itself, namely Nelson Mandela Metropolitan University, and the financial viability of interventions that contribute to the bottom line of the institution. For the purposes of this study, it is assumed that Nelson Mandela Metropolitan University is financially viable. Therefore, it provides the opportunity for the institution to expand its development path should that particular development path deemed to be viable.

As such, the financial viability of cumulative alternative infrastructure provision, namely, Nelson Mandela Metropolitan University’s identified development path for the purposes of this study, should result in the university being able to continue to achieve its infrastructural operating objectives thereby contributing to the fulfilment of its mission over the long term.

1.2.5 Definition of university operations

Operations management, as defined by Randor and Barnes (2007), involves the management of organisational activities which deliver services as required by its customers. Randor and Barnes (2007) further distinguish the broad approach to operations management as relevant to three distinctive time periods, namely:

- Early twentieth century where the foundations of operations management were developed based on scientific management, namely, to produce / service as efficiently as possible
- Second World War years to the mid-1980s where operations management encompassed aspects such quality, flexibility and timeliness along with cost and efficiency
- Mid-1980s to date where operations management encompass the measurement of the effectiveness of the delivery of the services

The delivery of infrastructure is a direct component of operations management within the university. Although operations management within the context of university operations may still focus on the effectiveness of the delivery of services, the key operational management element for the purposes of this study is achieving service delivery effectiveness and efficiency through the alternative means of infrastructure provision.

1.3 PROBLEM DEFINITION

The topic of sustainability often conjures conceptual interventions in the form of stated objectives and goals. These objectives and goals often lack the necessary detail to determine whether or not the interventions undertaken by a community or institutions truly move towards a more sustainable method of operation and / or existence.

Conversely, specific sustainability interventions such as that of the development of Green Buildings as per the Green Building Council (GBCSA) rating tools, do not relate to the broader environment in which they are located but rather focus on specific entity intervention. For example, the GBCSA defines a green building as "*a building which is energy efficient, resource efficient and environmentally* *responsible*" (Green Building Council South Africa, 2011). This results in an institutional and / or community sustainability void when viewed from a cumulative operational perspective.

Given the above, the problem of this study is how to collectively determine the financial benefits of sustainability interventions in a manner that will provide a more holistic yet detailed perspective on sustainability.

1.4 A PROPOSED FRAMEWORK FOR THE STUDY

To address the problem of the study, a sustainability indicator per intervention area along with a relational cost factor needs to be specifically determined. This process will form the basis of a proposed framework for the study.

This process requires a calculation to determine the contribution made to sustainability by each intervention area considering the green attributes of infrastructure along with the three pillars of sustainability, namely, the social, economic and environmental pillars (World Summit, 2005). Each pillar relates specifically to the following:

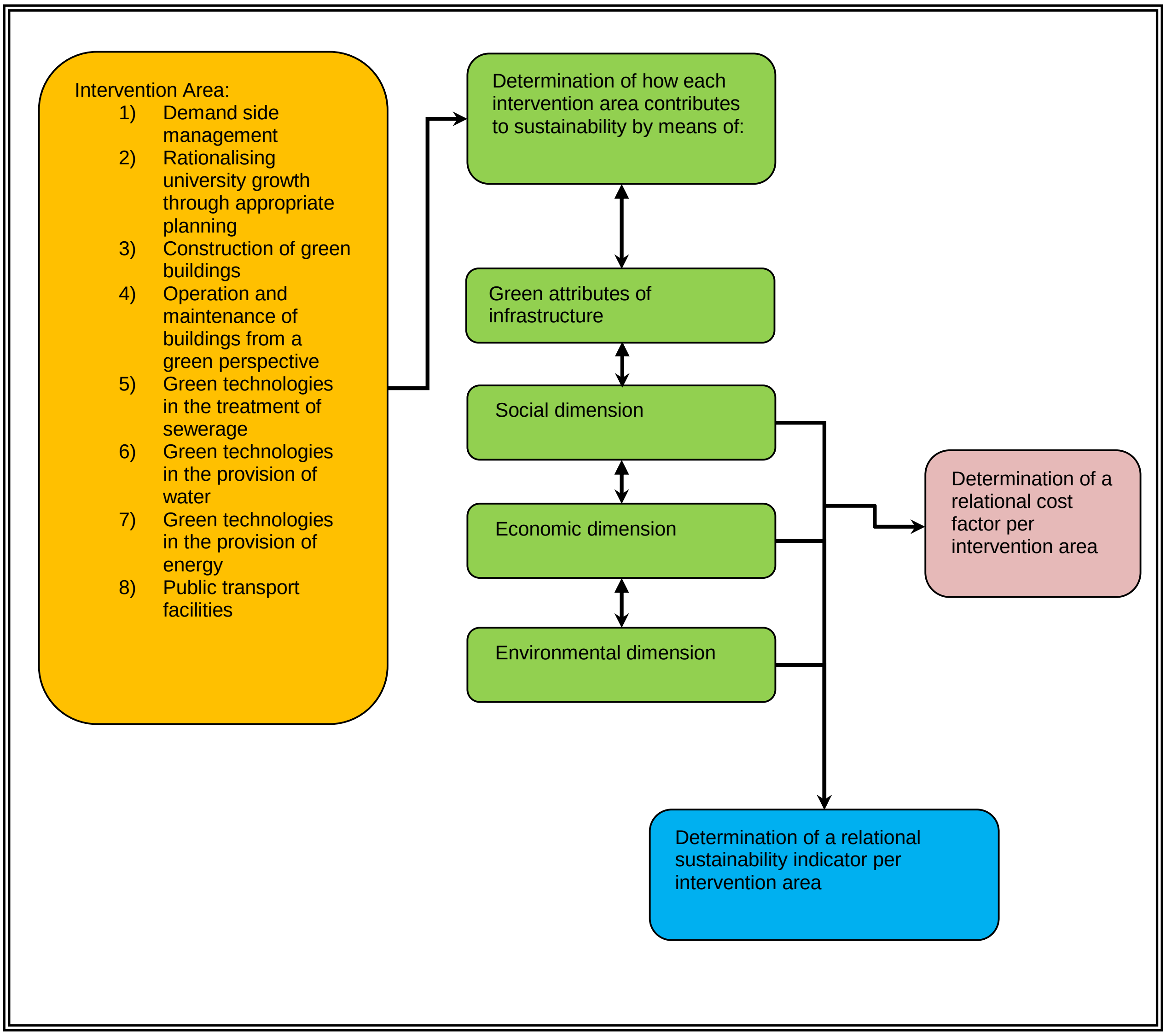
- Social pillar: Socially desirable, culturally acceptable, psychologically nurturing
- Financial pillar: Economically sustainable, technologically feasible, operationally viable
- Environmental pillar: Environmentally robust, generationally sensitive, capable of continuous learning

Once the contribution made to the sustainability on each intervention area is determined, a relational sustainability indicator can be calculated by means of an index. This relational sustainability indicator will be derived from each intervention area's contribution to the components of the green attributes of infrastructure along with the identified social, financial and environmental pillars.

It is important to note that the sustainability indicator per intervention area will be a relational indicator, as this study examines the benefits of intervention areas in relation to one another within an isolated system, namely, a university campus.

The same process needs to be followed to determine a relational cost factor per intervention area. This process of determining the relational sustainability factor and relational cost factor is portrayed diagrammatically in Figure 1.1.

Figure 1.1: A proposed framework for the study



Source: Author's own compilation

Figure 1.1 demonstrates that a sustainability indicator may be derived from the proposed intervention areas.

Once a relational cost factor per intervention area has been calculated, a determination is made on the benefit of each intervention area by means of a relational cost benefit analysis. This would serve as the foundation from which to determine the extent of investment in each intervention area along with the financial relation between each intervention area.

In order to populate the research, information needed to be sourced from the university, local and international government as well as non-governmental institutions. The outcome would demonstrate the financial viability of a collective green campus approach to development.

1.5 RESEARCH OBJECTIVES

The primary and secondary objectives of the study are outlined as follows:

1.5.1 Primary research objective

The primary research objective of this study is to develop a framework that demonstrates the financial viability of pursuing collective sustainable infrastructural development across a university campus.

1.5.2 Secondary research objectives

To give effect to the primary objective of this study, the following secondary research objectives have been formulated:

- To devise a comparison between current conventional and alternative infrastructural interventions by means of:
  - Determining the relationship between sustainable planning, infrastructural development and an enhanced working environment
  - Providing an overview of conventional and alternative infrastructural interventions
  - Developing relational sustainability indicators for alternative infrastructural interventions
  - Developing relational cost factors for alternative infrastructural interventions
- To define financial viability within the context of integrated alternative infrastructural provision within a closed entity such as Nelson Mandela Metropolitan University
- To select an appropriate research methodology and research methods for the study

- To develop a framework for Nelson Mandela Metropolitan University where:
  - Possible infrastructural interventions can be measured against one another in the form of a sustainability indicator
  - Appropriate weightings per infrastructural intervention area can be devised based on the outcomes of the sustainability indicator process
  - A relational cost benefit framework can serve as the basis for determining the financial viability of specific infrastructural intervention areas
- To provide pertinent conclusions and recommendations based on the findings

1.5.3 Research questions

This study intends to provide answers to the following research questions:

- How does cumulative cross-sectoral alternative infrastructural provision within a closed system such as a university campus contribute to the sustainability of the campus?
- Can a viable sustainability indicator per infrastructural intervention area be derived in relation to another that would serve as the basis for determining infrastructural development focus?
- Is it practical to determine the financial viability of cumulative infrastructural provision on the basis of individual sectoral sustainability ratings?
- Can a framework be developed that attempts to guide capital investment with respect to alternative infrastructure provision based on relational sustainability criteria along with relational cost factors?

The relation of the research objectives to the research questions is illustrated in Table 1.1.

Table 1.1: Relationship of study's research questions to research objectives

RESEARCH QUESTIONS	RESEARCH OBJECTIVES
• How does cumulative cross-sectoral alternative infrastructural provision within a closed system such as a university campus contribute to sustainability of the campus?	• To devise a comparison between current conventional and alternative infrastructural interventions by means of: ○ Determining the relationship between sustainable planning, infrastructural development and an enhanced working environment ○ Providing an overview of conventional and alternative infrastructural interventions ○ Developing relational sustainability indicators for alternative infrastructural interventions ○ Developing relational cost factors for alternative infrastructural interventions
• Can a viable sustainability indicator per infrastructural intervention area be derived in relation to another that would serve as the basis for determining infrastructural development focus?	• To select an appropriate research methodology and research methods for the study.
• Is it practical to determine the financial viability of cumulative infrastructural provision on the basis of individual sectoral sustainability ratings?	• To define financial viability within the context of integrated alternative infrastructural provision within a closed entity such as that of Nelson Mandela Metropolitan University.
• Can a framework be developed that attempts to guide capital investment with respect to alternative infrastructure provision based on relational sustainability criteria along with relational cost factors?	• To develop a framework for Nelson Mandela Metropolitan University where: ○ Possible infrastructural interventions can be measured against one another in the form of a sustainability indicator ○ Appropriate weightings per infrastructural intervention area can be devised based on the outcomes of the sustainability indicator process ○ A relational cost benefit framework can serve as the basis of determining the financial viability of specific infrastructural intervention areas • To provide pertinent conclusions and recommendations based on the findings

Source: Author's own compilation

1.6 RESEARCH PROCESS

The research process followed entails both secondary and primary research.

1.6.1 Secondary research

A comprehensive literature search will be conducted to identify as many factors as possible that could influence the outcome of the study. International and national data searches will be done through the Library of Nelson Mandela Metropolitan

University which include: Sabinet databases, ISAP (National library of South Africa), SAe Publications, EBSCO (MasterFile premier, Business Source premier, Academic Source premier), FS Articles First, Kovsidex, SA Cat and FS Worldcat, ScienceDirect, UPECAT, Google searches, Dialog and Dissertation Abstracts database.

Data will also be accessed from other international and national libraries by means of the inter-library loan facilities at Nelson Mandela Metropolitan University. As far as can be ascertained, no similar research study has been previously undertaken in South Africa.

1.6.2 Primary research

A qualitative research paradigm will be adopted in this study.

1.6.3 Study research design

The research process to be undertaken in this study includes five steps, namely:

a) Step 1: Review the delivery mechanisms and associated costs of conventional and alternative infrastructure provision.
b) Step 2: Develop a sustainability indicator per infrastructure sector for alternative infrastructure provision. The sustainability indicator is to be a relational indicator per infrastructural sector within a closed system, namely, a university campus.
c) Step 3: Determine a relational cost factor by means of a calculation, namely, a weighted cost, per alternative infrastructure category.
d) Step 4: Present the results of the calculation as a framework to determine the relational cost–benefits of cumulative alternative infrastructure provisions on a university campus.
e) Step 5: Present the framework to independent observers who acted as independent raters to evaluate and comment on the proposed framework.

1.7 SCOPE OF THE STUDY

This study applies to Nelson Mandela Metropolitan University in Port Elizabeth, South Africa as information pertaining to the university is readily accessible to the author, inexpensive and not overly time-consuming.

1.8 STRUCTURE OF THE RESEARCH

The structure of the research is as follows:

Chapter 1: Introduction to the study
Chapter 2: Research design and methodology
Chapter 3: Conventional and alternative infrastructural interventions
Chapter 4: Relational sustainability indicators and relational cost factors
Chapter 5: Sustainable infrastructure provision financial framework
Chapter 6: Conclusions and recommendations

1.9 SUMMARY

This chapter introduces the research problem, proposes how the research problem as well as the research questions are to be analysed. Then the study is justified, and definitions of key terms as well as concepts are presented. The methodology is briefly described and justified, the study report outlined, and the key terminology defined. Chapter Two presents the study's research methodology.

CHAPTER 2

RESEARCH DESIGN AND METHODOLOGY

2.1 INTRODUCTION

The primary objective of this study was to develop a framework that demonstrated the financial viability of pursuing collective sustainable infrastructural development across a university campus.

To develop such a framework, a holistic perspective on infrastructural-related sustainability across a university campus was needed to assess comparative costs along with an associated factor that could potentially guide the level of subsequent investment within the various infrastructural sectors. To give effect to the primary purpose of the study, it was important to identify the components that constituted the framework. These components included identifying what constituted sustainable infrastructure on a university campus, costing the various components of sustainable infrastructure provision on a university campus, determining a sustainability indicator per component of sustainable infrastructure provision and, finally, populating the framework to demonstrate the relational cost factor per component.

This chapter identifies and describes in detail the processes followed during the research process. The nature of research and the various research classifications are first described. The different research paradigms are then discussed, and the specific paradigm chosen is motivated. The data collection and subsequent analysis is finally addressed.

2.2 NATURE OF RESEARCH

Research is the implementation of appropriate steps to produce original knowledge that will satisfy the users of the research. The implementation of the research steps needs to be performed rigorously, implying that it should be done in a systematic manner and that the results of the research answer the research questions (Oates, 2006). Collis and Hussey (2003) summarise research as a process that enquires and investigates in a systematic and methodical manner with the ultimate aim to increase knowledge.

Research design is a step-by-step master plan detailing the methods and procedures to be followed when collecting and analysing data to ensure that the primary objective is attained (Zikmund, W.G., Babin, B.J., Carr, J.C. & Griffen, M. 2010).

2.3 RESEARCH PARADIGMS

There are two research paradigms that can be adopted in research, namely, the positivistic and the phenomenological research paradigms. The positivistic paradigm refers to quantitative, objectivist, scientific, experimentalist or traditional research. The phenomenological paradigm refers to qualitative, subjectivist, humanistic or interpretive research (Cooper & Schindler, 2008). For Collis and Hussey (2003), the data produced by a positivistic paradigm can be qualitative, and the data produced by the phenomenological paradigm can be quantitative.

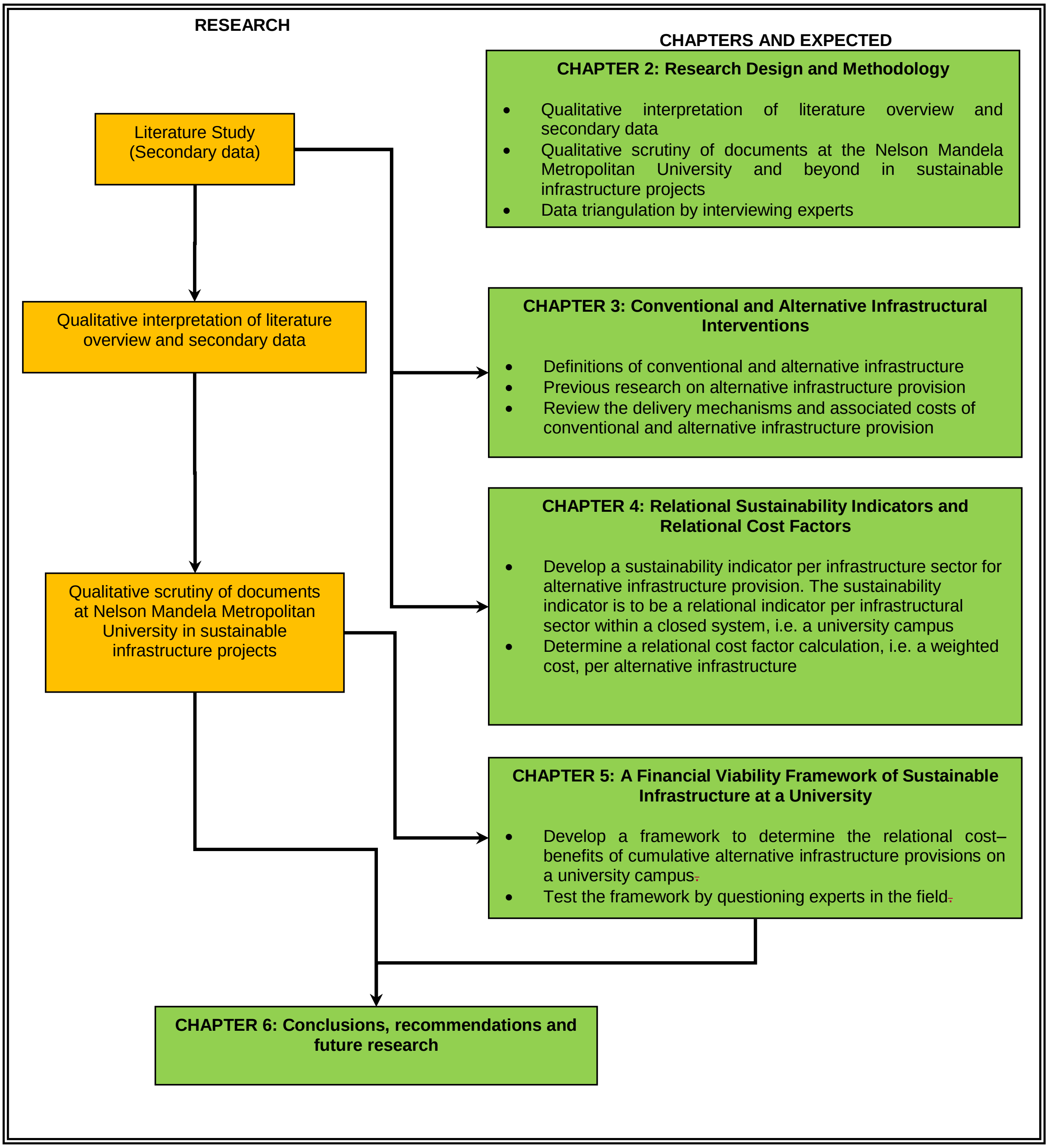
For the purpose of this study, the phenomenological paradigm (qualitative research) was adopted as secondary data was used to populate a framework where:

- Possible infrastructural interventions could be measured against one another in the form of a sustainability indicator
- Appropriate weightings per infrastructural intervention area could be devised based on the outcomes of the sustainability indicator process
- A relational cost benefit framework could serve as the basis of determining the financial viability of specific infrastructural intervention areas

2.4 CONCEPTUAL OUTLINE OF THE STUDY

The conceptual outline of this study is reflected in Figure 2.1.

Figure 2.1: Study's conceptual outline



As depicted in Figure 2.1, the study comprised of four predominant chapters, namely, Research Design and Methodology, Conventional and Alternative Infrastructural Interventions, Relational Sustainability Indicators and Relational Cost Factors and, finally, A Financial Viability Framework of Sustainable Infrastructure at a University.

2.5 SECONDARY AND PRIMARY RESEARCH

Secondary research was undertaken by means of literature review whereas primary research followed a qualitative approach (see Sections 2.5.1 and 2.5.2).

2.5.1 Secondary research

A comprehensive literature search was conducted to identify as many factors as possible that could influence the outcome of the study. International and national data searches were done by Nelson Mandela Metropolitan University library and these included: Sabinet databases, ISAP (National library of South Africa), and SAe Publications; EBSCO (MasterFile premier, Business Source premier, Academic Source premier), FS Articles First, Kovsidex, SA Cat and FS Worldcat, ScienceDirect, UPECAT, Google searches, Dialog and Dissertation Abstracts database.

Data was also accessed from other international and national libraries by means of the inter-library loan facilities at Nelson Mandela Metropolitan University. As far as could be ascertained, no similar research study had been previously undertaken in South Africa.

2.5.2 Primary research

There are two types of research that are classified according to the processes that are followed during the research, namely, quantitative and qualitative research. As a qualitative approach had been selected for this study, qualitative research was the focus.

Qualitative research is an anti-positivist approach, where the research object, the human experience, cannot be separated from the individual who is experiencing the phenomenon. Therefore, for qualitative research studies, human behavioural experience and not the behaviour of the individual is the focus (Welman, C., Kruger, F. & Mitchell, B. 2010). Zikmund *et al.* (2010) describe qualitative research as research that focuses on discovering meanings and new insights into phenomena without relying on numerical data. Qualitative research is also subjective in nature as it involves examining and reflecting views of humans in the understanding of the social and human activities investigated (Collis & Hussey, 2003).

2.6 THE RESEARCH DESIGN OF THE STUDY

The research process to be undertaken in this study included five steps.

2.6.1 Step 1: Review the delivery mechanisms and associated costs of alternative infrastructure provision

To execute this step, a literature review was undertaken. The literary review provided the distinction between conventional and alternative infrastructure provision along with the components of:

- Demand-side management
- Rationalising spatial growth
- Construction of green buildings
- Sustainable operation and maintenance of existing buildings
- Alternative wastewater treatment
- Alternative water provision
- Alternative energy provision
- Sustainable transportation

2.6.2 Step 2: Develop a sustainability indicator per infrastructure sector for alternative infrastructure provision

The sustainability indicator was to be a relational indicator per infrastructural sector within a closed system such as a university campus.

To execute this step, the following were undertaken:

- Literature review: A literary review was conducted on the attributes of sustainable infrastructure along with the components of corporate sustainability.
- Data collection: Documentation review occurred both externally and internally to Nelson Mandela Metropolitan University.
- Data analysis: The following themes were coded::
    - Basis of sustainable alternative infrastructure provision

- Weighting parameters amongst alternative infrastructure sectors within a closed system
- Parameters of infrastructural relational comparison

From this analysis, it was possible to determine a relational sustainable indicator.

2.6.3 Step 3: Determine a relational cost factor

The basis of cost determination for alternative infrastructure provision was done by analysing literature. It was envisaged that the literature overview resulted in the development of a framework that indicated the costs. Thereafter, the framework was populated with the actual costs. This enabled the calculation of a relational sustainable cost factor. To populate the framework, data needed to be collected. To collect data, a review of documentation from both external and internal parties to Nelson Mandela Metropolitan University was done. This included data specific to recent and current infrastructure development at Nelson Mandela Metropolitan University. Where data did not exist within Nelson Mandela Metropolitan University, infrastructural data was sourced from external parties from which comparisons relevant to the operations at Nelson Mandela Metropolitan University could be made. To analyse the data, coding as per the following themes were selected:

- Sectors of alternative infrastructure provision, such as water provision, energy provision, sewerage treatment and top structure provision
- Cost parameters of alternative infrastructure provision
- Operating costs of alternative infrastructure provision
- Sustainability parameters surrounding alternative infrastructure provision

2.6.4 Step 4: Determine the relational cost–benefits of cumulative alternative infrastructure provisions on a university campus

To determine the relational cost-benefit of alternative infrastructure provisions, the framework was populated with actual costs at Nelson Mandela Metropolitan University. Costs relating to the year 2011 were used as complete costs details for 2012 were not as yet available.

The relational cost factor of each of the components in the framework was assigned a relational sustainability indicator based on the attributes of green infrastructure along with the social, economic and environmental dimensions of sustainability. The application of the relational sustainable indicator was used with the relational cost factor per intervention area to calculate a relational cost benefit per intervention area ultimately.

2.6.5 Step 5: Present the framework to independent raters in the built environment to evaluate and comment on the proposed framework

Once the framework was populated, unstructured interviews were conducted with five experts in the fields of infrastructure planning and development, quantity surveying and executive management within a university to present the basis of the framework along with the outcomes thereof. Questions related to the appropriateness of the framework, cost relational factors, the rationale behind the relational sustainability indicators along with the relevance of the outcomes of the framework (see Appendix A for questionnaire structure).

In addition to these five steps, the following were also undertaken in support of the research process:

- Ensuring the trustworthiness of the research: An audit trail complemented the research process
- Ensuring the reliability of the research: A review of the method of coding and the subsequent analysis of the data was performed by an external party to verify the appropriateness of the classifications
- Ensuring the ethical practice of the research: Ethical considerations are also a great concern for all researchers. As all the data used was secondary in nature and most were freely available in the public domain, no ethical clearance needed to be obtained. In the case where Nelson Mandela Metropolitan University data was used, ethics clearance to use the data was obtained from management.

2.7 SUMMARY

In Chapter Two, the research process and methodology of the study was outlined. The conceptual outline of the study was presented along with the research design. In Chapter Three, a distinction is made between conventional infrastructure provision and that of alternative infrastructure provision. Thereafter, the components that make up alternative infrastructure provision are discussed.

CHAPTER 3

CONVENTIONAL AND ALTERNATIVE INFRASTRUCTURAL INTERVENTIONS

3.1 INTRODUCTION

In Chapter Two, the research methodology to be followed in this study was outlined. As the primary objective of this study was to develop a framework that demonstrated the financial viability of pursuing collective sustainable infrastructural development across a university campus, it was important to make a distinction between conventional and alternative infrastructural interventions. Thereafter, the nature of the costs related to alternative infrastructure provision could be determined. As such, this chapter is comprised of a distinction between conventional and alternative infrastructure and the type of costs associated with alternative infrastructure provision. First, a distinction between conventional infrastructure and alternative infrastructure is made based on specific characteristics and attributes. Thereafter, a framework for the assessment of sustainable infrastructure costs is presented inclusive of varying cost and sustainability components.

3.2 A DISTINCTION BETWEEN CONVENTIONAL AND ALTERNATIVE INFRASTRUCTURE

The Real Estate and Infrastructure Division of the Deutsche Bank (2007) define infrastructure as being comprised of various characteristics. For the sake of this study, these characteristics may be associated with that of conventional infrastructure.

The various sectors of infrastructure, for example, Roads, power generation and distribution and water utilities have no identical attributes. Each sector has its own distinct performance behaviour which is closely-linked to the lifecycle of that particular sector of infrastructure. Although there are no identical attributes within the various sectors of infrastructure, certain common traits do occur, namely:

- Infrastructure typically has high initial fixed costs

- Infrastructure provides benefits to society as a whole, namely, are non-excludable. For example, the use of infrastructure by one individual does not reduce the use of that infrastructure by others.
- Infrastructure assets are long lived often lasting over fifty years.
- As infrastructure assets are essentially monopolies in the provision of services, the demand for infrastructure services is relatively inelastic. As such infrastructure assets are relatively immune to business cycles, this ensures a stable cash return.

Alternative, or sustainable infrastructure, does not necessarily deviate from the characteristics identified but rather dictates further attributes that contribute to the concept of sustainability.

The Federation of Canadian Municipalities (2004) defines integrated and green infrastructure as consisting of the following attributes:

- A focus on end-use where demand side management and efficiency measures effect savings in source supply and service capacity.

  Demand side management refers to interventions that reduce the demand on existing resources. The use of various improved technologies along with the method of operation and maintenance relevant to a particular sector of infrastructure can result in greater efficiencies along with cost reductions.

- Multiple functions served by common devices
  This refers to instances in which infrastructure can serve multiple functions within existing capacities so as to avoid the development of new infrastructure, for example, the concentration of various infrastructure components. A typical example is that of buried infrastructure, for example, water, electricity and sewerage being concentrated into road design.

- Secondary resource value available in a service
  Useful bi-products or secondary resources can result from the application of certain infrastructure technologies. For example, wastewater and organic waste

can act as resources which can be processed into nutrients for horticultural uses.

- Compatibility of siting and placement
  By pursuing the co-location of compatible infrastructure facilities, efficiencies of land use and synergies between functions can be achieved.

- Creation of social amenities as intrinsic attributes
  Alternative means of infrastructure provision may add value to communities in form of their social contribution. For example, non-structural stormwater management retention ponds can enhance a biologically diverse landscape and serve as a passive recreation area.

- Matching resources to end user requirements
  Infrastructure provision may be enhanced so that resources are more efficiently processed, treated and utilised so as to make the most out of the supply stream and reduce waste. The current norm in infrastructure provision is to provide water and energy from source to sink without considering greater efficiencies and needs.

- Engaging natural functioning in service provision
  Increasing passive functioning in service provisioning such as gravity, geothermal energy, sunlight and wind makes use of free services without exploiting non-renewable systems.

- Strengthening local resilience to external and internal disruptions
  The provision of infrastructure in terms of multiple sourcing, closed-loop systems and on-site harvesting, for example, can add resilience to local areas where imported resources are affected and limited by external factors.

For the purposes of this study, alternative infrastructure should seek to satisfy one or more of the attributes identified. Table 3.1 illustrates how this study’s defined components of sustainable infrastructure provision seek to satisfy the attributes of green infrastructure.

Table 3.1: Relation of study's components of sustainable infrastructure to the attributes of green infrastructure

	GREEN INFRASTRUCTURE ATTRIBUTES							
COMPONENTS OF SUSTAINABLE GREEN INFRASTRUCTURE	**Focuses on end use where demand side management and efficiency measures effect savings in source supply and service capacity**	**Multiple functions served by common devices**	**Secondary resource value available in a service**	**Compatib ility of siting and placemen t**	**Creation of social amenities as intrinsic attributes**	**Matching resources to end user requirements**	**Engaging natural functioning in service provision**	**Strengthening local resilience to external and internal disruptions**
Demand side management	X					X		X
Rationalising university growth through appropriate planning				X	X	X		X
Construction of green buildings		X				X		X
Operation and maintenance of buildings from a green perspective		X				X		X
Green technologies in the treatment of sewerage		X	X			X	X	X
Green technologies in the provision of water		X	X			X	X	X
Green technologies in the provision of energy		X				X	X	X
Public transportation facilities				X		X		

Source: Author's own compilation

As illustrated in Table 3.1, sustainable infrastructure provision cannot be categorised into an individual sector nor defined as consisting of a singular attribute, hence the premise behind this study, namely, viewing sustainable infrastructure provision from a holistic viewpoint consisting of a number of attributes. Green infrastructure attributes are not always applicable to this study's components of sustainable infrastructure provision. However, when the components of sustainable infrastructure provision are viewed holistically, all the attributes of green infrastructure attributes may be achieved.

3.3 THE BASIS OF COST DETERMINATION FOR ALTERNATIVE INFRASTRUCTURE PROVISION

The sections that follow illustrate the basis of cost determination for alternative infrastructure provision. The quantification of costs of defined alternative infrastructure provision is discussed further in Chapter Four.

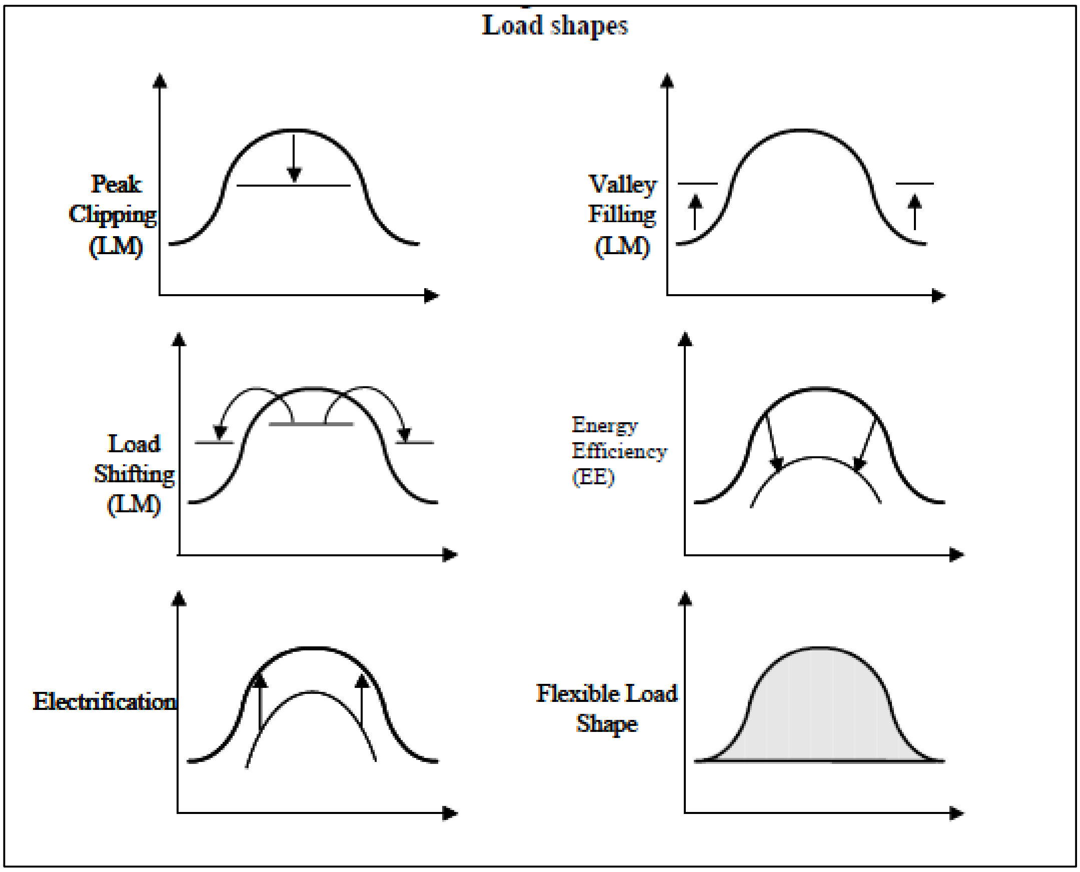
3.3.1 Demand side management

River and Associates (2005), in a publication prepared for the World Bank, define demand-side management as activities designed to alter the amount and / or timing of the use of energy for the collective benefit of society, the utility responsible for providing the energy and its customers. Components traditionally incorporated within demand side management include:

- Load management where peak clipping, valley filling and load shifting are pursued
- Energy efficiency where a reduction in overall energy use is pursued
- Electrification which involves load building

The demand side components are further illustrated in Figure 3.1.

Figure 3.1: DSM load shapes



Source: River and Associates (2005)

For River and Associates (2005), in addition to the traditional components of demand side management as illustrated in Figure 3.1, additional demand side management programmes have recently been developed that are targeted towards price responsiveness. These include load curtailment programmes that "*pay a customer for reducing peak load during critical times"* and dynamic pricing programmes that "*give customers an incentive to lower peak loads in order to reduce electricity bills*." River and Associates (2005).

In the context of Nelson Mandela Metropolitan University's operations, the components of load management, energy efficiency and load curtailment may be possible to implement. As such, the cost effectiveness of these components needed to be determined. The primary test to ascertain this cost effectiveness is the Total Resource Cost Test (River & Associates, 2005) which assesses whether or not a particular demand side management programme improves economic efficiency. The benefits include the avoided costs of energy and capacity while the costs include the equipment and administrative costs involved in undertaking the various components.

In addition to the Total Resource Cost Test, additional tests such as the Utility Cost Test and the Participant Test were utilised to determine a cumulative cost of demand side management interventions. As Utility Cost refers to utility, for Nelson Mandela Metropolitan University the running of a demand side management programme includes marketing expenses and incentive payments. The Participant Test measures the impact of demand-side management programmes on participating customers by measuring the change in their monthly electric bills and by subtracting participation fees and equipment costs incurred by customers.

Thus, in this study, demand side management was quantified as per the categories of load management, energy efficiency and load curtailment.

The components of demand side management along with the associated costs as determined by the cost effective measurements is developed in Chapter Four.

3.3.2 Rationalising spatial growth

Wadley and Smith (1998) define planning, or rationalising spatial growth, as a "*microeconomic process of facility and land use determination in the conversion of environments".* On this basis, the concept of rationalising spatial growth underpins the financial viability of collective sustainable infrastructure provision.

Wadley and Smith (1998) further identify the costs of planning under certain conditions. The first condition is that it could be deemed obvious to plan when the costs of not planning are both apparent and considerable. Wadley and Smith (1998) consider these costs as *"imputed as they will remain hypothetical until the non-planned project is completed*", therefore, they equate this planning as follows.

Plan if: $Icnp > (Icp + Acp)$

where:

$Icnp$ = imputed costs of not planning

Icp = imputed costs of planning

Acp = accounting or real financial costs of planning

This equation would apply to a single project scenario. The costs of planning may, however, be determined under more complex scenarios where the social benefit is taken into account. Wadley and Smith (1998) equate this as follows:

If $(Ibs + Tbs) > (Icp + Acp)$ then $Ua > Ub$

where:

Ibs = intangible benefits to society (e.g. amenity)

Tbs = tangible benefits to society

U = utility (social wealth) in periods *a* after and *b* before planning

For the purposes of this study, the costs and benefits of rationalising spatial growth were determined by utilising the scenarios as depicted by the planning and social benefit equations identified. Chapter Four elaborates further on the extent of these calculations.

3.3.3 Construction of green buildings

Sustainable or green buildings, as defined by the Green Building Council of South Africa (GBCSA) (2011), are "*buildings which are energy efficient, resource efficient and environmentally responsible*." By implication, conventional buildings are less energy efficient, less resource efficient and less environmentally responsible. The measure of energy efficiency, resource efficiency and environmental responsibility is achieved through the GBCSA's rating tools which sets standards and benchmarks for green buildings. As such, the extent of interventions necessary could be measured so as to attain green building status when constructing a new building. Furthermore, costs can be allocated to the extent of interventions, thereby allowing the cost of constructing a conventional building versus the cost of constructing a green rated building to be determined. For the purposes of this study, this was the basis of determining the cost for green buildings.

The GBCSA has also developed a pilot Public and Education Building rating tool (2011) so as to assess the sustainability attributes of new educational buildings and, as such, provide industry with an objective measurement of green educational buildings. The rating tool is comprised of the following components:

- Management: seeks to promote a sustainable approach to building development from project inception through to design, construction, commissioning, tuning and the eventual operation thereof.

- Indoor environment quality: seeks to promote the well-being of the occupants of a building and would typically include aspects such as the HVAC system, lighting and indoor air pollutants. In addition, comfort factors such as external views, individual climate control and noise levels are assessed along with heath related issues such as assessing the level of indoor Volatile Organic Compounds and Formaldehyde emissions.

- Energy: seeks to reduce energy consumption through the more efficient use of energy within the building and / or through the generation of energy from alternative sources.

- Transport: seeks to reduce automotive commuting through simultaneously discouraging conventional transportation to and from the relevant site along with encouraging the use of alternative transportation. This typically could be achieved through the deliberate design and location of a building that supports alternative transport modes.

- Water: seeks to reduce the use of potable water through the efficient design of building systems, rainwater collection and water reuse.

- Materials: seeks to optimise the use of resources through the selection and reuse of materials along with efficient management practices, namely, minimising the use of natural resources, reuse of materials and recycling.

- Land use and ecology: seeks to reduce a building's impact on ecological systems and biodiversity.

- Emissions: seeks to reduce a buildings impact in relation to watercourse pollution, light pollution, ozone depletion and global warming.

- Innovation: seeks to encourage, recognise, and reward of alternative technologies and designs within the design of the building that can improve environmental performance over and above other components identified.

Components within the categories identify the extent of intervention required to achieve the points necessary for an eventual Green Star rated building. Chapter Four discusses the nature of these interventions along with the associated costs further.

3.3.4 Operation and maintenance

Although the GBCSA has developed rating tools so as to evaluate a new building's energy and resource efficiency along with its environmental responsibility, no rating system exists within South Africa with respect to the operation and maintenance of existing buildings. For the purposes of this study, the United States Green Building Council's LEED (Leadership in Energy and Environmental Design) (2009) rating tool for existing buildings was utilised to measure the extent of interventions necessary to attain green building status through the operation and maintenance of an existing building. Costs could then be allocated to the intervention extent thereby allowing the cost of implementing green operations and improvements versus maintaining the status quo of operations within an existing building to be determined.

The LEED rating tool for existing buildings "*measures operations, improvements and maintenance on a consistent scale with the goal of maximising operational efficiency while minimising environmental impacts*." (LEED , 2009). The rating tool is comprised of the following components:

- Sustainable sites: seek to improve and enhance efficiencies through aspects such as building exterior management, landscape management, reduce site disturbance, stormwater management, heat island reduction and light pollution reduction.

- Water efficiency: seeks to improve operations through enhancing indoor plumbing efficiency, implementing water performance measurement along with ensuring water efficient landscaping.

- Energy and atmosphere: seeks to optimise energy efficiency performance, enhance performance measurement through building automation systems and encouraging on-site and off-site renewable energy sources.

- Materials and resources: seek to improve operations through ensuring sustainable purchasing with respect to consumables and durable goods, facility alterations and additions as well as food. This component further seeks to improve operations through ongoing solid waste management.

- Indoor environmental quality: seeks to ensure best management practices in terms of increased ventilation, occupant comfort, thermal comfort, sustainable cleaning equipment and indoor pest management.

- Innovation in operations: seeks to encourage, recognise, and reward of alternative technologies and designs within the operations and maintenance of a building that can improve environmental performance over and above other identified components.

Components within these categories describe/identify the extent of interventions required to achieve the points necessary for an eventual LEED rated building. Chapter Four discusses the nature of these interventions along with the associated costs further.

3.3.5 Wastewater

For the purposes of this study, alternative wastewater treatment refers to the treatment of wastewater where there is no dilution of high strength wastes with clean water, a maximum recovery and re-use of treated water, an application of reliable treatment technologies which are low in cost along with having a relatively long lifetime, and are applicable at any scale (Volkman & Candidate, 2003). As such, the possible application of alternative wastewater treatment (Volkman & Candidate, 2003) within the context of Nelson Mandela Metropolitan University's operations includes:

- Wetlands: refers to utilising the natural chemical, physical and solar components to purify wastewater.

- Treated wastewater reuse by means of reclaimed water: refers to the use of reclaimed water from municipal supplies for the purposes of grounds irrigation.

For this study, the costs of alternative wastewater treatment were determined through analysing the costs of identified alternative water source categories. Chapter Four discusses the extent of the cost calculations further.

3.3.6 Water

For the purposes of this study, alternative water supplies are those potential water supplies that were best suited to non-potable uses as potable water requires high levels of purity and safety which was outside the ambit of Nelson Mandela Metropolitan University's operations. As such, the possible application of alternative sources of water for non-potable uses within the context of Nelson Mandela Metropolitan University's operations includes:

- Rainwater harvesting: harvesting of rainwater by means of rain barrels.

- Grey water systems: wastewater collected from clothes washers, showers and bathtubs.

- Desalination plants: process of removing salts and impurities from seawater or brackish water.

For the purposes of this study, the costs of alternative water supply were determined through analysing the costs of the identified water categories. Chapter Four discusses the extent of these cost calculations further.

3.3.7 Energy

Renewable energy utilises inexhaustible resources as opposed to utilising exhaustible resources. The possible application of renewable sources of energy within the context of Nelson Mandela Metropolitan University's operations includes:

- Wind power: refers to energy that is captured from the wind with small scale wind turbines.

- Photovoltaics: refer to the direct conversion of light into electricity.

For the purposes of this study, the costs of alternative energy supply were determined through analysing the costs of renewable energy categories. Chapter Four discusses the extent of these cost calculations further.

3.3.8 Transport

Transportation to and around Nelson Mandela Metropolitan University's campuses has a significant impact on infrastructure provision such as internal and external road networks, parking facilities and inter-modal transfer points. Currently, the predominant mode of transport to Nelson Mandela Metropolitan University campuses is that of private, single occupant, vehicular traffic. Should a more sustainable form of transportation to and within the various campuses be pursued, the costs and benefits of the various modes of possible transportation and their associated conditions would need to be analysed. For the purposes of this study, the transportation cost / benefit categories as advocated by the Victoria Transport Policy Institute (2009), were utilised to quantify the associated costs and benefits of conventional single occupant vehicular traffic versus alternative forms of transportation. These included:

- Vehicle ownership
- Operating subsidies
- Travel time
- Internal parking
- External parking
- Congestion
- Road facilities
- Traffic services
- Transport diversity value
- Noise
- Resource consumption
- Barrier effect
- Land-use impacts

The specific modes of travel to determine transportation cost / benefit categories, as advocated by the Victoria Transport Policy Institute (2009) include:

- Average single occupant vehicle
- Rideshare passenger (incremental cost of an additional carpool or transit rider)
- Bus / taxi
- Motorcycle
- Bicycle
- Walk
- Telework (telecommunications that substitutes the need for physical travel)

For the purposes of this study, the costs of sustainable transportation were determined through analysing the costs of the identified transportation / benefit categories. Chapter Four discusses the extent of these cost calculations further.

3.4 FRAMEWORK FOR THE ASSESSMENT OF COSTS

Table 3.2 illustrates how the costs of sustainable infrastructure provision within the context of components identified in Section 3.3 were assessed against conventional infrastructure provision. This assessment resulted in a cost benefit determination of sustainable infrastructure provision versus conventional infrastructure provision.

Thereafter, the sustainability benefit of each primary component of sustainable infrastructure provision was determined through the assignment of a sustainability indicator based on the attributes of green infrastructure along with the social, economic and environmental dimensions of sustainability. The application of the indicator resulted in a relational cost factor per intervention area and, ultimately, a relational cost benefit per intervention area.

The assessment of sustainable infrastructure included the following cost components:

A. Cost benefit of the component

Cost benefit of the component (C) = Resource utilisation without the sustainability intervention (B) – cost of the sub-components (A)
[C = B – A]

B. Sustainability indicator

Sustainability indicator (E) = f (relation of intervention to the attributes of green infrastructure (D1) along with the social (D2), economic (D3) and environmental dimensions (D4) of sustainability)
[E = f(D1, D2, D3, D4)]

To undertake these calculations, the contribution made to sustainability needed to be determined considering the attributes of green infrastructure along with the three pillars of sustainability, namely, the social, economic and environmental pillars. Each pillar relates specifically to the following three pillars:

- Social pillar: socially desirable, culturally acceptable, psychologically nurturing
- Financial pillar: economically sustainable technologically feasible, operationally viable
- Environmental pillar: environmentally robust, generationally sensitive, and capable of continuous learning

It is important to note that the sustainability indicator per intervention area was a relational indicator, as this study examined the benefits of intervention areas in relation to one another within an isolated system, namely, a university campus. The sustainability indicator for a university campus could be calculated by using the factors of relational sustainability to determine the contribution of each of the eight components of infrastructural provision.

The factors of relational sustainability include:

- Green infrastructure attributes
- Environmental sustainability dimension
- Social sustainability dimension
- Economic sustainability dimension

C. Relational cost factor per intervention

Relational cost factor [(F) = f (C1, C2, C3, C4, C5, C6, C7, C8)]

D. Relational cost benefit

Relational cost benefit (G) = Sustainability indicator (E) x Relational cost factor (F) [G = E X F]

Table 3.2 summarises the framework for cost assessment.

Table 3.2: Framework for the assessment of costs

COMPONENTS OF SUSTAINABLE INFRASTRUCTURE PROVISION			CONVENTIONAL INFRASTRUCTURE PROVISION		RELATION OF PRIMARY COMPONENT OF SUSTAINABLE INFRASTRUTURE PROVISION TO THE ATTRIBUTES OF GREEN INFRASTRUCTURE ALONG WITH THE SOCIAL, ECONOMIC AND ENVIRONMENTAL DIMENSIONS OF SUSTAINABILILITY	DETERMINATION OF RELATIONAL SUSTAINABILITY INDICATOR	DETERMINATION OF A RELATIONAL COST FACTOR PER PRIMARY INTERVENTION AREA	FINANCIAL VIABILITY OF SUSTAINABLE INFRASTRUCTURE PROVISION
Primary component	**Sub-component (Item against which cost will be measured)**		**Primary components (Item against which cost will be measured)**					
	A		**B**	**B – A = C**	**D**	**E= F(D1, D2, D3, D4) x WEIGHT**	**F= F (C1, C2, C3, C4, C5, C6, C7, C8) x WEIGHT**	**G= E X F**
Demand-side management	Total resource cost Utility cost Participant test	versus	Resource utilisation without demand side management interventions	Equals Cost Benefit	Relation of demand side management to the attributes of green infrastructure along with the social, economic and environmental dimensions of sustainability within the context of Nelson Mandela Metropolitan University	Equals sustainability indicator	Relational cost factor	Relational cost benefit
Rationalising spatial growth	Single project scenario Social benefit scenario	versus	Uncontrolled urban growth	Equals Cost Benefit	Relation of demand side management to the attributes of green infrastructure along with the social, economic and environmental dimensions of sustainability within the context of Nelson Mandela Metropolitan University	Equals sustainability indicator	Relational cost factor	Relational cost benefit

COMPONENTS OF SUSTAINABLE INFRASTRUCTURE PROVISION			CONVENTIONAL INFRASTRUCTURE PROVISION		RELATION OF PRIMARY COMPONENT OF SUSTAINABLE INFRASTRUTURE PROVISION TO THE ATTRIBUTES OF GREEN INFRASTRUCTURE ALONG WITH THE SOCIAL, ECONOMIC AND ENVIRONMENTAL DIMENSIONS OF SUSTAINABILILITY	DETERMINATION OF RELATIONAL SUSTAINABILITY INDICATOR	DETERMINATION OF A RELATIONAL COST FACTOR PER PRIMARY INTERVENTION AREA	FINANCIAL VIABILITY OF SUSTAINABLE INFRASTRUCTURE PROVISION
Primary component	**Sub-component (Item against which cost will be measured)**		**Primary components (Item against which cost will be measured)**					
	A		**B**	**B – A = C**	**D**	**E= F(D1, D2, D3, D4) x WEIGHT**	**F= F (C1, C2, C3, C4, C5, C6, C7, C8) x WEIGHT**	**G= E X F**
Construction of green buildings	Management Indoor environmental quality Energy Transport Water Materials Land use and ecology Emissions Innovation	versus	Development of academic infrastructure in the absence of stipulated management, indoor environmental quality, energy, transport, water, materials, land and ecology, emissions and innovation interventions	Equals Cost Benefit	Relation of demand side management to the attributes of green infrastructure along with the social, economic and environmental dimensions of sustainability within the context of Nelson Mandela Metropolitan University	Equals sustainability indicator	Relational cost factor	Relational cost benefit
Operation and maintenance	Sustainable sites Water efficiency Energy and atmosphere Materials and resources Indoor environmental quality Innovation in operations	Versus	Operation and maintenance of academic infrastructure in the absence of stipulated sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality and innovation in operations interventions	Equals Cost Benefit	Relation of demand side management to the attributes of green infrastructure along with the social, economic and environmental dimensions of sustainability within the context of Nelson Mandela Metropolitan University	Equals sustainability indicator	Relational cost factor	Relational cost benefit

COMPONENTS OF SUSTAINABLE INFRASTRUCTURE PROVISION			CONVENTIONAL INFRASTRUCTURE PROVISION		RELATION OF PRIMARY COMPONENT OF SUSTAINABLE INFRASTRUTURE PROVISION TO THE ATTRIBUTES OF GREEN INFRASTRUCTURE ALONG WITH THE SOCIAL, ECONOMIC AND ENVIRONMENTAL DIMENSIONS OF SUSTAINABILILITY	DETERMINATION OF RELATIONAL SUSTAINABILITY INDICATOR	DETERMINATION OF A RELATIONAL COST FACTOR PER PRIMARY INTERVENTION AREA	FINANCIAL VIABILITY OF SUSTAINABLE INFRASTRUCTURE PROVISION
Primary component	**Sub-component (Item against which cost will be measured)**		**Primary components (Item against which cost will be measured)**					
	A		**B**	**B – A = C**	**D**	**E= F(D1, D2, D3, D4) x WEIGHT**	**F= F (C1, C2, C3, C4, C5, C6, C7, C8) x WEIGHT**	**G= E X F**
Wastewater / Sewerage	Wetlands Treated wastewater reuse	Versus	Conventional wastewater treatment processes	Equals Cost Benefit	Relation of demand side management to the attributes of green infrastructure along with the social, economic and environmental dimensions of sustainability within the context of Nelson Mandela Metropolitan University	Equals sustainability indicator	Relational cost factor	Relational cost benefit
Water	Rainwater harvesting Grey water systems Desalination plants	Versus	Conventional municipal water supply	Equals Cost Benefit	Relation of demand side management to the attributes of green infrastructure along with the social, economic and environmental dimensions of sustainability within the context of Nelson Mandela Metropolitan University	Equals sustainability indicator	Relational cost factor	Relational cost benefit
Energy	Wind power Photovoltaics	Versus	Conventional utility energy supply	Equals Cost Benefit	Relation of demand side management to the attributes of green infrastructure along with the social, economic and environmental dimensions of sustainability within the context of Nelson Mandela Metropolitan University	Equals sustainability indicator	Relational cost factor	Relational cost benefit

COMPONENTS OF SUSTAINABLE INFRASTRUCTURE PROVISION			CONVENTIONAL INFRASTRUCTURE PROVISION		RELATION OF PRIMARY COMPONENT OF SUSTAINABLE INFRASTRUTURE PROVISION TO THE ATTRIBUTES OF GREEN INFRASTRUCTURE ALONG WITH THE SOCIAL, ECONOMIC AND ENVIRONMENTAL DIMENSIONS OF SUSTAINABILILITY	DETERMINATION OF RELATIONAL SUSTAINABILITY INDICATOR	DETERMINATION OF A RELATIONAL COST FACTOR PER PRIMARY INTERVENTION AREA	FINANCIAL VIABILITY OF SUSTAINABLE INFRASTRUCTURE PROVISION
Primary component	**Sub-component (Item against which cost will be measured)**		**Primary components (Item against which cost will be measured)**					
	A		**B**	**B – A = C**	**D**	**E= F(D1, D2, D3, D4) x WEIGHT**	**F= F (C1, C2, C3, C4, C5, C6, C7, C8) x WEIGHT**	**G= E X F**
Transport	Rideshare passenger	Versus	Average single occupant vehicle and associated infrastructure	Equals Cost Benefit	Relation of demand side management to the attributes of green infrastructure along with the social, economic and environmental dimensions of sustainability within the context of Nelson Mandela Metropolitan University	Equals sustainability indicator	Relational cost factor	Relational cost benefit
	Bus / taxi							
	Motorcycle							
	Bicycle							
	Walk							
	Telework							

Source: Author's own compilation

3.5 SUMMARY

In Chapter Three, the basis of alternative infrastructure was defined. A framework (see Table 3.2) was developed to demonstrate the means of calculation with respect to the financial viability of sustainable infrastructure provision in relation to demand side management, rationalising university growth through appropriate planning, the construction of green buildings, the operation and maintenance of green buildings, the treatment of wastewater, the provision of water, the provision of energy and public transportation.

In Chapter Four, the framework components are populated with data to determine applicable sustainability indicators along with relational cost factors.

CHAPTER 4

RELATIONAL COST FACTORS AND RELATIONAL SUSTAINABILITY INDICATORS

4.1 INTRODUCTION

In Chapter Three, conventional and alternative infrastructural interventions were discussed. A distinction was made between conventional infrastructure provision and that of alternative infrastructure provision. The detailing of the basis of alternative infrastructure provision resulted in a framework for the assessment of costs.

This chapter seeks to quantify the costs associated with alternative infrastructure provision. In particular, costs associated with demand side management, rationalising spatial growth, green building development, operation and maintenance of existing buildings, wastewater infrastructure, water infrastructure, energy infrastructure and transport infrastructure.

Once the costs outlined in the framework as illustrated in Table 3.2 were populated with the actual costs, a relational sustainable cost factor was calculated. The relational cost factor of each of the components in the framework was then assigned a relational sustainability indicator based on the attributes of green infrastructure along with the social, economic and environmental dimensions of sustainability. The application of the relational sustainable indicator was used with the relational cost factor per intervention area to ultimately calculate a relational cost benefit per intervention area. In Chapter Four, the relational sustainable cost factor is first determined. Thereafter, the relational sustainable indicator is calculated.

4.2 CALCULATING RELATIONAL COSTS

To calculate the relational costs, it is important to first assess the cost of each intervention area. To populate each intervention area with actual costs, data was firstly obtained from available information sources within Nelson Mandela Metropolitan University. In intervention areas where there was no data available from university, data was sourced from existing literature where previous research indicated such costs. A subsequent current Rand value was attached to those costs.

4.2.1 Assessing costs of each intervention area

To address the primary purpose of this study, it was necessary to quantify the financial implication of sustainable infrastructural interventions in relation to one another and, in turn, provide a basis for the determination of budget split between the various interventions. As such, the study focuses on the cost assessment per sustainable infrastructure intervention, and eventual relational cost benefit, rather than determining the cost benefit of each sustainable infrastructure intervention area. However, this does not indicate that the cost benefit of each sustainable infrastructure intervention area is unimportant. The premise behind undertaking a cost assessment per sustainable infrastructure intervention is that the cost benefit of doing so has already been proven. This will be elaborated upon within the relevant sections that follow.

For the sake of completeness, lifecycle costs per sustainable infrastructure intervention area are also reflected. The proposed basis for the determination of a budget split between the various sustainable infrastructure interventions is based on the initial capital cost and operational costs associated with the first year of operations as an initial investment. Lifecycle costs should be catered for through the normal budgeting processes as indicated in Table 4.1.

Table 4.1: Lifecycle costs per infrastructure type

TYPE OF INFRASTRUCTURE	CAPITAL COST	AVERAGE ANNUAL MAINTENANCE BUDGET AS A % OF REPLACEMENT COST	KEY ASSUMPTIONS	REPLACEMENT OR MAJOR REHABILITATION OVER AND ABOVE THE ANNUAL MAINTENANCE BUDGET REQUIRING SPECIFIC CAPITAL BUDGET
Bulk water infrastructure	Capital cost	4-8%	Mostly for periodic repair of electrical and mechanical works, storm damage repair, routine maintenance and periodic maintenance	Every 30 to 50 years
Water treatment works	Capital cost	4-8%	Mostly for electrical and mechanical equipment	Every 20 to 30 years
Water reservoirs	Capital cost	2-3%	Generally low maintenance mostly of telemetry and electrical equipment, storm damage repair, pipe work repair, safety and security, routine maintenance and periodic maintenance	Every 20 to 30 years
Water reticulation	Capital cost	4-8%	Mostly for telemetry and pumping equipment, emergency leak repair and ongoing leak repair due to degradation, storm damage repair	Every 20 to 30 years
Sewerage treatment works	Capital cost	4-8%	Mostly for electrical and mechanical equipment, storm damage and periodic maintenance	Every 20 to 30 years
Sewer reticulation	Capital cost	4-8%	Mostly for pumping equipment, emergency leak repair and ongoing leak repair due to degradation, blockage removal, storm damage repair	Every 20 to 30 years
Roads and storm water	Capital cost	5-10%	Mostly for emergency repair, storm damage repair and periodic maintenance (resurfacing every 7 to 10 years)	Every 20 to 30 years
Electricity reticulation	Capital cost	10-15%	Mostly for emergency repair, storm damage repair, safety and security, routine maintenance and periodic maintenance	Every 20 to 30 years
Public buildings	Capital cost	4-6%	Mostly for emergency repair, storm damage repair and periodic maintenance	Every 30 to 50 years
Hospitals	Capital cost	5-8%	Mostly for emergency repair, storm damage repair and periodic maintenance	Every 20 to 30 years
Schools	Capital cost	4-6%	Mostly for emergency repair, storm damage repair and periodic maintenance	Every 30 to 50 years
Electricity generation	Capital cost	5-8%	Mostly for electrical and mechanical equipment and dependent on age and technology of works	Every 30 to 50 years

Source: CIDB, Infrastructure Maintenance Budgeting Guideline (2009)

The structure of the assessment of costs per intervention area occurs as shown in Table 4.2.

Table 4.2: Structure of the assessment of costs per sustainable intervention area

STEP	COMPONENT
Step 1	Assessment of the costs relating to a sustainable infrastructure intervention area with respect to: • Initial Capital costs • Operational costs (year 1)
Step 2	Comparison of sustainable infrastructure cost to that of conventional infrastructure
Step 3	Detailing the cost of the intervention area in terms of 2012 figures. This is the figure that will populate the eventual framework in determining a relational cost benefit per intervention area subject to the application of a sustainability indicator per intervention area

Source: Author's own compilation

In addition to steps 1 to 3 as illustrated in Table 4.2, reference is made to:

- Cost benefits of undertaking the specific sustainable infrastructure intervention areas
- Estimated lifecycle costs (namely, initial cost of the investment + life time cost of maintenance + cost of precautionary maintenance) of the specific sustainable infrastructure intervention area

As illustrated in Table 4.2, the determination of a budget split per sustainable infrastructure intervention area is based on the cost assessment of the initial capital cost and first year of operation. Reference is, however, made, where applicable, to the lifecycle cost per intervention area so as to illustrate the longer time financial commitments of each intervention area given that the cost benefit of each intervention area has already been proven. For example, the utilisation of heat pumps as a means to heat water typically consumes one unit of electrical energy for every three units of heating produced (Rankin & van Eldik, 2008). As such, an average of two-thirds (67%) of electrical energy can be saved as opposed to conventional electrical heating.

(a) Cost of Intervention area 1: Demand side management costs

Costs associated with the provision of water and electricity to all of Nelson Mandela Metropolitan University's campuses is reflected in Table 4.3. These costs reflect the monthly water and electricity costs from January 2011 to December

2011 without any official demand side management programme in operation. Electricity costs for the year of 2011 total R15,997,241 whereas water costs total R2,700,597. The cumulative electricity and water costs for all campuses for the year 2011 totals R18,697,838.

Table 4.3: Nelson Mandela Metropolitan University electricity and water costs for 2011

MONTH	SOUTH CAMPUS ELECTRICITY COSTS	SOUTH CAMPUS WATER COSTS	NORTH CAMPUS ELECTRICITY COSTS	NORTH CAMPUS WATER COSTS	2ND AVENUE CAMPUS ELECTRICITY COSTS	2ND AVENUE CAMPUS WATER COSTS	BIRD STREET CAMPUS ELECTRICITY COSTS	BIRD STREET CAMPUS WATER COSTS	MISSIONVALE CAMPUS ELECTRICITY COSTS	MISSIONVAL E CAMPUS WATER COSTS	TOTAL
Jan-11	R 597,453	R 122,905	R 212,366	R 25,490	R 41,934	R 4,861	R 21,002	R 1,550	R 125,623	R 17,414	
Feb-11	R 685,529	R 22,745	R 267,402	R 18,870	R 58,165	R 17,000	R 19,726	R 1,816	R 144,152	R 15,765	
Mar-11	R 779,907	R 336,740	R 275,755	R 59,078	R 71,245	R 20,598	R 19,897	R 2,006	R 158,634	R 14,022	
Apr-11	R 734,851	R 103,986	R 275,045	R 16,665	R 57,793	R 16,217	R 21,309	R 2,290	R 132,410	R 10,894	
May-11	R 773,123	R 248,820	R 257,454	R 83,423	R 66,189	R 13,547	R 20,771	R 1,982	R 137,244	R 8,497	
Jun-11	R 729,729	R 135,973	R 223,883	R 4,453	R 56,446	R 10,580	R 24,271	R 1,848	R 124,011	R 8,851	
Jul-11	R 860,820	R 99,752	R 285,203	R 49,478	R 83,234	R 6,773	R 27,418	R 2,315	R 176,090	R 8,606	
Aug-11	R 1,017,234	R 173,988	R 330,729	R 33,456	R 95,885	R 15,920	R 26,073	R 1,764	R 194,333	R 8,584	
Sep-11	R 975,670	R 161,337	R 321,987	R 35,347	R 83,865	R 14,412	R 26,141	R 1,867	R 185,505	R 35,886	
Oct-11	R 943,700	R 173,928	R 334,656	R 32,689	R 76,014	R 13,570	R 24,079	R 1,698	R 203,694	R 39,319	
Nov-11	R 881,484	R 162,950	R 318,257	R 32,515	R 74,727	R 12,271	R 23,129	R 1,808	R 176,068	R 43,127	
Dec-11	R 685,339	R 108,923	R 213,567	R 17,558	R 53,970	R 4,225	R 23,163	R 2,115	R 161,893	R 55,531	
	R 9,664,838	**R 1,852,049**	**R 3,316,303**	**R 409,020**	**R 819,466**	**R 149,974**	**R 276,978**	**R 23,058**	**R 1,919,656**	**R 266,496**	**R 18,697,838**

Source: Nelson Mandela Metropolitan University Infrastructure Projects Database (2012)

In the context of Nelson Mandela Metropolitan University's operations, the demand side management components of load management, energy efficiency and load curtailment may be possible to implement. Possible interventions include:

- Load management

The process of balancing the supply of electricity with the electrical load by controlling the load is known as load management. Eskom is currently underway with a load management pilot project for residential consumers to become more energy aware and efficient (Eskom, 2012). The pilot project utilises load limiting technology known as an electricity demand display instrument (eddi) which displays the real-time demand of various electrical appliances within the household. Load limits are specified which are based on required power reductions for a particular residential area. Should those limits be exceeded, the resident has the option to switch off appliances within set timeframes so as to ensure that their electricity consumption stays within prescribed limits for particular periods. Should the reduction in consumption not occur within the prescribed timeframe, power will be disconnect to the household.

The principle behind the pilot project as described may possibly be applied within the context of Nelson Mandela Metropolitan University's operations including the office environment and student residences. Student residences (approximately three thousand students are catered for in on-campus accommodation) have similar appliances to those of residential households. The principle can be applied to the office environment as each department within a particular faculty utilises electricity so as to power computers, laptops, printers, fax machines, kettles and a number of other auxiliary items. Not all of these forms of equipment are required to be simultaneously powered / charged.

As the electricity demand display instrument (eddi) is currently a pilot programme as promoted by Eskom, no capital costs are associated with the procurement of the device. Given the nature of the device, namely, a self-regulatory tool by which a user can manage electricity consumption, no immediate operational costs are associated with the electricity demand display instrument.

- Energy efficiencies

Energy efficiency refers to actions that seek to reduce the amount of energy required to undertake a particular function. Within the context of Nelson Mandela Metropolitan University, these actions can include lighting interventions and hot water management interventions.

  - Direct lighting interventions

According to Eskom (2010), lighting is responsible for between 37% and 45% of electricity consumption in office buildings. In order to improve energy efficiencies with respect to lighting, the following interventions may be implemented:

    - Switch to energy efficient lighting: Current magnetic ballast luminaires can be replaced with energy efficient lights such as LEDs as LEDs utilise less energy and last longer
    - Installation of occupancy sensors: Occupancy sensors manage lighting based on occupant detection

Table 4.4 illustrates the cost comparisons of conventional magnetic ballast luminaires versus LED lights.

Table 4.4: Cost comparison- LED lamps

			CONVENTIONAL		**ALTERNATIVE**
	Luminaire Name		**2x18W Bulkhead**	**2x9W Bulkhead**	**BEKA SERIES 31 LED6**
	Price of luminaire including lamp	R	R575.00	R315.00	R1,154.30
Electrical	Electricity rate	R/kWh	R 0.95	R 0.95	R 0.95
	Annual operation period (365*24)	H	8760	8760	8760
	System power consumption – per luminaire	kW	0.046	0.022	0.014
	Energy consumption per year, based on R 0.95 per kWh	R	383	183	117
Lamp replacement	Lamp cost	R	R 24.00	R 16.00	R 718.25
	Lamp replacement cost, labour	R	R 100.00	R 100.00	R 100.00
	Life time of the lamp	H	10,000	10,000	50,000
	No of lamps to be replaced annually		1.75	1.75	0.00
	Total annual lamp	R	217.2	203.2	0.0

			CONVENTIONAL		ALTERNATIVE
	Luminaire Name		**2x18W Bulkhead**	**2x9W Bulkhead**	**BEKA SERIES 31 LED6**
	replacement costs				
	Cost of ownership over 3 years				
	Initial capital cost	R	R 575.00	R 315.00	R 1,154.30
	Total energy cost	R	R 1,148.44	R 549.25	R 349.52
	Total lamp replacement cost	R	R 651.74	R 609.70	R 0.00
	TOTAL COST OF OWNERSHIP AFTER 3 YEARS	**R**	**R 2,375.18**	**R 1,473.95**	**R 1,503.82**
	Energy cost over 3 years (PER LUMINAIRE)				
	Electricity rate	R/kWh	0.95	0.95	0.95
	Operation period over 3 years	H	26280.00	26280.00	26280.00
	System power Consumption over 3 years	kW	0.046	0.022	0.014
	Energy consumption cost over 3 years, based on 0.95 R/kWh	R	**R 1,148.44**	**R 549.25**	**R 349.52**
	Cost of ownership over 7 years				
	Initial capital cost	R	R 575.00	R 315.00	R 1,154.30
	Total cnergy cost	R	R 2,679.68	R 1,281.59	R 815.56
	Total lamp replacement cost	R	R 1,520.74	R 1,422.62	R 0.00
	TOTAL COST OF OWNERSHIP AFTER 7 YEARS	**R**	**R 4,775.42**	**R 3,019.21**	**R 1,969.86**
	Energy cost over 7 years (PER LUMINAIRE)				
	Electricity rate	R/kWh	0.95	0.95	0.95
	Operation period over 7 years	H	61320.00	61320.00	61320.00
	System power Consumption over 7 years	kW	0.046	0.022	0.014
	Energy consumption cost over 7 years, based on 0.95 R/kWh	R	**R 2,679.68**	**R 1,281.59**	**R 815.56**

Source: Richard Nzuza and Associates(2012)

As illustrated in Table 4.4, the cost of ownership of LED lights totals R1,503.82 over three years, and R1,969.86 over seven years. Should Nelson Mandela Metropolitan University initially install one thousand LED lights, this would equate to immediate expenditure of R1,154,300 (R1154.30 x 1000).

Occupancy sensors control building lighting systems by detecting human presence thereby efficiently controlling light usage. Furthermore, occupancy sensor based lighting control systems guarantees the lowest energy consumption and operating cost as lighting is only used when it is required (Cram, 2007).

Cram (2007) illustrates the cost of utilising occupancy sensors by means of a case study involving an office park facility in Johannesburg referred to as *The Campus*. The buildings area totalled 80,000m² and parameters of the case study building are reflected in Table 4.5.

Table 4.5: Parameters of the campus occupancy sensor case study

Total number of buildings	16
Total watts of switchable lighting	1,256,661
Total sensors required	2,534
Average watts control per sensor	496
Average total campus KWh per month	2,939,714
Total campus switchable lighting KWh	917,363
Switchable lighting percentage	31.2%
Average cost per KW hour for 2004	R0.152
Savings percentage projected	67%

Source: Cram (2007)

In order to verify achievable savings within the building through the use of occupancy sensors, 20% of a possible occupancy sensor system was installed at *The Campus*. The results delivered immediate measurable and verifiable savings with respect to the utilisation of energy. Costs pertaining to the intervention are reflected in Table 4.6 .

Table 4.6: Cost of occupancy sensor system

COMPONENT	COST
Cost of the system (installed and commissioned)	R5,449,350
Cost per sensor inclusive of system design and materials	R2,150

Source: Cram (2007)

Nelson Mandela Metropolitan University currently occupies two hundred and two buildings across its various campuses. Of those two hundred and two buildings, approximately nineteen buildings are dedicated to office accommodation of both academic and administrative staff. If, for the purposes of this study, a parallel was drawn between *The Campus* case study and Nelson Mandela Metropolitan University, given that similar operating hours exist between the two, similar costs comparisons could occur owing to a similar amount of switchable lighting and associated occupancy sensors. Furthermore, it is deemed prudent to suggest that the installation and commissioning of sensor systems across 20% of the university's office accommodation, given the range of possible sustainable infrastructure interventions across the university. As such, the cost of an installed and commissioned system across 20% of the university's office accommodation could be expected to fall within the region of R5,449,350 as per 2007 prices.

If this were to be quantified in terms of 2012 prices, as per the annual average CPI rate of 5.5%, this would equate to R7,122,080.

- Direct hot water management

According to Eskom (2010), properties with facilities such as kitchens and ablutions can save 40% to 60% of their energy costs by adopting more efficient water heating processes. Within the context of Nelson Mandela Metropolitan University, energy efficiencies might be gained through the utilisation of heat pumps as opposed to conventional electric geysers. Heat pumps significantly lower energy consumption thereby reducing the costs related to water heating.

The utilisation of heat pumps typically consumes one unit of electrical energy for every three units of heating produced (Rankin & van Eldik, 2008). As such, an average of two-thirds (67%) of electrical energy could be saved as opposed to conventional electrical heating.

Rankin and van Eldik (2008) provide various scenarios with respect to analysing the cost implications of utilising heat pumps as reflected in Table 4.7.

Table 4.7: Cost estimates associated with utilising heat pumps

MAXIMUM OCCUPANCY (Average occupancy 67% in all cases)	PROPOSED SYSTEM	COST ESTIMATE
100	1 x 50kW heat pump (Av COP = 2.9)	R195,000
200	2 x 50kW heat pumps (Av COP = 2.9)	R303,000
300	2 x 70 kW heat pumps (Av COP = 3.1)	R350,000

Source: Rankin and van Eldik (2008)

Nelson Mandela Metropolitan University currently houses three thousand students on its on-campus residences. If, for the purposes of this study, parallels had to be drawn between the estimates as contained within Table 4.7, providing heat pumps to service three thousand students would cost approximately R3,500,000 at 2008 prices.

If this cost had to be quantified in terms of 2012 prices, as per the annual average CPI rate of 5.5%, this would equate to R4,335,885.

- Load curtailment

For the purposes of this study, load curtailment may be defined as the voluntary reduction of load coupled with an associated reward system. This concept of load curtailment may be applied to student residences within the context of Nelson Mandela Metropolitan University. Although voluntary, regular expenditure would be required for on-going energy reduction awareness campaigns so as to facilitate constant voluntary action along with the relative cost of the associated reward system. Based on existing awareness campaigns within Nelson Mandela Metropolitan University, approximately R15,000 per annum could be spent on recurring energy reduction awareness campaigns.

These cost-saving components could potentially form the basis of a demand side management programme for Nelson Mandela Metropolitan University. In summary, the respective costs of the various potential interventions of a demand side management programme at Nelson Mandela Metropolitan University are reflected in Table 4.8.

Table 4.8: Summary of the respective costs of potential interventions of a demand side management programme at Nelson Mandela Metropolitan University

COMPONENT	COSTS / COMMENT
Assessment of the costs relating to a sustainable infrastructure intervention area (demand side management) with respect to: • Capital costs (2012 prices). This is the figure that will populate the eventual framework in determining a relational cost benefit per intervention area subject to the application of a sustainability indicator per intervention area • Operational costs (year 1)	• Load management- Electricity demand display instrument: o Capital cost: R0 o Operational cost (year 1): R0 • Energy efficiencies- Direct lighting interventions: o Capital cost: R1,154,300 o Operational cost (year 1): R0 • Energy efficiencies- Occupancy sensors: o Capital cost: R7,122,080 o Operational cost (year 1): R0 • Energy efficiencies- Direct hot water management: o Capital cost: R4,335,885 o Operational cost (year 1): R0 • Load curtailment- Awareness raising programmes: o Capital cost:R0 o Operational cost (year 1): R15,000
Comparison of sustainable infrastructure cost to that of conventional infrastructure	The total initial cost of undertaking a demand side management programme as per the components as detailed in Section 4.3 totals R12,627,265. Of this, the estimated payback period for that amount equates between 3.5 to 6 years. From thereon, savings result from a reduction in energy consumption.
Reference is made to: • Cost benefita of undertaking the specific sustainable infrastructure intervention areas • Estimated lifecycle costs (namely, initial cost of the investment + life time cost of maintenance + cost of precautionary maintenance) of the specific sustainable infrastructure intervention area	• Cost benefits of undertaking a demand side management programme as per the components as detailed in Section 4.3 results in a payback period of between 3.5 years and 6 years • Estimated lifecycle costs of the programme would equate to R12,627,265+ 10% of the annual replacement value of the components per year for up to 20 to 30 years

Source: Author's own compilation

As illustrated in Table 4.8, the total initial demand side management costs total R12,672,265 and entails interventions with respect to load management, direct lighting interventions, occupancy sensors, direct hot water management and awareness raising programmes.

(b) Cost of Intervention area 2: Rationalising spatial growth costs

Rationalising spatial growth in the context of Nelson Mandela Metropolitan University occurs through a hierarchy of plans as illustrated in Figure 4.1.

Figure 4.1: Hierarchy of plans

Tier 1	Sub-Metropolitan Concept
Tier 2	Campus Scale Framework
Tier 3	Precinct Plan 1 Precinct Plan 2 Precinct Plan 3
Tier 4	Site Development Plan 1 Site Development Plan 2 Site Development Plan 3
Tier 5	Building Plan 1 Building Plan 2 Building Plan 3

Source: Nelson Mandela Metropolitan University Urban Design Framework (2011)

Each of the tiers as shown in Figure 4.1 contributes to the development of the built environment from an economic, social and environmental perspective. This is supported by the North West Development Agency (2007), who validates the economic, social and environmental benefit.

- Economic value includes elements such as:

- Improvements in occupational rent and capital value: Appropriate planning in the form of urban spaces or elements within those spaces can be associated to an increase in capital value.
- Market attractiveness: Properties are easier to rent or sell as a relationship exists between design / spatial quality and that of market attractiveness.
- Whole life costs: Benefits of appropriate design / planning accrue over the long-term as appropriate planning can allow for space saving thereby reducing whole-life costs.
- User performance: Design / spatial functioning of buildings and space can be linked to the users operating within those buildings and spaces as the environment has a large impact on the productivity of those operating within the environment.
- Image and external perception: An institution's immediate environment needs to communicate the beliefs and values of the organisation through choice of location along with the design of buildings and surrounding spaces.

- Social value includes elements such as:

  - Civic pride and a sense of identity: Increased levels of a sense of identity may be achieved with appropriate design / planning contributing to community cohesiveness along with promoting an open and inclusive society.
  - Place vitality: Level of use that an environment or place enjoys throughout the day is referred to as place vitality. Appropriate design / planning seek to entrench place vitality.
  - Social inclusion and equity: Appropriate design / planning contribute to an environment in which everyone is able to participate equally and independently in everyday activities by celebrating the diversity of people and disabling barriers.
  - Social interaction: Quality spaces act as destinations and not just through routes thereby facilitating social interaction.

- Community safety and crime reduction: Appropriate design / planning can enhance community safety whilst also contributing to a reduction in the levels of crime.

- Environmental value includes aspects such as:

  - Energy efficiency and resource use: Appropriate planning and design can minimise environmental impact through the use of sustainable materials, promoting energy efficiency and renewable energy sources and promoting sustainable transport.
  - Ecological value: Appropriate planning and design can protect and promote biodiversity along with reducing an institution's ecological footprint.

In Chapter Three, reference to the costs of planning applied to two conditions, namely, that it could be deemed obvious to plan when the costs of not planning are both apparent and considerable (Wadley & Smith, 1998) along with relating the costs of planning to the social benefit thereof. The value of planning / design as illustrated by the economic, social and environmental components, demonstrate the obviousness of planning along with the associated social benefit. This if further supported by Table 4.9 which illustrates the benefits of appropriate design / planning in terms of conclusive evidence, strong evidence and suggestive evidence.

Table 4.9: Benefit of appropriate design / planning

	ECONOMIC VALUE	SOCIAL VALUE	ENVIRONMENTAL VALUE
Local character	Attracts highly-skilled workers	Reinforces a sense of identity among the residents of Nelson Mandela Metropolitan University	Supports conservation on non-renewable resources
	Assists the promotion and branding of Nelson Mandela Metropolitan University	Encourages people to become actively involved in managing their neighbourhood	
	Contributes to a competitive edge by providing a 'point of difference'	Offers choice among a wide range of distinct places and experiences	
Connectivity	Increases a site or area's accessibility	Enhances natural surveillance and security	Reduces vehicle emissions through reduced vehicular traffic
		Encourages walking and cycling leading to health benefits	
		Shortens walking distances, encouraging people to walk	
Density	Provides land savings	Contributes to social cohesion	Reinforces green space preservation if linked into clustered form

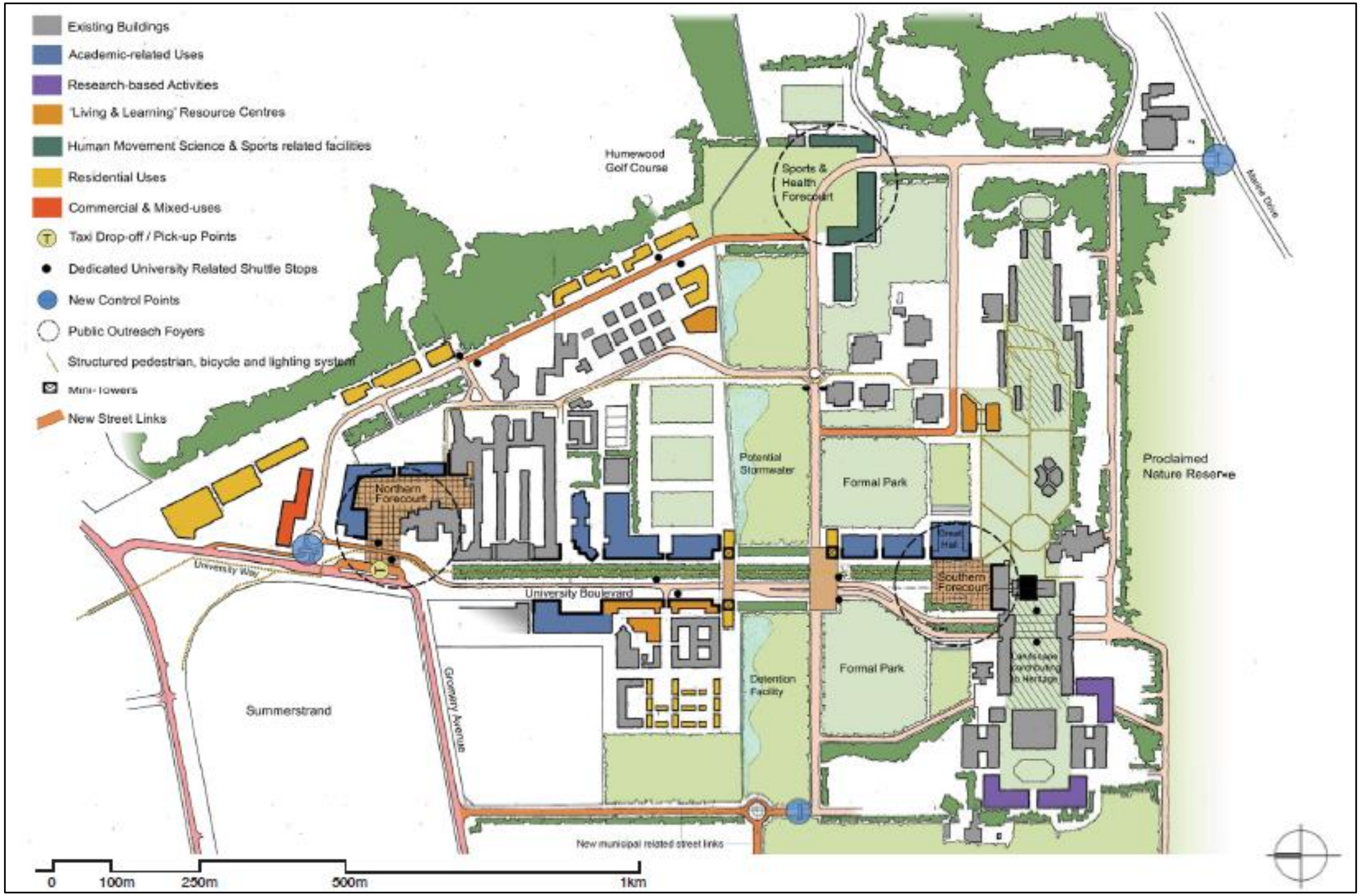
	ECONOMIC VALUE	SOCIAL VALUE	ENVIRONMENTAL VALUE
	Provides infrastructure and energy savings	Tends to promote health through encouraging greater physical activity	Reduces run-off from vehicles to water
	Reduces the economic cost of time allocated to mobility	Enhances vitality	Reduces emissions to air and atmosphere
	Associates with the concentration of knowledge and innovative activity in urban cores		
Adaptability	Contributes to economic success over time	Increases diversity and duration of use for public space	Supports conservation of non-renewable resources
	Extends useful economic life by delaying the loss of vitality and functionality	Gives ability to resist functional obsolescence	
High-quality public realm	Attracts people and activity, leading to enhanced economic performance	Ensures higher participation in community and cultural activities	
	Ensures public art contributes to enhanced economic activity	Increases use of public space	
		Gives greater sense of personal safety	
		Attracts social engagement, pride and commitment to further achievements	
		Ensures public art contributes to greater community engagement with public space	

Source: North West Development Agency (2007)

(orange)	Conclusive evidence
(yellow)	Strong evidence
(green)	Suggestive evidence

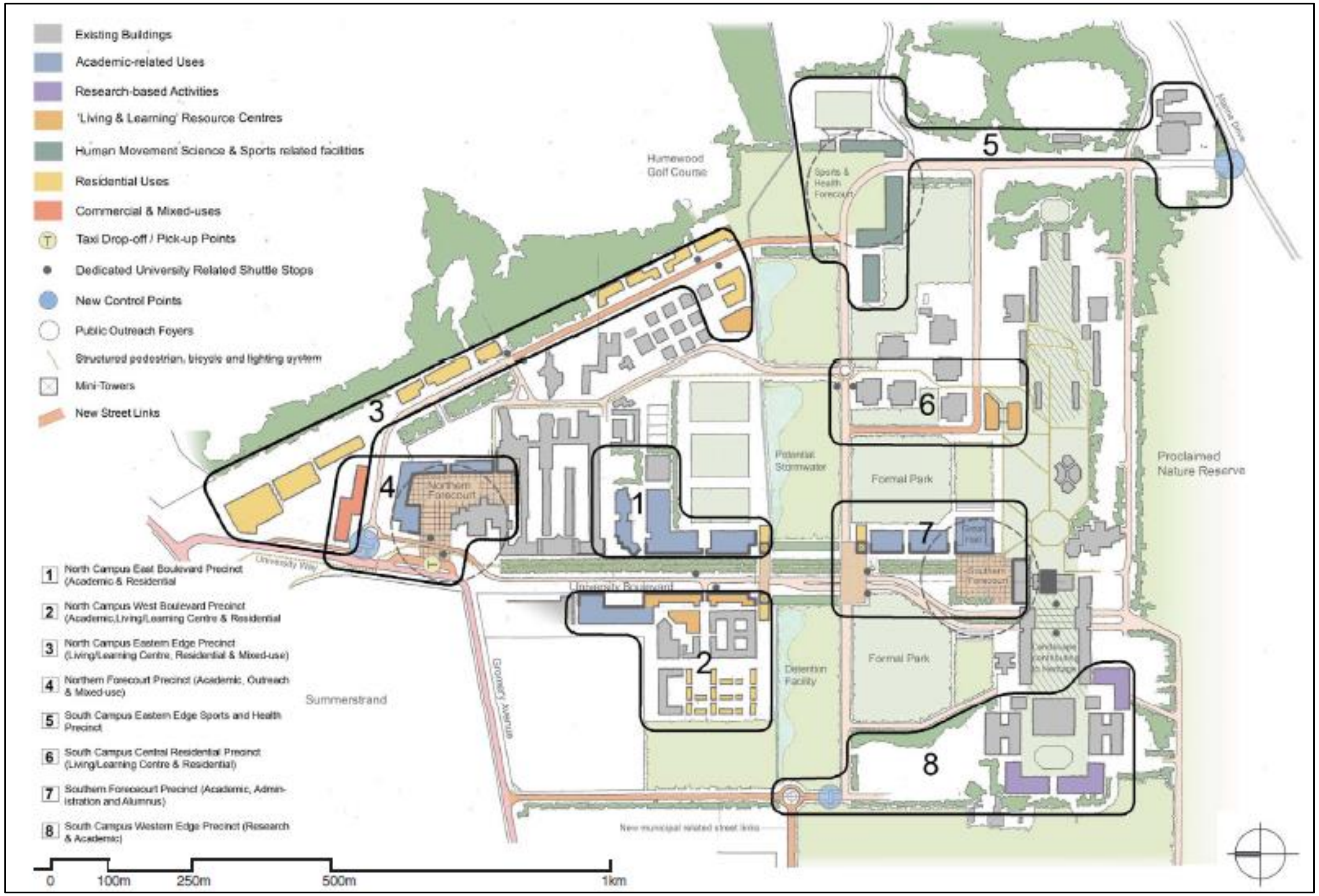
As illustrated by Table 4.9, there is extensive evidence of the value of appropriate planning / design. Within the context of Nelson Mandela Metropolitan University, the costs of appropriate planning / design can be quantified through the hierarchy of plans as illustrated in Figure 4.1. Nelson Mandela Metropolitan University completed its Urban Design Framework in 2011 along with identifying the extent of precinct plans required to compliment the Urban Design Framework. The visual representation of Nelson Mandela Metropolitan University's Urban Design Framework along with the identified areas which require more detailed precinct plans are illustrated in Figures 4.2 and 4.3 respectively.

Figure 4.2: Nelson Mandela Metropolitan University urban design framework, Summerstrand campus (2011)



Source: Nelson Mandela Metropolitan University (2011)

Figure 4.3: Precinct plans to be developed as per the urban design framework, Summerstrand campus (2011)



Source: Nelson Mandela Metropolitan University (2011)

The costs, within the context of Nelson Mandela Metropolitan University, of implementing the necessary hierarchy of plans are illustrated in Table 4.10.

Table 4.10: Costs of planning / design at Nelson Mandela Metropolitan University (2011)

NELSON MANDELA METROPOLITAN UNIVERSITY PLANNING INTERVENTION	COST
Multi campus urban design framework (year 1)	R1,499,418
Precinct plans 1 to 8 (year 1)	R2,000,000
Site development plans- only relevant to a particular building project	n/a
Building plans- only relevant to a particular building project	n/a
TOTAL YEAR 1	**R3,499,418**
Review of the multi campus urban design framework (year 3)	R500,000
Review of precinct plans 1-8 (year 3)	R400,000
TOTAL YEAR 3	**R900,000**
Review of the multi campus urban design framework (year 7)	R500,000
Review of precinct plans 1-8 (year 7)	R400,000
TOTAL YEAR 7	**R900,000**

Source: Nelson Mandela Metropolitan University (2011)

As illustrated in Table 4.10, the total costs to undertake the master Urban Design Framework along with the associated precinct plans total R3,499,418. Site development plans and building plans are developed as and when necessary construction commences and, as such, is not included within this calculation. Furthermore, costs for the necessary review of the Urban Design Framework and the associated precinct plans are included both after a three year and seven year period respectively.

If the R3,499,418 amount had to be quantified in terms of 2012 prices, as per the annual average CPI rate of 5.5%, this would equate to R3,691,885.

In summary, the respective costs of rationalising spatial growth at Nelson Mandela Metropolitan University are reflected in Table 4.11.

Table 4.11: Summary of the costs of rationalising spatial growth at Nelson Mandela Metropolitan University

COMPONENT	COSTS / COMMENT
Assessment of the costs relating to a sustainable infrastructure intervention area (rationalising spatial growth) with respect to:	• Capital cost: R0 • Operational cost (year 1): R3,691,885

COMPONENT	COSTS / COMMENT
• Capital costs (2012 prices). This is the figure that would populate the eventual framework in determining a relational cost benefit per intervention area subject to the application of a sustainability indicator per intervention area • Operational costs (year 1)	
Comparison of sustainable infrastructure cost to that of conventional infrastructure	The total initial cost of undertaking rationalised spatial planning totals R3,691,885. This is a cost over and above the provision of pure infrastructure
Reference will be made to: • Cost benefits of undertaking the specific sustainable infrastructure intervention areas • Estimated lifecycle costs (namely, initial cost of the investment + life time cost of maintenance + cost of precautionary maintenance) of the specific sustainable infrastructure intervention area	• .Although no defined payback period is possible given the nature of planning there is evidence that planning contributes to the economic, social and environmental value of an area. • The estimated lifecycle cost is non-applicable with respect to the rationalising spatial growth component.

Source: Author's own compilation

From Table 4.11, it is clear that the cost of rationalising spatial growth at Nelson Mandela Metropolitan University amounts to R3,691 885.

(c) Cost of Intervention area 3: Green building costs

During 2011, Nelson Mandela Metropolitan University initiated the design and development of a new Business School. In order to ensure alignment with Nelson Mandela Metropolitan University's and the Business School's sustainability vision, the principle of "green" design was advocated. As such, the GBCSA's pilot Public and Education Building rating tool (2011) was used as the mechanism from which to measure "green" design. Green design, as per the GBCSA's pilot Public and Education Building rating tool (2011), was ensured through the application of criteria within those categories as detailed in Chapter Three, namely, the categories of management, indoor environmental quality, energy, transport, water, materials, land use and ecology, emissions and innovation. Points were awarded for the achievement of the stipulated criteria within each category. A category score was thus determined for each category based on the percentage of criteria achieved.

A weighting factor was then applied to each of the eight categories of management, indoor environmental quality, energy, transport, water, materials, land use and ecology and emissions. A single score was thus determined by adding the weighted category scores along with the points achieved for the innovation category. A subsequent Green Star SA rating was then determined as per the following scale.

Table 4.12: Green star rating schedule

OVERALL SCORE	RATING	OUTCOME
10-19	One Star	Not eligible for formal certification
20-29	Two Star	Not eligible for formal certification
30-44	Three Star	Not eligible for formal certification
45-59	Four Star	Eligible for Four Star Certified rating that recognises / rewards 'Best Practice'
60-74	Five Star	Eligible for Five Star Certified rating that recognises / rewards 'South Africa Excellence'
75+	Six Star	Eligible for Six Star Certified rating that recognises / rewards 'World Leadership'

Source: GBCSA pilot Public and Education Building rating tool (2011)

Nelson Mandela Metropolitan University pursued the four star option with regards to the development of the Business School. As such, the costs of attaining the 45-59 point margin were used as the basis of determining the costs associated with developing a "green" building. These are additional costs over and above the provision of conventional infrastructure associated with the development of a new building. Given the nature of infrastructure development, applicable scores, and hence the cost implications thereof, would vary per project. The conventional versus green building comparison in relation to the Business School project did, however, provide a good indication as to what additional costs were involved in delivering a four star rating green building. The actual costs of implementing a four star rated green building as per the stipulations of the rating tool are illustrated in Tables 4.13 to 4.28.

Table 4.13 illustrates the credits associated with the Management category along with the aim of each credit.

Table 4.13: Management credits and credit aims

CATEGORY REFERENCE	CREDIT	CREDIT AIM
Man-1	Green Star accredited professional	Engagement of a Green Star accredited professional in the design team from design phase through to construction completion
Man-2	Commissioning clauses	To encourage and recognise commissioning and handover initiatives to

CATEGORY REFERENCE	CREDIT	CREDIT AIM
		ensure that all building services can operate to optimal design potential
Man-3	Building tuning	To encourage and recognise commissioning initiatives that ensures optimum occupant comfort as well as energy and water efficient services performance throughout the year
Man-4	Independent commissioning agent	To ensure buildings are designed with regard to future maintenance and are correctly commissioned before handover
Man-5	Building users guide	To encourage and recognise information management that enables building users to optimise the building's environmental performance
Man-6	Environmental management	To encourage and recognise the adoption of a formal environmental management system in line with established guidelines during construction
Man-7	Waste management	To encourage and recognise management practices that minimise the amount of construction waste going to disposal
Man-8	Air tightness testing	To encourage and recognise measures to reduce air leakage in buildings, and reward the testing and achievement of good airtightness levels
Man-10	Building management systems	To encourage and recognise the incorporation of Building Management Systems to actively control and maximise the effectiveness of building services
Man-13	Learning resources	To encourage and recognise sustainability initiatives implemented in the development as learning resources for building users and visitors
Man-14	Life cycle costing	To encourage and recognise the development of a Life Cycle Cost (LCC) analysis model for the project to improve design, specification and through-life maintenance and operation
Man-15	Maintainability	To encourage and recognise building design that facilitates ongoing maintenance, and minimises the need for ongoing building maintenance throughout a building's lifecycle.

Source: GBCSA (2011)

As illustrated in Table 4.13, twelve management categories are applicable.

Table 4.14 illustrates the costs associated with the targeted points relevant to the management category.

Table 4.14: Management category project costs

MANAGEMENT CATEGORY: WEIGHT 11%				
Category Reference	**Credit**	**Points Available**	**Points Targeted for a 4 Star Rated Building**	**Cost**
Man-1	Green Star accredited professional	2	2	R2,114,700
Man-2	Commissioning clauses	2	2	R31,152
Man-3	Building tuning	2	0	R0
Man-4	Independent commissioning agent	1	0	R0

MANAGEMENT CATEGORY: WEIGHT 11%				
Category Reference	Credit	Points Available	Points Targeted for a 4 Star Rated Building	Cost
Man-5	Building users guide	1	1	R5,894
Man-6	Environmental management	2	2	R56,054
Man-7	Waste management	3	2	R0
Man-8	Air tightness testing	1	0	R0
Man-10	Building management systems	1	1	R401,604
Man-13	Learning resources	1	1	R64,829
Man-14	Life cycle costing	1	0	R0
Man-15	Maintainability	2	2	R0
TOTAL		**19**	**12**	R2,674,232

Source: Nelson Mandela Metropolitan University (2012)

The predominant costs associated with the management category as illustrated in Table 4.14 are that of the green star accredited professional and building management systems.

Table 4.15 illustrates the credits associated with the Indoor Environmental Quality category along with the aim of each credit.

Table 4.15: Indoor environmental quality credits and credit aims

CATEGORY REFERENCE	CREDIT	CREDIT AIM
IEQ-1	Ventilation rates	To encourage and recognise designs that provide ample amounts of good quality outside air to counteract build-up of indoor pollutants
IEQ-2	Air change effectiveness	To encourage and recognise systems that effectively deliver optimum air quality to any occupant throughout the occupied area
IEQ-3	Carbon dioxide monitoring	To encourage and recognise the provision of response monitoring of carbon dioxide levels to ensure delivery of optimum quantities of outside air
IEQ-4	Daylight	To encourage and recognise designs that provide good levels of daylight for building users
IEQ-5	Daylight glare control	To encourage and recognise buildings that are designed to reduce the discomfort of glare from natural light
IEQ-6	High frequency ballasts	To encourage and recognise the increase in workplace amenity by avoiding low frequency flicker that may be associated with fluorescent lighting
IEQ-7	Lighting levels	To encourage and recognise public building lighting that is not over designed
IEQ-8	External views	To encourage and recognise designs that provide occupants with a visual connection to the external environment
IEQ-9	Thermal comfort	To encourage and recognise buildings that achieve a high level of thermal

CATEGORY REFERENCE	CREDIT	CREDIT AIM
		comfort
IEQ-11	Hazardous materials	To encourage and recognise actions taken to reduce health risks to occupants from the presence of hazardous materials
IEQ-12	Internal noise levels	To encourage and recognise buildings that are designed to maintain internal noise levels at an appropriate level and provide indoor acoustics for students to effectively communicate
IEQ-13	VOCs	To encourage and recognise specification of interior finishes that minimise the contribution and levels of Volatile Organic Compounds in buildings
IEQ-14	Formaldehyde	To encourage and recognise the specification of products with low formaldehyde emission levels
IEQ-15	Mould prevention	To encourage and recognise the design of services that eliminate the risk of mould growth and its associated detrimental impact on occupant health
IEQ-16	Tenant exhaust riser	To encourage and recognise the design of buildings with a dedicated exhaust riser that is used to remove indoor pollutants from printing and photocopy rooms
IEQ-17	Tobacco smoke avoidance	To encourage and recognise the air quality benefits to occupants by prohibiting smoking inside the building
IEQ-23	Stairs	To encourage and recognise designs that promote the wellbeing of occupants by encouraging the use of stairs as an alternative to vertical transportation by lift

Source: GBCSA (2011)

As illustrated in Table 4.15, seventeen Indoor Environmental Quality categories are applicable.

Table 4.16 illustrates the costs associated with the targeted points relevant to the Indoor Environmental Quality category.

Table 4.16: Indoor environmental quality category project costs

INDOOR ENVIRONMENTAL QUALITY CATEGORY: WEIGHT 15%				
Category Reference	Credit	Points Available	Points Targeted for a 4 Star Rated Building	Cost
IEQ-1	Ventilation rates	3	0	R0
IEQ-2	Air change effectiveness	2	0	R0
IEQ-3	Carbon dioxide monitoring	1	0	R0
IEQ-4	Daylight	3	1	R0
IEQ-5	Daylight glare control	1	1	R1,800,000
IEQ-6	High frequency ballasts	1	1	R5,894
IEQ-7	Lighting levels	1	0	R58,936
IEQ-8	External views	2	1	R0
IEQ-9	Thermal comfort	2	1	R673,550
IEQ-11	Hazardous materials	0	N/A	R0

INDOOR ENVIRONMENTAL QUALITY CATEGORY: WEIGHT 15%				
Category Reference	**Credit**	**Points Available**	**Points Targeted for a 4 Star Rated Building**	**Cost**
IEQ-12	Internal noise levels	3	3	R0
IEQ-13	VOCs	3	3	R0
IEQ-14	Formaldehyde	1	1	R0
IEQ-15	Mould prevention	1	0	R0
IEQ-16	Tenant exhaust riser	1	1	R67,355
IEQ-17	Tobacco smoke avoidance	1	1	R0
IEQ-23	Stairs	1	1	R0
TOTAL		**27**	**16**	R2,605,734

Source: Nelson Mandela Metropolitan University (2012)

The predominant costs associated with the Indoor Environmental Quality category as illustrated in Table 4.16 are that of daylight glare control and thermal comfort.

Table 4.17 illustrates the credits associated with the Energy category along with the aim of each credit.

Table 4.17: Energy category credits and credit aims

CATEGORY REFERENCE	CREDIT	CREDIT AIM
Ene-1	Greenhouse gas emissions	To encourage and recognise designs that minimise the greenhouse gas emissions associated with operational energy consumption, and maximise potential operational energy efficiency of the base building
Ene-2	Energy sub metering	To encourage and recognise the installation of electrical energy sub-metering to facilitate ongoing management of electrical energy consumption
Ene-4	Lighting zoning	To encourage and recognise lighting design practices that offer greater flexibility for light switching, making it easier to light only occupied areas
Ene-5	Peak energy demand reduction	To encourage and recognise designs that reduce maximum demand on electrical supply infrastructure
Ene-6	Thermal energy sub-metering	To encourage and recognise the installation of thermal energy sub-metering to facilitate ongoing management of thermal energy consumption
Ene-11	Unoccupied spaces	To encourage and recognise designs that minimise or eliminate energy use for spaces when unoccupied

Source: GBCSA (2011)

As illustrated in Table 4.17, six Energy categories are applicable.

Table 4.18 illustrates the costs associated with the targeted points relevant to the Energy category.

Table 4.18: Energy category project costs

ENERGY CATEGORY: WEIGHT 26%				
Category Reference	**Credit**	**Points Available**	**Points Targeted for a 4 Star Rated Building**	**Cost**
Ene-1	Greenhouse gas emissions	20	6	R5,894
Ene-2	Energy sub-metering	2	1	R106,926
Ene-4	Lighting zoning	2	1	R5,894
Ene-5	Peak energy demand reduction	2	1	R623,034
Ene-6	Thermal energy sub-metering	0	N/A	R0
Ene-11	Unoccupied spaces	2	2	R5,894
TOTAL		**28**	**11**	R747,640

Source: Nelson Mandela Metropolitan University (2012)

The predominant costs associated with the Energy category as illustrated in Table 4.18 are that of peak energy demand reduction and energy sub-metering.

Table 4.19 illustrates the credits associated with the Transportation category along with the aim of each credit.

Table 4.19: Transport category credits and credit aims

CATEGORY REFERENCE	CREDIT	CREDIT AIM
Tra-1	Provision of car parking	To encourage and recognise developments that facilitate the use of alternative modes of transport for staff and visitors/students travelling to Public and Education Buildings
Tra-2	Fuel efficient transport	To encourage and recognise developments that facilitate the use of more efficient vehicles for staff and visitors/students travelling to Public and Education Buildings
Tra-3	Cyclist facilities	To encourage and recognise developments that facilitate the use of bicycles by staff and visitors / students
Tra-4	Commuting mass transport	To encourage and recognise developments that select a site near public transport and facilitate the use of mass transport for staff and visitors / students travelling to the Public and Education building
Tra-5	Local connectivity	To encourage and recognise Public and Education buildings that are integrated with or built adjacent to community amenities and / or dwellings in order to reduce the overall number of automobile trips taken by building users
Tra-7	Vehicle operating emissions	To encourage and recognise Public and Education buildings that reduces vehicular emissions resulting from traffic congestion by upgrading road

CATEGORY REFERENCE	CREDIT	CREDIT AIM
		infrastructure around the building

Source: GBCSA (2011)

As illustrated in Table 4.19, six Transport categories are applicable.

Table 4.20 illustrates the costs associated with the targeted points relevant to the Transport category.

Table 4.20: Transport category project costs

TRANSPORT CATEGORY: WEIGHT 12%				
Category Reference	**Credit**	**Points Available**	**Points Targeted for a 4 Star Rated Building**	**Cost**
Tra-1	Provision of car parking	2	2	R0
Tra-2	Fuel efficient transport	2	1	R0
Tra-3	Cyclist facilities	3	3	R505,162
Tra-4	Commuting mass transport	5	1	R0
Tra-5	Local connectivity	2	1	R0
Tra-7	Vehicle operating emissions	2	0	R0
TOTAL		**14**	**8**	R505,162

Source: Nelson Mandela Metropolitan University (2012)

The predominant costs associated with the Transport category as illustrated in Table 4.20 is that of cyclist facilities.

Table 4.21 illustrates the credits associated with the Water category along with the aim of each credit.

Table 4.21: Water category credits and credit aims

CATEGORY REFERENCE	CREDIT	CREDIT AIM
Wat-1	Potable water	To encourage and recognise designs that reduce potable water consumption by building occupants
Wat-2	Water meters	To encourage and recognise the design of systems that both monitor and manage water consumption
Wat-5	Fire system water consumption	To encourage and recognise building design which reduces consumption of potable water for the building's fire protection and essential water storage systems

CATEGORY REFERENCE	CREDIT	CREDIT AIM
Wat-9	Building specific major water use	To encourage and recognise building design that reduces potable water consumption from major water uses in the building

Source: GBCSA (2011)

As illustrated in Table 4.21, four Water categories are applicable.

Table 4.22 illustrates the costs associated with the targeted points relevant to the Water category.

Table 4.22: Water category project costs

WATER CATEGORY: WEIGHT 13%				
Category Reference	**Credit**	**Points Available**	**Points Targeted for a 4 Star Rated Building**	**Cost**
Wat-1	Potable water	12	6	R84,194
Wat-2	Water meters	3	2	R47,220
Wat-5	Fire system water consumption	0	N/A	R0
Wat-9	Building specific major water use	0	N/A	R0
TOTAL		**15**	**8**	R131,414

Source: Nelson Mandela Metropolitan University (2012)

The predominant costs associated with the Water category as illustrated in Table 4.22 is that of potable water.

Table 4.23 illustrates the credits associated with the Materials category along with the aim of each credit.

Table 4.23: Materials category credits and credit aims

CATEGORY REFERENCE	CREDIT	CREDIT AIM
Mat-1	Recycling waste storage	To encourage and recognise the inclusion of storage space that facilitates the recycling of resources used within buildings to reduce waste going to disposal
Mat-2	Building reuse	To encourage and recognise developments that reuse existing buildings to minimise materials consumption
Mat-3	Recycled content and reused materials	To encourage and recognise designs that prolong the useful life of existing products and materials and encourage uptake of products with

CATEGORY REFERENCE	CREDIT	CREDIT AIM
		recycling content
Mat-5	Concrete	To encourage and recognise the reduction of embodied energy and resource depletion occurring through use of concrete
Mat-6	Steel	To encourage and recognise the reduction in embodied energy and resource depletion associated with reduced use of virgin steel
Mat-7	PVC minimisation	To encourage and recognise the reduction in use of Poly Vinyl Chloride (PVC) products in South African buildings
Mat-8	Sustainable timber	To encourage and recognise the specification of reused timber products or timber that has certified environmentally responsible forest management practices
Mat-9	Design for disassembly	To encourage and recognise designs that minimise the embodied energy and resources associated with demolition
Mat-10	Dematerialisation	To encourage and recognise designs that produce a net reduction in the total amount of material used
Mat-11	Local sourcing	To encourage and recognise the environmental advantages gained in the form of reduced transportation emissions by using materials and products that are sourced within close proximity to the site
Mat-13	Masonry	To encourage and recognise the reduction of embodied energy and resource depletion associated with a reduction of virgin material in masonry units

Source: GBCSA (2011)

As illustrated in Table 4.23, eleven Materials categories are applicable.

Table 4.24 illustrates the costs associated with the targeted points relevant to the Materials category.

Table 4.24: Materials category project costs

MATERIALS CATEGORY: WEIGHT 9%				
Category Reference	**Credit**	**Points Available**	**Points Targeted for a 4 Star Rated Building**	**Cost**
Mat-1	Recycling waste storage	3	3	R0
Mat-2	Building reuse	0	N/A	R0
Mat-3	Recycled content and reused materials	2	0	R0
Mat-5	Concrete	3	1	R0
Mat-6	Steel	3	3	R0
Mat-7	PVC minimisation	1	1	R115,345
Mat-8	Sustainable timber	2	0	R0
Mat-9	Design for disassembly	1	0	R0
Mat-10	Dematerialisation	1	0	R0
Mat-11	Local sourcing	2	2	R0
Mat-13	Masonry	2	1	R0
TOTAL		**20**	**11**	R115,345

Source: Nelson Mandela Metropolitan University (2012)

The predominant costs associated with the Materials category as illustrated in Table 4.24 is that of PVC minimisation.

Table 4.25 illustrates the credits associated with the Land Use and Ecology category along with the aim of each credit.

Table 4.25: Land use and ecology category credits and credit aims

CATEGORY REFERENCE	CREDIT	CREDIT AIM
Eco-1	Topsoil	To encourage and recognise construction practices that preserve the ecological integrity of topsoil
Eco-2	Reuse of land	To encourage and recognise the reuse of land that has previously been developed and where the site is within an existing municipally approved urban edge
Eco-3	Reclaimed contaminated land	To encourage and recognise developments that reclaim contaminated land that otherwise would not have been developed
Eco-4	Change of ecological value	To encourage and recognise developments that maintain or enhance the ecological value of their sites
Eco-5	Urban heat island	To reduce 'urban' heat islands to subsequently minimise impacts on microclimates and human and wildlife habitats
Eco-8	Community facilities	To encourage and recognise integrated planning and shared land use in developments through the provision of on-site outdoor facilities for use by the local community

Source: GBCSA (2011)

As illustrated in Table 4.25, six Land Use and Ecology categories are applicable.

Table 4.26 illustrates the costs associated with the targeted points relevant to the Land Use and Ecology category.

Table 4.26: Land use and ecology category project costs

LAND USE AND ECOLOGY CATEGORY: WEIGHT 7%				
Category Reference	Credit	Points Available	Points Targeted for a 4 Star Rated Building	Cost
Eco-1	Topsoil	1	1	R0
Eco-2	Reuse of land	2	2	R0

LAND USE AND ECOLOGY CATEGORY: WEIGHT 7%				
Category Reference	**Credit**	**Points Available**	**Points Targeted for a 4 Star Rated Building**	**Cost**
Eco-3	Reclaimed contaminated land	2	0	R0
Eco-4	Change of ecological value	4	2	R0
Eco-5	Urban heat island	2	1	R0
Eco-8	Community facilities	1	0	R0
TOTAL		**12**	**6**	R0

Source: Nelson Mandela Metropolitan University (2012)

No additional costs are associated are associated with the Land Use and Ecology as illustrated in Table 4.26.

Table 4.27 illustrates the credits associated with the Emissions category along with the aim of each credit.

Table 4.27: Emissions category credits and credit aims

CATEGORY REFERENCE	CREDIT	CREDIT AIM
Emi-1	Refrigerant / gaseous ODP	To encourage and recognise the selection of refrigerants and other gases that do not contribute to long-term damage to the Earth's stratospheric ozone layer
Emi-2	Refrigerant GWP	To encourage and recognise the selection of refrigerants that reduce the potential for increased global warming from the emission of refrigerants to the atmosphere
Emi-3	Refrigerant leaks	To encourage and recognise building systems design that minimises environmental damage from refrigerant leaks
Emi-4	Insulant ODP	To encourage and recognise the selection of insulants that does not contribute to long-term damage to the Earth's stratospheric ozone layer.
Emi-5	Watercourse pollution	To encourage and recognise developments that minimise stormwater run-off to, and the pollution of, the natural watercourses
Emi-6	Discharge to sewer	To encourage and recognise developments that minimise discharge to the municipal sewerage system
Emi-7	Light pollution	To encourage and recognise developments that minimise light pollution into the night sky
Emi-8	Legionella	To encourage and recognise building systems design that eliminates the risk of Legionnaires' disease (Legionellosis)
Emi-9	Boiler and generator emissions	To encourage and recognise the use of boilers and generators that minimise harmful emissions

Source: GBCSA (2011)

As illustrated in Table 4.27, nine Emissions categories are applicable.

Table 4.28 illustrates the costs associated with the targeted points relevant to the Emissions category.

Table 4.28: Emissions category project costs

EMISSIONS CATEGORY: WEIGHT 6%				
Category Reference	**Credit**	**Points Available**	**Points Targeted for a 4 Star Rated Building**	**Cost**
Emi-1	Refrigerant / gaseous ODP	1	1	R3,500
Emi-2	Refrigerant GWP	2	0	R0
Emi-3	Refrigerant leaks	2	0	R0
Emi-4	Insulant ODP	1	1	R3,500
Emi-5	Watercourse pollution	3	0	R0
Emi-6	Discharge to sewer	4	1	R0
Emi-7	Light pollution	1	1	R22,732
Emi-8	Legionella	1	1	R0
Emi-9	Boiler and generator emissions	1	1	R5,894
TOTAL		**16**	**7**	R345,626

Source: Nelson Mandela Metropolitan University (2012)

The predominant costs associated with the Emissions category as illustrated in Table 4.28 is that of light pollution.

In summary, the costs per category are illustrated in Table 4.29.

Table 4.29: Additional costs per green building category

CATEGORY	COSTS
Management	R2,674,232
Indoor Environmental Quality	R2,605,734
Energy	R747,640
Transport	R505,162
Water	R131,414
Materials	R115,345
Land Use and Ecology	R0
Emissions	R345,626
TOTAL	**R7,125,153**

Source: Nelson Mandela Metropolitan University (2012)

The total budget for the development of the new Business School wasR116,000,000. Within the context of Nelson Mandela Metropolitan University, the additional costs required so as to attain a four star rated green building totalled R7,125,153, which was 6.14% of the total budget as illustrated in Table 4.30.

Table 4.30: Nelson Mandela Metropolitan University Business School development costs

	TOTAL BUDGET	GREEN COMPONENT WITHIN THE TOTAL BUDGET	BUDGET EXCLUDING GREEN COMPONENT
Development of a new Business School	R116,000,000	R7,125,153	R108,874,847

Source: Nelson Mandela Metropolitan University (2012)

In summary, the respective costs of developing green buildings at Nelson Mandela Metropolitan University are reflected in Table 4.31. Considering that Nelson Mandela Metropolitan University is to embark on constructing further buildings to the value of R263,000,000 during the next year, an additional approximate amount of R16,148,200 (R263,000,000 x 6,14%) would be required to attain four star rated green buildings.

Table 4.31: Summary of the respective costs of developing green buildings at Nelson Mandela Metropolitan University

COMPONENT	COSTS / COMMENT
Assessment of the costs relating to a sustainable infrastructure intervention area (construction of green buildings) with respect to: • Capital costs (2012 prices). This is the figure that would populate the eventual framework in determining a relational cost benefit per intervention area subject to the application of a sustainability indicator per intervention area • Operational costs (year 1)	• Capital cost: R16,148,200 • Operational cost (year 1): R0
Comparison of sustainable infrastructure cost to that of conventional infrastructure	The total initial cost of undertaking a green building programme based on R263,000,000 of new development totals R16,148,200
Reference is made to: • Cost benefits of undertaking the specific sustainable infrastructure intervention areas • Estimated lifecycle costs (namely, initial cost of the investment + life time cost of maintenance + cost of precautionary maintenance) of the	• Conventional buildings are less energy efficient, less resource efficient and less environmentally responsible. As such the cost benefit of green buildings in ensured through greater energy and resource efficiencies • Estimated lifecycle costs of the programme would equate to R279,148,200 + 4%% of the annual replacement value

COMPONENT	COSTS / COMMENT
specific sustainable infrastructure intervention area	of the components per year for up to 30 to 50 years

Source: Author's own compilation

From Table 4.31, it is evident that the total cost of developing green buildings at Nelson Mandela Metropolitan University would amount to R16,148,200 in addition to the R263,000,000 amount.

(d) Cost of Intervention area 4: Operation and Maintenance costs

The 2008, edition of the Leonardo Academy's annual white paper on the economics of LEED (Leadership in Energy and Environmental Design) for existing buildings seeks to determine the costs of implementing LEED for existing buildings. As no rating system exists within South Africa with respect to the operation and maintenance of existing buildings, for the purposes of this study, the findings of the 2008 study was used as a basis in determining the costs associated in attaining green building status for operation and maintenance.

Two predominant categories of cost were analysed in the 2008 Leonardo Academy report when determining the economics of LEED for existing buildings, namely:

- Certification, implementation and process costs; and
- Operating costs.

Certification, implementation and process costs include internal staff costs associated with achieving a LEED certification, consultant fees, total soft costs along with total hard costs for building improvement. Operating cost comparisons are achieved by comparing LEED certified building operating costs against non-certified building operating costs.

As with the GBCSA's pilot Public and Education Building rating tool (2011) with respect to the development of new buildings, the LEED (2009) Green Building Rating System for the Operation and Maintenance of Existing Buildings utilises a set of performance standards for certifying the operations and maintenance of existing buildings. These performance standards, which were discussed Chapter Three, include sustainable sites, water efficiency, energy and atmosphere, indoor environmental quality and innovation. Points are awarded for the achievement of the stipulated criteria within each category. A category score is thus determined for each category based on the percentage of criteria achieved. A LEED rating is then determined as per the scale illustrated in Table 4.32

Table 4.32: LEED rating schedule- existing buildings: operation and maintenance

OVERALL SCORE	RATING
40-49 points	Certified
50-59 points	Silver
60-79 points	Gold
80 points and above	Platinum

Source: LEED (2009) for Existing Buildings, Operations and Maintenance

As with the construction of the Green Building component discussed in Section 4.5, for the purposes of this study, costs would be analysed as per the silver rating with respect to the operations and maintenance of existing buildings as per the LEED rating tool.

The Leonardo Academy (2008) obtained the costs for the operation and maintenance of LEED rated buildings by means of a survey. The survey obtained information from the owners and managers of LEED certified buildings wherein each owner distinguished between low or no cost measures and significant cost measures for the respective prerequisites of the LEED rating tool. In summary the distinction between no or low costs and that of significant costs per each prerequisite emanating from the survey is reflected in Table 4.33.

Table 4.33: Distinction between no or low costs and significant costs per each prerequisite for the operation and maintenance of LEED rated buildings

PREREQUISITE CATEGORY	NO OR LOW COST	SIGNIFICANT COST
Sustainable sites	73.7%	26.3%
Water efficiency	75.5%	24.5%
Energy and atmosphere	58.4%	41.6%
Materials and resources	82.5%	17.5%
Indoor environmental quality	71.4%	28.6%

PREREQUISITE CATEGORY	NO OR LOW COST	SIGNIFICANT COST
Innovations	71.7%	28.3%

Source: Leonardo Academy (2008)

As illustrated in Table 4.33, the energy and atmosphere category is the prerequisite with significant costs when compared to the other categories.

Further analysis indicated that in implementing the prerequisites for a Silver rated LEED building, the following average costs were applicable.

- Total soft costs: An average of $0.91 per square foot
- Total hard costs: An average of 0.31 per square foot
- Total costs: An average of $1.22 per square foot

These costs reflect the costs associated with implementing a LEED rated building. The Leonardo Academy (2008) paper further analysed the subsequent operational costs of conventional buildings as opposed LEED rated buildings with respect to the following:

- Utility expenses
- Administrative expenses
- Security expenses
- Roads / grounds expenses
- Repair / maintenance expenses
- Cleaning expenses

The summary of the average building operating expenses per square foot of conventional buildings versus that of LEED rated buildings is reflected in Table 4.34.

Table 4.34: Average building operating expenses per square foot of conventional buildings versus LEED rated buildings

EXPENSES	AVERAGE COST PER SQUARE FOOT
Cleaning in LEED certified buildings	$1.79
Cleaning in conventional buildings	$1.28
Repair / maintenance in LEED certified buildings	$1.73

EXPENSES	AVERAGE COST PER SQUARE FOOT
Repair / maintenance in conventional buildings	$1.52
Roads and grounds in LEED certified buildings	$0.31
Roads and grounds in conventional buildings	$0.22
Security expenses in LEED certified buildings	$0.24
Security expenses in conventional buildings	$0.53
Administrative expenses in LEED certified buildings	$0.85
Administrative expenses in conventional buildings	$1.21
Utility expenses in LEED certified buildings	$1.76
Utility expenses in conventional buildings	$2.09
Total expenses in LEED certified buildings	$6.68
Total expenses in conventional buildings	$6.85

Source: Leonardo Academy (2008)

As illustrated in Table 4.34, expenses in relation to cleaning, repair and maintenance, roads and grounds and security are higher in LEED certified buildings as opposed to conventional buildings. Expenses in relation to administration and utility services are higher in conventional buildings as opposed to LEED certified buildings. Overall, total operational expenses in conventional buildings are $0.17 / square foot more costly than in LEED certified buildings.

The information in Tables 4.33 and 4.34 illustrates the costs of implementing and certifying a LEED rated building along with the subsequent operational expenses once a building is certified. Based on the information contained in Table 4.34, for the purposes of this study, it was presumed that total operational costs (utility expenses, administrative expenses, security expenses, grounds expenses, maintenance expenses and cleaning expenses) would decrease with a LEED certified building. As such, for the purposes of this study, the implementation and certification costs associated with implementing LEED for existing buildings needs to be considered. The total costs as determined by the Leonardo Academy's white paper (2008) were $1.22 per square foot. In 2008, the average Rand / US Dollar exchange rate equalled R12.28 to the Dollar. For the South African context, this translates to a rate of R161.26 / square meter (assuming a Rand / Dollar exchange of R12.28 to the Dollar).

Applying the R161.26 / square meter rate to the area of buildings currently located on Nelson Mandela Metropolitan University campuses is reflected in Table 4.35.

Table 4.35: Estimation of costs required to upgrade existing buildings as per a Silver LEED certification

CAMPUS	AREA OF BUILDINGS (SQM)	ESTIMATION OF COST TO IMPLEMENT AS PER A SILVER LEED CERTIFICATION (@ A RATE OF R161.26 /SQM)
South Campus	143,737	R23,179,028
North Campus	61,560	R9,927,165
2nd Avenue Campus	17,160	R2,767,222
Missionvale Campus	23,539	R3,795,899
Bird Street Campus	4,767	R768,726
TOTAL	250,763	R40,438,041

Source: Author's own compilation

As illustrated in Table 4.35, the estimated costs in upgrading existing buildings as per a Silver LEED certification totalled R40,438,041 across all of Nelson Mandela Metropolitan University campuses. This estimation was based on 2008 prices. If this were to be quantified in terms of 2012 prices, as per the annual average CPI rate of 5.5%, this would equate to R50,095,641.

Davis Langdon (2012) makes an international building cost rate comparison between various countries. With respect to South Africa and the United States of America, a broad cost comparison ratio of 1:2,96 can be calculated between the two countries. Applying the ratio to the R50,095,641 figure would loosely translate to a cost of R16,924,203. As such, it can be broadly estimated that the costs in upgrading existing buildings as per a Silver LEED certification would approximately total R16,924,203 across all of Nelson Mandela Metropolitan University campuses.

In summary, the respective costs of upgrading existing buildings as per a Silver LEED certification are reflected in Table 4.36.

Table 4.36: Summary of the respective costs of upgrading existing buildings as per a Silver LEED certification at Nelson Mandela Metropolitan University

COMPONENT	COSTS / COMMENT
Assessment of the costs relating to a sustainable infrastructure intervention area (construction of green buildings) with respect to: • Capital costs (2012 prices). This is the figure that would populate the eventual framework in determining a relational cost benefit per intervention area subject to the application of a sustainability indicator per intervention area • Operational costs (year 1)	• Capital cost: R16,924,203 • Operational cost (year 1): R0
Comparison of sustainable infrastructure cost to that of conventional infrastructure	The total initial cost of undertaking an upgrade programme totals R16,924,203
Reference would be made to: • Cost benefits of undertaking the specific sustainable infrastructure intervention areas • Estimated lifecycle costs (namely, initial cost of the investment + life time cost of maintenance + cost of precautionary maintenance) of the specific sustainable infrastructure intervention area	• As depicted in Section 4.6 costs (utility expenses, administrative expenses, security expenses, grounds expenses, maintenance expenses and cleaning expenses) would decrease with a LEED certified building • Estimated lifecycle costs of the programme would equate to the total capital value of all buildings on campus + 4% of the annual replacement value of the components per year for up to 30 to 50 years

Source: Author's own compilation

Table 4.36 depicts that the initial cost to undertake an upgrade programme as per a LEED Silver rating which totals approximately R16,924,203.

(e) Cost of Intervention area 5: Wastewater costs

As discussed in Chapter Three, for the purposes of this study, alternative wastewater treatment refers to the treatment of wastewater by means of constructed wetlands, and treated wastewater reuse. The costs related to implementing each of these components need to be considered.

- Constructed wetlands

Constructed wetland wastewater treatment systems are more suited for small communities owing to their low construction and operation and maintenance costs (Tsihrintzis, Akratos, Gikas, Karamouzis & Angelakis, 2007). Two predominant constructed wetland systems occur, namely, a free water surface constructed wetland and a vertical surface wetland system.

A free water surface constructed wetland allows water to flow above ground through a series of channels that aims to replicate the natural processes of a natural wetland, namely, removing nutrients from wastewater and degrading organics. A vertical flow constructed wetland is a filter bed that is planted with aquatic plants. Wastewater is fed into the wetland surface utilising a mechanical dosing system.

Tsihrintzis *et al* (2007) evaluated the costs of both a free water surface constructed wetland and that of a vertical flow constructed wetland. It is possible to implement both forms of constructed wetland within Nelson Mandela Metropolitan University. The approximate land area required for each system is as follows:

- Free water surface constructed system: 5500 m²
- Vertical flow constructed system: 2040 m²

As Nelson Mandela Metropolitan University possesses sufficient land, either of the free water surface or vertical flow systems could be constructed from a land area perspective. In addition, land costs need not be taken into account as Nelson Mandela Metropolitan University possesses the land.

The respective costs of both the free water surface constructed wetland (FSW) and that of the vertical flow constructed wetlands (VSW) as determined by Tsihrintzis *et al* (2007) are illustrated in Table 4.37.

Table 4.37: Capital and operating costs (€) for a free water surface constructed wetland and a vertical flow constructed wetland

COST CATEGORY	COST (€) 2010 Prices	
	FWS SYSTEM	VSF SYSTEM
Capital, including VAT (construction cost)	344,615	410,850
Construction cost per organic load (p.e.)	287.18	410.85
Net present value cost	25,036	29,848
Annual average operation and maintenance (O&M) cost	1,445	6,960
O&M cost per organic load (p.e.) per year	1.20	6.96
O&M cost per m³ per year	0.03	0.11
Total annual cost (capital and O&M)	26,481	36,808
Total annual cost per organic load (p.e.)	22.07	36.81
Total annual cost per m³ of influent	0.50	0.56

Tsihrintzis *et al* (2007)

Table 4.37 illustrates that the construction costs of a free water surface system is cheaper than that of a vertical flow system. In 2010, the average Rand / Euro exchange rate equalled R10.32 to the Euro. For the South African context, this translates to an amount of R3,556,427 to implement a free water surface system as per cost criteria. As the estimation was based on 2010 prices, this would equate to R3,958,391 if this were to be quantified in terms of 2012 prices, as per the annual average CPI rate of 5.5%.

In Turner and Townsend's (2012) International Construction Cost Survey, an international building cost rate comparison was made between various countries. With respect to the Rand and the Euro, a broad cost comparison ratio of 1:1,57 could be calculated between the two currencies. Applying the ratio to the R3,958,391 cost, would loosely translate to a cost of R2,521,268. As such, it can be broadly estimated that the costs in developing a free water surface system could approximately total R2,521,268.

- Treated wastewater reuse

Nelson Mandela Metropolitan University currently makes use of reclaimed water from a municipal supply for the purposes of grounds irrigation. The current reticulation, however, does not service all grounds and sport fields within Nelson Mandela Metropolitan University. The university thus investigated the option of establishing a treated wastewater dam which would be able to service all grounds and sport fields within the Summerstrand Campus.

The cost breakdown of constructing such a facility is depicted in Table 4.38.

Table 4.38: Costs of constructing a 4000kl HDPE line raw water dam

COMPONENT	COST
Section A: Construction of 4000kl HDPE Lined Raw Water Dam	
Preliminary and general items	R200,000
Site clearance	R50,000
Earthworks	R300,000
Layerworks (imported gravel layers)	R500,000
1.5mm HDPE liner	R350,000
Steel pipework and valve chambers	R100,000
Total Section A: Construction (excl. contingencies and VAT)	R1,500,000

COMPONENT	COST
10% contingencies	R150,000
Total Section A: Construction (excl. VAT)	R1,650,000
Section B: Engineering Services	
Fees (12.5% on construction value)	R200,000
Occupational health and safety agent	R15,000
Disbursements	R10,000
Total Section B: Engineering Services (excl. VAT)	R225,000
Section C: Other Services	
Geotechnical investigation	R25,000
Contour survey	R25,000
Total Section C: Additional Services (excl. VAT)	R50,000
Totals Sections A, B and C (excl. VAT)	R1,925,000
Add 14% VAT	R269,500
Total Sections A, B and C (incl. VAT)	R2,194,500
Section D: Other Costs	
Booster pump station	R380,000
TOTAL COSTS	R2,574,500

Source: Nelson Mandela Metropolitan University (2011)

As illustrated by Table 4.38, the total costs associated with establishing a treated wastewater dam for the purposes of irrigation totalled R2,574,500. If this had to be quantified in terms of 2012 prices, as per the annual average CPI rate of 5.5%, this would equate to a cost of R2,716,097.

The cost components identified could potentially form the basis of an alternative wastewater management programme for Nelson Mandela Metropolitan University. In summary, the respective costs of the various potential interventions of a wastewater management programme at Nelson Mandela Metropolitan University are reflected in Table 4.39.

Table 4.39: Summary of the respective costs of potential interventions of an alternative wastewater management programme at Nelson Mandela Metropolitan University

COMPONENT	COSTS / COMMENT
Assessment of the costs relating to a sustainable infrastructure intervention area (demand side management) with respect to:	• Wetland: Free water surface constructed wetland: ○ Capital cost: R2,521,268 ○ Operational cost (year 1): R0

COMPONENT	COSTS / COMMENT
• Capital costs (2012 prices). This is the figure that would populate the eventual framework in determining a relational cost benefit per intervention area subject to the application of a sustainability indicator per intervention area • Operational costs (year 1)	• Treated wastewater reuse: ○ Capital cost: R2,716,097 ○ Operational cost (year 1): R0
Comparison of sustainable infrastructure cost to that of conventional infrastructure	The total initial cost of undertaking an alternative wastewater management programme as per the components as detailed in Section 4.7 totals R5,237,365
Reference would be made to: • Cost benefits of undertaking the specific sustainable infrastructure intervention areas • Estimated lifecycle costs (namely, initial cost of the investment + life time cost of maintenance + cost of precautionary maintenance) of the specific sustainable infrastructure intervention area	• Conventional forms of wastewater management are less energy efficient, less resource efficient and less environmentally responsible. As such the cost benefit of alternative forms of wastewater management was ensured through greater energy and resource efficiencies • Estimated lifecycle cost of the programme would equate to R5,237,365 + 4% of the annual replacement value of the components per year for up to 20 to 30 years

Source: Author's own compilation

As illustrated in Table 4.39, the total initial wastewater management costs total R5,237,365 and entails interventions with respect to wetland establishment and treated wastewater reuse.

(f) Cost of Intervention area 6: Water costs

As detailed in Chapter 3, for the purposes of this study, alternative water provision refers to the conservation of water by means of rainwater harvesting, grey water systems and desalination plants. The costs related to implementing each of these components needs to be considered.

- Rainwater harvesting

Within the context of Nelson Mandela Metropolitan University, rainwater harvesting could be utilised to reduce the demand on potable water for the purposes of grounds and field irrigation thereby effecting a saving in terms of municipal water bills. The primary components of a rainwater harvesting system consist of a catchment area, for example, a building roof, a coarse filtration unit and a storage tank and pump (Roebuck, Oltean-Dumbrava & Tait, 2011). The respective capital, operational and maintenance costs that can typically be associated with a 50,000m² catchment area are illustrated in Table 4.40.

Table 4.40: Typical costs associated with a rain water harvesting system with a catchment area of 50,000m²

COMPONENTS	COST (KOREAN WON)
CAPITAL COMPONENTS	
Excavation work, tank installation and pipeline work	150,000
Electronic and mechanical work, pump installation, control system	300,000
TOTAL CAPITAL COSTS	**450,000**
OPERATION AND MAINTENANCE COMPONENTS	
Electricity usage	1,935,678
Monitoring, repair, labour	10,000,000
TOTAL OPERATION AND MAINTENANCE COSTS	**11,934,678**
TOTAL COSTS	**12,384,678**

Source: Mun, Ki and Han(2008)

Table 4.40 illustrates the total costs broadly required so as to implement a rainwater harvesting system associated with a catchment area of 50,000m². The lifespan of such a system is estimated to total thirty-five years (Mun, *et al*, 2008).

In 2008, the average Rand / South Korean Won exchange rate equalled R1 to 132.98 South Korean Won. For the South African context, this translates to an amount of R93,132 to implement a rain water harvesting system with a catchment area of 50,000m². As this estimation was based on 2008 prices, if this were to be quantified in terms of 2012 prices, as per the annual average CPI rate of 5.5%, this would equate to R115,373.

In Turner and Townsend's (2012) International Construction Cost Survey, an international building cost rate comparison was made between various countries. With respect to the Rand and the Won, a broad cost comparison ratio of 1,03:1 could be calculated between the two currencies. Applying the ratio to the R115,373 cost would loosely translate to a cost of R118,834. As such, it could be broadly estimated that the costs in establishing a rainwater harvesting system with a catchment area of 50,000m² could approximately total a cost of R118,834.

- Grey water systems

Grey water refers to wastewater collected from clothes washers, showers and bathtubs to be utilised for reuse for toilet flushing and irrigation.

For the purposes of this study, the basis of determining the associated costs of potentially implementing a grey water reuse system at Nelson Mandela Metropolitan University will be applied against a cost benefit analysis case study of Greywater Reuse In Residential Schools in Madhya Pradesh, India (Godfrey, Labhaselwar & Wate, 2009). The case study was based on a girl's boarding school which contained three hundred occupants, required water of 10,000 litres where greywater was able to generate 4,000 to 6,000 litres. Given that Nelson Mandela Metropolitan University has 3,000 on-campus student residents, similar assumptions would made with respect to the costs associated with applying a greywater system to on-campus student residences.

The capital costs associated with implementing a greywater system that is able to generate 4,000 to 6,000 litres for a population of 300 people is reflected in Table 4.41.

Table 4.41: Capital costs of implementing a greywater system capable of generating 4,000 to 6,000 Litres

COMPONENT	QUANTITY	COST (Indian Rupee)
Gravels 40mm	$2m^3$	1,200
Gravels 10-20mm	1.25^3	600
Fine sand	$4m^3$	1,500
Bricks	2000	4,000
Cement	30 bags	6,000
PVC and GI pipe for pipeline connectivity with HDPE tank, screen, socket and nipple	Lump sum	8,000
0.25 HP pump	1	3,000
WRS covers	Lump sum	3,500
Filter material	Lump sum	2,500
Labour charges	Lump sum	5,000
Bunkers	Lump sum	3,000
Sprinkler system	Lump sum	5,000
Flush system	Lump sum	2,000
HDPE tanks	2	5,000
TOTAL		**50,300**

Source: Godfrey, *et al* (2009)

As reflected in Table 4.41, the total capital costs associated with implementing a greywater system capable of generating 4,000 to 6,000 litres of water totals 50,300 Indian Rupees.

The annual operating and maintenance costs associated with implementing a greywater system that is able to generate 4,000 to 6,000 litres for a population of 300 people is reflected in Table 4.42.

Table 4.42: Annual operating and maintenance costs of implementing a greywater system capable of generating 4,000 to 6,000 Litres

COMPONENT	COST (Indian Rupee)
Manpower	2,500
Energy	2,500
Maintenance of civil works (0,5% of cost of civil works)	175
Maintenance of electro mechanical works (3% of cost of electro mechanical works)	300
Cost of chlorine tablets	250
TOTAL	**5,725**

Source: Godfrey, *et al* (2009)

As reflected in Table 4.42, the annual operating and maintenance costs associated with implementing a greywater system capable of generating 4,000 to 6,000 totals 5,725 Indian Rupees.

Given that Nelson Mandela Metropolitan University currently houses 3,000 students on-campus, the potential exists to implement a grey water system as per the parameters as listed in Tables 4.41 and 4.42. If undertaken, potential costs for 3000 students would be as follows:

- Capital costs: 503,000 Rupees
- Operational costs: 57,250 Rupees

In 2009, the average Rand / Indian Rupee exchange rate equalled R1 to 5.8 Rupees. For the South African context this translated to an amount of R85,724 for capital costs and R9,871 for operational costs to implement a grey water system catering for 3,000 students. As this estimation was based on 2009 prices, if this were to be quantified in terms of 2012 prices, as per the annual average CPI rate of 5.5%, this would equate to R100,660 with respect to the capital costs and R11,589 with respect to the operational costs.

In Turner and Townsend's (2012) International Construction Cost Survey, an international building cost rate comparison was made between various countries. With respect to the Rand and the Rupee, a broad cost comparison ratio of 1,53:1 could be calculated between the two currencies. Applying the ratio to the R100,660 cost would loosely translate to a cost of R65,791. As such, it could be broadly estimated that the costs in establishing a grey water system catering for 3,000 on-campus students could approximately total R65,791 with respect to capital costs.

- Desalination plants

Desalination refers to the process of removing salts and impurities from seawater or brackish water, thereby allowing usage of the water as opposed to potable municipal water supply. Investigations undertaken by Nelson Mandela Metropolitan University indicated that the establishment of a desalination plant on its Missionvale Campus was a viable option with respect to addressing a potable water need of 650m³ / week. The costs associated with the establishment of a desalination plant, which would address the capacity need through the removal of salts and impurities from the current borehole water supply, is reflected in Table 4.43.

Table 4.43: Costs for the establishment of a desalination plant at Nelson Mandela Metropolitan University's Missionvale Campus (in order to produce 650m³ / week)

COMPONENT	COST
Capital cost	R623,700
Installation / delivery	R63,000
Tanks, slabs and housing	R309,750
Total Capital Cost	**R996,450**
Annual cost- Consumables	R68,000
Annual cost- Electricity @ R0.44 / kwh	R22,733
Total Operating Cost	**R90,733**
Annual Cost Total (Year One)	**R1,087,183**

COMPONENT	COST
Annual Cost (Year Two)	**R117,733**

Source: Nelson Mandela Metropolitan University (2011)

Table 4.43 illustrates the total costs required so establish a desalination plant in order to produce a potable volume of water of 650m³ / week. This estimation was based on 2011 prices. If this were to be quantified in terms of 2012 prices, as per the annual average CPI rate of 5.5%, this would equate to R1,051,254.

These cost components could potentially form the basis of an alternative water conservation programme for Nelson Mandela Metropolitan University. In summary, the respective costs of the various potential interventions of a water conservation programme at Nelson Mandela Metropolitan University are reflected in Table 4.44.

Table 4.44: Summary of the respective costs of potential interventions of an alternative water conservation programme at Nelson Mandela Metropolitan University

COMPONENT	COSTS / COMMENT
Assessment of the costs relating to a sustainable infrastructure intervention area (demand side management) with respect to: • Capital costs (2012 prices). This is the figure that would populate the eventual framework in determining a relational cost benefit per intervention area subject to the application of a sustainability indicator per intervention area • Operational costs (year 1)	• Rainwater harvesting: ○ Capital cost: R118,834 ○ Operational cost (year 1): R0 • Grey water system:: ○ Capital cost: R65,791 ○ Operational cost (year 1): R11,589 • Desalination plant: ○ Capital cost: R1,051,254 ○ Operational cost (year 1): R90,733
Comparison of sustainable infrastructure cost to that of conventional infrastructure	The total initial cost of undertaking an alternative water conservation programme as per the components as detailed in Section 4.8 totals R1,235,879.
Reference would be made to: • Cost benefits of undertaking the specific sustainable infrastructure intervention areas • Estimated lifecycle costs (namely, initial cost of the investment + life time cost of maintenance + cost of precautionary maintenance) of the specific sustainable infrastructure intervention area	• Conventional forms of water use are less energy efficient, less resource efficient and less environmentally responsible. As such the cost benefit of alternative forms of water conservation ensured through greater energy and resource efficiencies • Estimated lifecycle costs of the programme would equate to R1,235,879 + 4% of the annual replacement value of the components per year for up to 20 to 30 years

Source: Author's own compilation

As illustrated in Table 4.44, the total initial water conservation management costs total R1,235,879 and entails interventions with respect to rainwater harvesting, grey water systems and desalination plants.

(g) Cost of Intervention area 7: Energy costs

As detailed in Chapter Three, for the purposes of this study, alternative energy provision refers to small scale wind turbines and photovoltaics. The costs related to implementing each of these components need to be considered.

- Wind power

Wind power refers to energy that is captured from the wind with small wind turbines. Small wind turbines are generally programmed to generate power at an initial wind speed of 3m/s (Joubert & Keen, 2011). Nelson Mandela Metropolitan University is located within a region that is suitable for small wind turbine powered electricity.

For the purposes of this study, the parameters utilised in assessing the economic viability of wind turbines for Western Cape Farms, applying Germany's example (Joubert & Keen, 2011). This translates to analysing the cost benefits of twenty wind turbines per farms utilising a 3kW rated (vertical axis) turbine. Given the extent of each of Nelson Mandela Metropolitan University's campuses, twenty small wind turbines easily could be located on each campus. This equates to one hundred wind turbines in total.

The costs associated with the installation of small wind turbines on Western Cape Farms (Joubert & Keen, 2011) is illustrated in Table 4.45.

Table 4.45: Costs associated with the installation of small wind turbines on Western Cape farms

COMPONENT	COST
1- Capital investment (for 20 turbines)	R261,240
2- Cost of maintenance	R400,000
3- Precautionary maintenance	R4,000
4- Opportunity cost	R762,234
TOTAL LIFE CYCLE COST	**R1,427,654**

NOTES EXPLAINED
1- Represents initial installation cost and investment per 3kW turbine. Each farm would have a projected average. of 20 turbines. The $/R exchange rate was currently 6.92:1 (rounded to 7 for simplification. Total- R261 240).
2- Yearly maintenance cost per turbine is approx. 100 Euros. The Euro/Rand exchange rate was approx. 10:1 and there were 20 turbines on average per farm for 20 years. Total- R 400 000
3- Initial precautionary costs would be about R200 per turbine. These costs represent the safety mechanisms that are around each turbine, for example, sSigns to warn people of dangerous turbines. This would be an initial outlay of about R200 per turbine. Total- R4000
4- This was the opportunity cost of the initial investment for 20 years at current interest rates (5.5%) . Total-R 762234.96
Hence total LCC =261420+400000+4000+762234.96 *= R 1 427 654.90 for 20 years if wind turbines were installed on a WC farm*

Source: Joubert and Keen (2011)

Applying the Western Cape example as illustrated in Table 4.45 to Nelson Mandela Metropolitan University's five campuses equated to an initial capital cost of R1,306,200. This estimation was based on 2011 prices, and if the costs were to be quantified in terms of 2012 prices, as per the annual average CPI rate of 5.5%, this would equate to R1,378,041.

- Photovoltaics

Photovoltaics refer to the direct conversion of light into electricity. Given the layout of the built environment at Nelson Mandela Metropolitan University, the university has extensive potential from which to utilise photovaltaics for the generation of electricity. An initial installation which would generate an estimated annual yield of 1,022,217 kWh requires an approximate area of 4,300m². This is made up of a 500kWp rooftop installation and a 100kWp tracking system.

The capital costs associated with such a system are reflected in Table 4.46.

Table 4.46: Capital costs associated with the Installation of a kWp rooftop installation and a 100 kWp tracking system

DESRIPTION	AMOUNT
Monocristalline PV Panels	R 9 900 000.00
Platinum Inverters	
Installation Material	
Installation and Commissioning	

Source: Tasol (2012)

As reflected in Table 4.46, the total capital costs associated with implementing a fully-functional photovoltaic system capable of generating 1,022,217kWh per annum totals R9,900,000.

The annual average operating and maintenance costs equates to 0.12% of initial system installed capital cost (Moore, Post & Mysak, 2005). This translates to an annual operating and maintenance cost of R11,880 per annum.

These cost components could potentially form the basis of an alternative energy provision programme for Nelson Mandela Metropolitan University. In summary, the respective costs of the various potential interventions of an energy provision programme at Nelson Mandela Metropolitan University are reflected in Table 4.47.

Table 4.47: Summary of the respective costs of potential interventions of an alternative energy provision programme at Nelson Mandela Metropolitan University

COMPONENT	COSTS / COMMENT
Assessment of the costs relating to a sustainable infrastructure intervention area (demand side management) with respect to: • Capital costs (2012 prices). This is the figure that would populate the eventual framework in determining a relational cost benefit per intervention area subject to the application of a sustainability indicator per intervention area • Operational costs (year 1)	• Small wind turbines:: o Capital cost: R1,378,041 o Operational cost (year 1): R0 • Photovoltaics: o Capital cost: R9,900,000 o Operational cost (year 1): R11,589
Comparison of sustainable infrastructure cost to that of conventional infrastructure	The total initial cost of undertaking an alternative energy provision programme as per the components as detailed in Section 4.9 totals R11,278,041
Reference will be made to: • Cost benefits of undertaking the specific sustainable infrastructure intervention areas • Estimated lifecycle costs (namely, initial cost of the investment + life time cost of maintenance + cost of precautionary maintenance) of the specific sustainable infrastructure intervention area	• Conventional forms of energy use are less energy efficient, less resource efficient and less environmentally responsible. As such the cost benefit of alternative forms of energy provision is ensured through greater energy and resource efficiencies • Estimated lifecycle costs of the programme would equate to R1,378,041 + R5,832,070 maintenance costs for the small scale wind turbines and R9,900,000 + 5% of the annual replacement value of the components per year for up to 30 to 50 years

Source: Author's own compilation

As illustrated in Table 4.47, the total initial alternative energy provision costs total R11,278,041 and entails interventions with respect to small scale wind turbines and photovoltaics.

(h) Cost of Intervention area 8: Transport costs

Transportation to and around Nelson Mandela Metropolitan University's campuses has a large impact on infrastructure provision such as internal and external road networks, parking facilities and inter-modal transfer points. Currently, the predominant mode of transport to Nelson Mandela Metropolitan University campuses is that of private, single occupant, vehicular traffic. Should a more sustainable form of transportation to and within the various campuses be pursued, the costs and benefits of the various modes of possible transportation and their associated conditions needed to be analysed.

The basis of comparing a more sustainable form of transportation to that of conventional transportation is Nelson Mandela Metropolitan University's draft transportation and mobility framework (2012). Broad principles within the draft framework include:

- Employing a park and ride system in partnership with Nelson Mandela Metropolitan Municipality
- Providing preferential access and parking facilities to users of scooters / motorbikes
- Providing preferential access to those students and staff members who make use of car pool schemes
- Exclusively dedicating university access routes and points to particular transportation modes
- Restricting a certain category of vehicle user from accessing and utilising Nelson Mandela Metropolitan University parking facilities
- Limiting a certain category of vehicle user from accessing and utilising Nelson Mandela Metropolitan University parking facilities

In terms of the draft framework, it was proposed that the principles identified could be implemented over a three year period as indicated in Table 4.48.

Table 4.48: Nelson Mandela Metropolitan University draft transportation and mobility proposed multi-year interventions

YEAR	INTERVENTION
Year 1	• Providing preferential access and parking facilities to individuals utilising bikes / scooters / motorbikes: i) No parking fee to be levied, ii) Appropriate facilities to be provided • Limiting a certain category of vehicle user from accessing and utilising Nelson Mandela Metropolitan University parking facilities: i) Students to pay R60 per month for open bays (discontinue practice of open reserved parking bays), ii) Staff to pay R50 per month for open bays (discontinue the practice of open reserved bays), iii) Staff to pay R60 per month for covered bays (first come first served basis, discontinue the practice of covered reserved bays) • Expanding Nelson Mandela Metropolitan University's shuttle service
Year 2	• Providing preferential treatment to those students and staff members who make use of car pool schemes: Introduce designated parking areas at a lower monthly tariff
Year 3	• Employing a park and ride system in partnership with Nelson Mandela Metropolitan Municipality: Discussions have taken place with the local municipal officials and their respective built environment consultants on the possibility of utilising Kings Beach as a park and ride facility. This has been favourably received, however, owing to current upgrade projects the concept could not be implemented immediately. Once the upgrade projects have been completed, taxi as well as bus facilities would be available at Kings Beach thereby facilitating the park and ride concept. • Restricting a certain category of vehicle user from accessing and utilising Nelson Mandela Metropolitan University parking facilities: First and second year student to be restricted from utilising parking facilities on campus. • Exclusively dedicating University access routes and points to particular transportation modes, for example, only buses and taxis would be permitted to utilise University Way

Source: Nelson Mandela Metropolitan University (2012)

The costs associated with implementing these transportation requirements needed to be viewed against costs associated with current transportation management mechanisms on the various Nelson Mandela Metropolitan University campuses. Currently, the only transportation management mechanism is that of the parking regulation of students and staff through the issuing of zone specific parking discs. Numbers specific to the issuing of zone specific parking discs are reflected in Table 4.49.

Table 4.49: Parking provision at Nelson Mandela Metropolitan University

CAMPUS	NUMBER OF EXISTING PARKING BAYS	NUMBER OF STUDENTS	NUMBER OF STAFF	OPTIMUM PARKING PROVISION	REGISTERED NUMBER OF CAR USERS
South Campus	2303	10449	1353	6578	3391
North Campus	862	5816	533	3441	1426
2nd Avenue Campus	521	4286	98	2241	502
Bird Street Campus	209	310	31	186	25
Missionvale Campus	309	1397	97	796	110
TOTAL	**4204**	**22258**	**2112**	**13242**	**5454**

Source: Nelson Mandela Metropolitan University (2011)

The implementation of Nelson Mandela Metropolitan University's proposed transportation and mobility strategy versus the current transportation management mechanism would, as advocated by the Victoria Transport Policy Institute (2009), have an effect on the following cost / benefit categories:

- Vehicle ownership
- Operating subsidies
- Travel time
- Internal parking
- External parking
- Congestion
- Road facilities
- Traffic services
- Transport diversity value
- Noise
- Resource consumption
- Barrier effect
- Land use impacts

The specific modes of travel, as advocated by the Victoria Transport Policy Institute (2009), to which the identified transportation cost / benefit categories would apply are as follows:

- Average single occupant vehicle
- Rideshare passenger (incremental cost of an additional carpool or transit rider)
- Bus / taxi
- Motorcycle
- Bicycle
- Walk
- Telework (telecommunications that substitutes the need for physical travel)

Applying Nelson Mandela Metropolitan University's draft Transportation and Mobility Strategy (2012), would by implication lead to the greater utilisation of rideshare passengers, buses and taxis, motorcycles, bicycles and pedestrian movement. The would result in the indirect benefits of the decreased need for vehicle ownership, improved travel time, decreasing the need for internal parking, decreasing congestion, decreasing the need for traffic services, enhancing transport diversity, reducing noise and enhancing the use of existing resources. The direct costs of applying the strategy would include operating subsidies and road facilities to cater for the various transportation categories.

In providing a possible shuttle service to Nelson Mandela Metropolitan University staff and students, various options are available. This, in turn, has an effect on the operating subsidy for which Nelson Mandela Metropolitan University would need to budget. The various shuttle service options that were possible as per Nelson Mandela Metropolitan University's Transportation and Mobility Strategy along with the associated operating subsidy required are illustrated in Table 4.50.

Table 4.50: Shuttle service operating subsidy options as per Nelson Mandela Metropolitan University's draft transportation and mobility strategy

SHUTTLE SERVICE OPERATING SUBSIDY OPTION	ANNUAL COST
Providing a shuttle service to staff and students within defined boundaries within the metropolitan area	R16,170,000
Providing a shuttle service to staff and students across the broader metropolitan area	R32,340,000
Providing a shuttle service for students staying in all accredited off-campus accommodation	R8,090,000
Providing a shuttle service only to students staying in on-campus residence to and from the Missionvale Campus and the 2nd Avenue Campus	R3,240,000

Source: Nelson Mandela Metropolitan University (2012)

As illustrated in Table 4.50, the costs associated with the operating subsidies vary dramatically per category. Owing to the costs involved, Nelson Mandela Metropolitan University has adopted the option where a shuttle service would be provided only to students staying in on-campus residences to and from the Missionvale Campus and the 2nd Avenue Campus.

In addition to the applicable operating subsidy in providing a shuttle service, in terms of NMMU's Draft Mobility and Transportation Strategy (2012), Nelson Mandela Metropolitan University would need to provide facilities for an intermodal transportation hub that would serve as a collection and distribution point for buses, taxis and pedestrians. In order to address demand, such a facility would be able to accommodate thirty two taxis, four buses along with catering for the associated pedestrian movement in the form of walkways. Costs associated with providing such a facility are illustrated in Table 4.51.

Table 4.51: Costs associated with implementing an intermodal transportation hub at Nelson Mandela Metropolitan University

COMPONENT	COST
Capital costs	R3,136,710
Annual operating costs	R215,244

Source: Nelson Mandela Metropolitan University (2012)

The capital costs associated with implementing an intermodal transportation hub as depicted in Table 4.51 would be a one-off expense. From thereon, annual operating costs, which include cleaning and security would total R215,244 per annum.

In summary, the respective costs of ensuring a more sustainable form of transportation in and around Nelson Mandela Metropolitan University are reflected in Table 4.52.

Table 4.52: Summary of the respective costs of ensuring a more sustainable form of transportation in and around Nelson Mandela Metropolitan University

COMPONENT	COSTS / COMMENT
Assessment of the costs relating to a sustainable infrastructure intervention area (construction of green buildings) with respect to: • Capital costs (2012 prices). This is the figure that would populate the eventual framework in determining a relational cost benefit per intervention area subject to the application of a sustainability indicator per intervention area • Operational costs (year 1)	• Shuttle service: ○ Capital cost: R0 ○ Operational cost (year 1): R3,240,000 • Construction of a taxi rank: ○ Capital cost: R3,136,710 ○ Operational cost (year 1): R215,244
Comparison of sustainable infrastructure cost to that of conventional infrastructure	The total initial cost of undertaking an improved transportation system totals R6,376,170.
Reference would be made to: • Cost benefits of undertaking the specific sustainable infrastructure intervention areas • Estimated lifecycle costs (namely initial cost of the investment + life time cost of maintenance + cost of precautionary maintenance) of the specific sustainable infrastructure intervention area	• Indirect benefits of the decreased need for vehicle ownership, improved travel time, decreasing the need for internal parking, decreasing congestion, decreasing the need for traffic services, enhancing transport diversity, reducing noise and enhancing the use of existing resources • Estimated lifecycle costs of the programme would equate to R3,136,710 + 5% of the annual replacement value of the components per year for up to 20 to 30 years

Source: Author's own compilation

As illustrated in Table 4.52, the initial costs of undertaking an improved transportation to and from Nelson Mandela Metropolitan University total R6,376,170.

4.2.2 Relational cost factors

Based on the information contained within Section 4.2.1, a relational cost factor could be calculated between the various interventions. A relational cost factor was calculated as some interventions as listed in Section 4.2.1 would require a larger investment as opposed to others given the nature of the intervention. It was, therefore, important to note the extent of the difference between the various interventions prior to applying a sustainability indicator to each intervention as eventual budgets will not be able to cater for the entire suite of interventions. The relational cost factor was calculated from the total estimated cost of R73,564,008, namely the total estimated cost of interventions relating to demand side management, rationalising spatial growth, the construction of green buildings, sustainable operations and maintenance, alternative wastewater, water, energy and transport provision. The resultant relational cost factor between the various interventions is illustrated in Table 4.53.

Table 4.53: Relational cost factor

COMPONENT	ESTIMATED COST	RELATIONAL COST FACTOR
Demand side management	R12,672,265	0.172
Rationalising spatial growth	R3,691,885	0.050
Construction of green buildings	R16,148,200	0.220
Operation and maintenance costs	R16.924,203	0.230
Wastewater costs	R5,237,365	0.071
Water costs	R1,235,879	0.017
Energy cost	R11,278,041	0.153
Transport costs	R6,376,170	0.087
Total	R73,564,008	1.000

Source: Author's own compilation

As illustrated in Table 4.53, the construction of green buildings along with the operations and maintenance component are by far the largest cost components followed closely by demand side management and the energy component.

4.3 RELATIONAL SUSTAINABILITY INDICATORS

Although the costing of each intervention area is illustrated in Sections 4.2, the contribution made to sustainability by each intervention area needed to be determined in the form of a relational sustainability indicator within the context of Nelson Mandela Metropolitan University campus. From thereon, a relational cost benefit could be determined.

In determining the sustainability indicator per intervention area, two components are applied, namely, green infrastructure attributes (Federation of Canadian Municipalities, 2004) as discussed in Chapter Three along with basic elements of Sustainability Measurement Systems as elaborated upon by Delai and Takahashi (2011).

4.3.1 Attributes of green infrastructure

The attributes of green infrastructure (Federation of Canadian Municipalities, 2004) as discussed in Chapter Three include:

- Focusing on end-use where demand side management and efficiency measures effect savings in source supply and service capacity
- Multiple functions served by common devices
- Secondary resource value available in a service
- Compatibility of siting and placement
- Creation of social amenities as intrinsic attributes
- Matching resources to end user requirements
- Engaging natural functioning in service provision
- Strengthening local resilience to external and internal disruptions

For the purposes of this study, alternative infrastructure should seek to satisfy one or more of these attributes of green infrastructure identified. Table 4.54 illustrates how this study's defined components of sustainable infrastructure provision sought to satisfy the attributes of green infrastructure as identified.

Table 4.54: Relation of study's components of sustainable infrastructure to the attributes of green infrastructure

		GREEN INFRASTRUCTURE ATTRINUTES								
		Focusing on end-use where demand side management and efficiency measures effect savings in source supply and service capacity	Serving multiple functions served by common devices	Ensuring secondary resource value available in a service	Ensuring compatibility of siting and placement	Creating social amenities as intrinsic attributes	Matching resources to end user requirements	Engaging natural functioning in service provision	Strengthening local resilience to external and internal disruptions	TOTAL
STUDY'S COMPONENTS OF SUSTAINABLE INFRASTRUCTURE PROVISION	Demand side management	X					X		X	3
	Rationalising university growth through appropriate planning				X	X	X		X	4
	Construction of green buildings		X				X		X	3
	Operation and maintenance of buildings from a green perspective		X				X		X	3
	Green technologies in the treatment of sewerage		X	X			X	X	X	5
	Green technologies in the provision of water		X	X			X	X	X	5

	GREEN INFRASTRUCTURE ATTRINUTES								
	Focusing on end-use where demand side management and efficiency measures effect savings in source supply and service capacity	Serving multiple functions served by common devices	Ensuring secondary resource value available in a service	Ensuring compatibility of siting and placement	Creating social amenities as intrinsic attributes	Matching resources to end user requirements	Engaging natural functioning in service provision	Strengthening local resilience to external and internal disruptions	TOTAL
Green technologies in the provision of energy		X				X	X	X	4
Public transportation facilities				X		X			2

Source: Author's own compilation

Table 4.54 illustrates that green technologies in the treatment of sewerage and in the provision of water most significantly satisfy the attributes of green infrastructure provision.

4.3.2 Elements of sustainability measurement systems

Delai and Takahashi (2011) developed a reference model for measuring corporate sustainability. For the purposes of this study, basic elements from the reference model were selected that were relevant to this study's components of sustainable infrastructure provision. These elements relate to the social, economic and environmental dimensions of sustainability. As with the attributes of green infrastructure, sustainable infrastructure provision should seek to satisfy one or more of the following elements within the social, economic and environmental dimensions of sustainability. The elements within the environmental, social and economic dimensions of sustainability need to be considered.

(a) Elements within the environmental dimension of sustainability

The elements included within the environmental dimension of sustainability include:

- Air
  - Global warming emissions: Interventions that seek to reduce global warming emissions

    - Ozone depletion emissions: Interventions that seek to reduce the emissions of gases that affect the ozone layer
    - Atmospheric acidification: Interventions that seek to reduce gases that cause acid rain
    - Human health effects: Interventions that seek to reduce the emissions of gases that have a carcinogenic effect on human health
    - Photochemical ozone formation: Interventions that seek to reduce the emission of gases that cause photochemical formation

- Land
    - Land usage: Interventions that seek to reduce the amount of land utilised by an organisation
    - Waste generation: Interventions that seek to reduce the impact on land caused by waste generation and its severity

- Materials
    - Material consumption: Interventions that seek to enhance material consumption efficiency thereby reducing an institution's impact on the availability of natural resources
    - Consumption of hazardous materials: Interventions that seek to reduce an institution's use of hazardous materials

- Water
    - Consumption: Interventions that seek to reduce an institution's impact on water resources whilst simultaneously improving water usage efficiency
    - Acidification: Interventions that seek to reduce aquatic pollution generated by the discharges of acids
    - Aquatic oxygen demand: Interventions that seek to reduce water pollution in water bodies
    - Ecotoxicity to aquatic life: Interventions that seek to reduce water pollution generated by heavy metals
    - Eutrophication: Interventions that seek to reduce the over fertilisation of water and soil

- Energy
    - Consumption and sources: Interventions that seek to optimise the usage of energy whilst moving from non-renewable to renewable sources of energy

- Biodiversity
    - Ecosystems: Interventions that seek to enhance the integrity of natural habitats
    - Protected areas: Interventions that seek to reduce the impacts on protected areas
    - Species: Interventions that seek to reduce impacts on endangered animal and plant species

- Products and services
    - Product recyclability: Interventions that seek to promote the recycling of products
    - Environmentally-friendly products

Table 4.55 illustrates how this study's defined components of sustainable infrastructure provision seek to satisfy the environmental dimensions of sustainability.

Table 4.55: Relation of study's components of sustainable infrastructure to the environmental dimensions of sustainability

		ENVIRONMENTAL DIMENSION																				
		AIR					LAND		MATERIALS		ENERGY	WATER					BIODIVERSITY			PRODUCTS AND SERVICES		
		Global warming emissions	Ozone depletion emissions	Atmospheric acidification	Human health effects	Photochemical ozone formation	Usage	Waste generation	Consumption	Consumption of hazardous materials	Consumption	Consumption	Acidification	Aquatic oxygen demand	Ecotoxicity to aquatic life	Eutrophication	Ecosystems	Protected areas	Species	Products recyclability	Ecofriendly products	TOTAL
STUDY'S COMPONENTS OF SUSTAINABLE INFRASTRUCTURE PROVISION	Demand side management	x	x						x		x										x	5
	Rationalising university growth through appropriate planning						x		x		x						X	x	x			6
	Construction of green buildings		x		x		x		x		x	x								x	x	8
	Operation and maintenance of buildings from a green perspective		x		x						x	x									x	5
	Green technologies in the treatment of sewerage											x					X			x	x	4
	Green technologies in the provision of water											x					X			x	x	4
	Green technologies in the provision of energy										x										x	2
	Public transportation facilities	x	x		x		x		x		x										x	7

Source: Author's own compilation

In terms of the environmental dimension of sustainability, Table 4.55 illustrates that the construction of green buildings and the rationalising of university growth through appropriate planning contribute most across the sectors of air, land, materials, energy, water, biodiversity and products and services.

(b) Elements within the social dimension of sustainability

The elements included within the social dimension of sustainability include:

- Labour practices and decent work
  - Employees' education, training and development: Interventions aimed at improving employee performance
  - Diversity and opportunity: Involves the concept of equity that encourages inclusiveness with regards to distributed resources, opportunities afforded and decisions made
  - Health and safety: Interventions aimed at improving employee occupational health and safety
  - Job creation: Interventions which seek to develop the region in which an institution operates focusing on job creation
  - Talent attraction and retention: Interventions which seek to manage the satisfaction and retention of an organisation's human capital
  - Human rights: Interventions that ensure that human rights are upheld in an organisation's operations
- Customer relationship management
  - Customer satisfaction: Interventions that ensure customer satisfaction where an organisation is able to deliver on its core product and service in a manner that considers the needs of its customers
  - Customer health and safety: Interventions so as to reduce the risks to a customer's health and safety when consuming the organisations product or service
  - Products and labels: Interventions aimed at providing appropriate information and labelling with regards to the sustainability implications of products

        - Advertising: Interventions to ensure that an organisation's marketing communication practices are of an appropriate ethical and cultural standards
        - Respect for privacy: Interventions that ensure the protection of customer's personal information
    - Corporate citizenship
        - Social actions: Interventions that enhance an organisation's social investment
        - Communication with society: Interventions in relation to the manner in which an organisation liaises with the community in which it operates
        - Political contributions: Extent of an organisation's involvement in political funding
        - Competition and pricing: Extent to which an organisation is following anti-monopoly legislation
        - Codes of conduct, corruption and bribery: Extent to which an organisation manages reputational risks arising from corrupt practices
    - Suppliers and partners
        - Selection, evaluation, development of suppliers: Systems employed by a company to assess and develop their suppliers with respect to sustainability performance
        - Contracts: Extent to which an organisation complies with suppliers contracts
    - Public sector
        - Taxes: Contribution of a company to government in the form of taxes
        - Subsidies: Contribution of government to companies through subsidies received

Table 4.56 illustrates how this study's defined components of sustainable infrastructure provision seek to satisfy the social dimensions of sustainability.

Table 4.56: Relation of study's components of sustainable infrastructure to the social dimensions of sustainability

		SOCIAL DIMENSION																				
		LABOUR PRACTICES AND DECENT WORK						CUSTOMER RELATIONSHIP MANAGEMENT					CORPORATE CITIZENSHIP					SUPPLIERS AND PARTNERS		PUBLIC SECTOR		
		Employees' education, training and development	Diversity and opportunity	Health and safety	Job creation	Talent attraction and retention	Human rights	Customer satisfaction	Customer health and safety	Products and labels	Advertising	Respect for consumer privacy	Social actions	Political contributions	Codes of conduct, corruption and bribery	Competition and pricing	Society communication	Selection, evaluation, development of suppliers	Contracts	Subsidies	Taxes	TOTAL
STUDY'S COMPONENTS OF SUSTAINABLE INFRASTRUCTURE PROVISION	Demand side management																					0
	Rationalising university growth through appropriate planning		x			x		x														3
	Construction of green buildings																					0
	Operation and maintenance of buildings from a green perspective									x												1
	Green technologies in the treatment of sewerage																					0
	Green technologies in the provision of water																					0
	Green technologies in the provision of energy																					0
	Public transportation facilities												x									1

Source: Author's own compilation

In terms of the social dimension of sustainability, Table 4.56 illustrates that rationalising university growth through appropriate planning and enhanced employee productivity contribute most across the sectors of labour practices, customer relationship management, corporate citizenship, suppliers and partners and the public sector.

(c) Elements within the economic dimension of sustainability

Elements within the economic dimension of sustainability include:

- Profit and value: Relates to the wealth creation of an organisation assessed by means of traditional financial measures

- Investments:
  - Capital employed: Relates to how efficient a company is in applying invested capital by means of the return on investment
  - Research and development: Relates to how a company invests in innovation with the intention of creating long term wealth

- Relationship with investors:
  - Corporative governance: Relates to the processes by which organisations are managed
  - Shareholders remuneration: Relates to the dividends paid by an organisation to its shareholders

- Crisis management: Relates to how a company mitigates possible risk through its organisational structure

Table 4.57 illustrates how this study's defined components of sustainable infrastructure provision seek to satisfy the economic dimensions of sustainability.

Table 4.57: Relation of study's components of sustainable infrastructure to the economic dimensions of sustainability

		ECONOMIC DIMENSION						
		INVESTORS		INVESTMENTS		PROFIT AND VALUE	CRISIS MANAGEMENT	
		Corporate governance	Shareholders' remuneration	Capital employed	Research and development			TOTAL
STUDY'S COMPONENTS OF SUSTAINABLE INFRASTRUCTURE PROVISION	Demand side management			x				1
	Rationalising university growth through appropriate planning							0
	Construction of green buildings							0
	Operation and maintenance of buildings from a green perspective							0
	Green technologies in the treatment of sewerage				X			1
	Green technologies in the provision of water			x	X			2
	Green technologies in the provision of energy			x	X			2
	Public transportation facilities							0

Source: Author's own compilation

In terms of the economic dimension of sustainability, Table 4.57 illustrates that green technologies in the provision of water and energy contribute most across the sectors of investors, investments, profit and value and crisis management.

Tables 4.54 to 4.57 illustrate the contribution made to sustainability by each intervention area with respect to the attributes of green infrastructure along with the environmental, social and economic dimensions of sustainability. The collective contribution is detailed in Table 4.58. From the cumulative total per intervention area, a relational sustainability indicator is developed per intervention area detailed as follows:

C= 100/B x A

Where:

A= Cumulative total of contribution made to sustainability by individual intervention area.

B= Total achievable factors of relational sustainability

C= Relational sustainability indicator per intervention area

Table 4.58: Relational sustainability indicator per intervention area

		FACTORS OF RELATIONAL SUSTAINABILITY				TOTAL	
		GREEN INFRASTRUCTURE ATTRIBUTES	ENVIRONMETNAL DIMENSION OF SUSTAINABILITY	SOCIAL DIMENSION OF SUSTAINABILITY	ECONOMIC DIMENSION OF SUSTAINABILITY		
STUDY'S COMPONENTS OF SUSTAINABLE INFRASTRUCTURE PROVISION	**Demand side management**	3	5	0	1	9	0.111
	Rationalising University growth through appropriate planning	4	6	3	0	13	0.160
	Construction of green buildings	3	8	0	0	11	0.136
	Operation and maintenance of buildings from a green perspective	3	5	1	0	9	0.111
	Green technologies in the treatment of sewerage	5	4	0	1	10	0.123
	Green technologies in the provision of water	5	4	0	2	11	0.136
	Green technologies in the provision of energy	4	2	0	2	8	0.099
	Public transportation facilities	2	7	1	0	10	0.123
	TOTAL						1.0

Source: Author's own compilation

From Table 4.58, the most prominent relational sustainability indicator relates to the intervention of rationalising university growth through appropriate planning followed by the construction of green buildings and the utilisation of green technologies in the provision of water.

4.4 SUMMARY

In Chapter Four, the costs associated with the various form of defined sustainable infrastructure were quantified. Based on the quantification of those costs a relational cost factor was developed relevant to the eight categories of sustainable infrastructure development. In addition to the relational cost factor, a relational sustainability indicator was developed relevant to the eight categories of sustainable infrastructure development.

In Chapter Five, the framework is populated with relevant data so as to determine the relational cost benefit per category of sustainable infrastructure development.

CHAPTER 5

A FINANCIAL VIABILITY FRAMEWORK OF SUSTAINABLE INFRASTRUCTURE AT A UNIVERSITY

5.1 INTRODUCTION

In Chapter Four, costs associated with the various form of defined sustainable infrastructure were quantified. Based on the quantification of those costs, a relational cost factor was developed relevant to the eight categories of sustainable infrastructure development. In addition to the relational cost factor, a relational sustainability indicator was developed relevant to the eight categories of sustainable infrastructure development.

This chapter seeks to populate the proposed framework with:

- Costs of sustainable infrastructure provision as per the eight defined categories
- Resultant relational cost factor per the eight categories of sustainable infrastructure provision
- Relational sustainability indicator per the eight categories of sustainable infrastructure provision
- Resultant relational cost benefit as per the eight defined categories of sustainable infrastructure provision derived from the relevant costs of sustainable infrastructure provision, the resultant relational cost factors and, finally, the relational sustainability indicators

The resultant relational cost benefit per category of sustainable infrastructure provision would by implication quantify the financial implication of sustainable infrastructural interventions in relation to one another and, in turn, provide a basis for the determination of budget split between the various interventions. In this chapter, a financial viability framework for sustainable infrastructure provision at a university first needs to be populated and then assessed. Thereafter, a discussion of how the framework was validated and tested is outlined.

5.2 A FINANCIAL VIABILITY FRAMEWORK FOR SUSTAINABLE INFRASTRUCTURE PROVISION AT A UNIVERSITY

Table 5.1 depicts a financial viability framework for sustainable infrastructure provision at a university. The intention of the framework is to provide a basis for the determination of budget split per sustainable infrastructure category. As such, it is presumed that the cost benefits of each category of sustainable infrastructure provision have already been proven.

Table 5.1: Financial viability framework for sustainable infrastructure provision at a University

COMPONENT	INITIAL COST OVER AND ABOVE COVENTIONAL INFRASTRUCTURE	RELATIONAL COST FACTOR E	RELATIONAL SUSTAINABILITY INDICATOR F	RELATIONAL COST BENEFIT G = EXF
Demand side management	R12,672,265	0.172	0.111	0.019
Rationalising spatial growth	R3,691,885	0.050	0.160	0.008
Construction of green buildings	R16,148,200	0.220	0.136	0.029
Operation and maintenance costs	R16.924,203	0.230	0.111	0.026
Wastewater costs	R5,237,365	0.071	0.123	0.009
Water costs	R1,235,879	0.017	0.136	0.002
Energy cost	R11,278,041	0.153	0.099	0.015
Transport costs	R6,376,170	0.087	0.123	0.011
TOTAL	**R73,564,008**	**1.000**	**1.000**	**0.119**

Source: Author's own compilation

Based on the information contained in Table 5.1, a potential sustainable infrastructure development fund at a university should ideally be split according to the following ratios:

- Demand side management interventions: 15.97% (100 / 0.119 x 0.019)
- Rationalising spatial growth: 6.72% (100 / 0.119 x 0.008)
- Construction of green buildings: 24.37% (100 / 0.119 x 0.029)
- Operations and maintenance: 21.85% (100 / 0.119 x 0.026)
- Wastewater: 7.56% (100 / 0.119 x 0.009)
- Water: 1.68% (100 / 0.119 x 0.002)
- Energy: 12.61% (100 / 0.119 x 0.015)
- Transport: 9.24% (100 / 0.119 x 0.011)

Given these percentage ratios, Nelson Mandela Metropolitan University, for example, should assign R50 million towards sustainability interventions with respect to infrastructure development, R7,985,000 (15.97%) of that should be assigned to demand side management interventions, R3,360,000 (6.72%) should be assigned to rationalising spatial growth, R12,185,000 (24.37%) should be assigned to the construction of green buildings, R10,925,000 (21.85%) should be assigned to operations and maintenance interventions, R3,780,000 (7.56%) should be assigned to wastewater interventions, R840,000 (1.68%) should be assigned to water interventions, R6,305,000 (12.61%) should be assigned to energy interventions and R4,620,000 (9.24%) should be assigned to transport interventions.

The application of these percentages is able to guide what components of sustainable infrastructure to invest in along with the extent thereof, a guideline which does not exist at this point in time. This results in an informed multi-year budgeting process with respect to the development of sustainable infrastructure.

As depicted in the framework, the results thereof are dependent on the cost estimates developed within the various components of sustainable infrastructure which has an effect on the indicative percentage ratios. As sustainable infrastructure is developed, and as demands in types of infrastructure vary, the framework can be amended through the relational cost factors in order to define amended percentage ratios. The framework also allows an institution the flexibility to amend relational cost factors should an institution, for strategic purposes, want to invest in a particular type of sustainable infrastructure. This would be reflected by the resultant relational cost factor. The relational sustainability indicator, however, remains a constant.

5.3 EVALUATION OF THE FRAMEWORK

The testing of the framework occurred via the means of observer triangulation. Observer triangulation occurs when more than one observer is used in a study as independent raters. Five independent observers who acted as independent raters were used to evaluate the framework. The independent raters interviewed in this study included both internal professionals within Nelson Mandela Metropolitan University along with external professionals. Internal professionals included the quantity surveying profession, architectural profession and construction project management profession. External professionals included the economic profession along with the construction project management profession.

The basis of the interviewees input was based on the interviewee’s:

- comment on the definition of sustainable infrastructure as contained within the study and whether or not any additional elements should be contained within the definition of sustainable infrastructure
- comment on the framework for the study
- comment on the components of green infrastructure attributes
- interpretation of the study’s components of sustainable infrastructure to the attributes of green infrastructure
- interpretation of the study’s components of sustainable infrastructure to the environmental dimension of sustainability
- interpretation of the study’s components of sustainable infrastructure to the economic dimension of sustainability
- interpretation of the study’s components of sustainable infrastructure to the social dimension of sustainability
- viewpoint on whether the attributes of green infrastructure and the environmental, economic and social dimensions of sustainability satisfy an eventual determination of a relational sustainability indicator
- interpretation of a resultant relational sustainability indicator
- interpretation of a resultant relational cost factor
- comment on the resultant financial viability framework and associated budget split
- comment on whether to proposed mechanism to implement an associated budget split is realistic

The subsequent feedback from the interviews is reflected in Table 5.2.

Table 5.2: Feedback from interviews

QUESTION	RESPONSES
Interviewee's comment on the definition of sustainable infrastructure as contained within the study and whether or not any additional elements should be contained within the definition of sustainable infrastructure	All interviewee's agreed that the components that made up the definition of sustainable infrastructure within the study were adequate. It was, however, noted that the utilisation of all the components of sustainable infrastructure would occur automatically, owing to the nature of the type of infrastructure, barring that of transport infrastructure. The use of transport infrastructure was reliant on the user's choice. This should be considered as a factor when determining a proposed budget split between various forms of infrastructure.
Interviewee's comment on the framework for the study	All interviewee's confirmed that there was rationale in the defined framework of the study
Interviewee's comment on the components of the attributes of green infrastructure	All interviewee's confirmed that there was rationale in the defined attributes of green infrastructure
Interviewee's interpretation of the study's components of sustainable infrastructure to the environmental dimension of sustainability	All interviewee's confirmed that there was rationale in the defined components of environmental sustainability
Interviewee's interpretation of the study's components of sustainable infrastructure to the economic dimension of sustainability	All interviewee's confirmed that there was rationale in the defined components of economic sustainability
Interviewee's interpretation of the study's components of sustainable infrastructure to the social dimension of sustainability	All interviewee's confirmed that there was rationale in the defined components of social sustainability
Interviewee's viewpoint on whether the attributes of green infrastructure and the environmental, economic and social dimensions of sustainability satisfy an eventual determination of a relational sustainability indicator	All interviewee's confirmed that the stated components satisfies the determination of a relational sustainability indicator
Interviewee's interpretation of a resultant relational sustainability indicator	All interviewee's agreed that the resultant relational sustainability indicator was a true reflection of the "prioritised" infrastructure sectors. This was based on the understanding that 'energy' interventions were included within the demand side management and operations and maintenance components of sustainable infrastructure
Interviewee's interpretation of a resultant relational cost factor	All interviewee's agreed that the resultant relational cost factor was a true reflection of relational infrastructure costs. This was based on the understanding that a large amount of 'energy' interventions were included within the demand side management and operations and maintenance components of sustainable infrastructure
Interviewee's comment on the resultant financial viability framework and associated budget split	All interviewee's agreed that the resultant financial viability framework provided a good base from which to determine associated budget splits. This was based on the understanding that the proposed budget split was based on "all things being equal" –closed system
Interviewee's comment on whether to proposed mechanism to implement an associated budget split was realistic	All interviewee's agreed that the proposed mechanism to implement an associated budget split was realistic.

Source: Author's own compilation

Table 5.2 illustrates that the interviewees in principle agreed with the concept and application of the framework. It can, therefore, be argued that the framework can be implemented at Nelson Mandela Metropolitan University.

5.4 SUMMARY

In Chapter Five, the financial viability framework for sustainable infrastructure provision was populated (see Table 5.1). Based on information contained within the framework a guideline was formulated as to what components of sustainable infrastructure to invest in along with the extent thereof. However, a guideline does not exist at this point in time. This results in an informed multi-year budgeting process with respect to the development of sustainable infrastructure.

Independent raters within the professions of quantity surveying, architecture, construction project management and economics confirmed that the application of the framework could be utilised for the determination of a possible budget split for sustainable infrastructure interventions.

In Chapter Six, conclusions, recommendations and possible further research are discussed.

CHAPTER 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

Chapter Two described the research methodology used in this study while Chapter Three provided the theoretical background to the study. Chapter Four quantified the costs associated with alternative infrastructure provision. In particular, attention was be paid to demand side management costs, rationalising spatial growth costs, green building development costs, operation and maintenance of existing buildings costs, wastewater infrastructure costs, water infrastructure costs, energy infrastructure costs and transport infrastructure costs. Thereafter, a relational cost factor and relational sustainability indicator was calculated. In Chapter Five, a framework was populated which resulted in a relational cost benefit per category of sustainable infrastructure provision which by implication quantified the financial implication of sustainable infrastructural interventions in relation to one another and, in turn, provided a basis for the determination of budget split between the various interventions.

This chapter summarises the study by addressing the problem statement, research objectives, research design and methodology employed in the study. A synopsis of the literature overview results is also provided. The main purpose of Chapter Six is to make recommendations regarding the possible utilisation of the framework in determining a budget split between various categories of sustainable infrastructure provision. The limitations of the study and possible future research areas are then given. To conclude the chapter and the study, some final remarks are made regarding the study.

6.2 SUMMARY OF THE RESEARCH

The main question that was asked during the study was whether a framework could be developed so as to quantify the financial implication of sustainable infrastructural interventions in relation to one another and, in turn, provide a basis for the determination of budget split between the various interventions.

6.2.1 The attainment of the objectives in the study

The attainment of the primary objective was supported by several secondary objectives. Table 6.1 summarises the attainment of the various secondary objectives to achieve the primary objective as presented in Chapter One.

Table 6.1: Attainment of research objectives

SECONDARY OBJECTIVE	CHAPTER ADDRESSING THE OBJECTIVE
To devise a comparison between current conventional and alternative infrastructural interventions	**Chapter 3**
To define financial viability within the context of integrated alternative infrastructural provision within a closed entity such as that of Nelson Mandela Metropolitan University	**Chapter 4**
To select an appropriate research methodology and research methods for the study	**Chapter 2**
To develop a framework for the NMMU	**Chapter 5**
To provide pertinent conclusions and recommendations based on the findings	**Chapter 6**

6.2.2 The answers to the research questions of the study

A number of research questions were formulated in this study. The answers to these questions are discussed and include:

- How does cumulative cross-sectoral alternative infrastructural provision within a closed system such as a university campus contribute to sustainability of the campus?

In Chapter Three, a framework (see Table 3.2) was developed to demonstrate the means of calculation with respect to the financial viability of sustainable infrastructure provision in relation to demand side management, rationalising university growth through appropriate planning, the construction of green buildings, the operation and maintenance of green buildings, the treatment of wastewater, the provision of water, the provision of energy and public transportation.

- Can a viable sustainability indicator per infrastructural intervention area be derived in relation to another that would serve as the basis for determining infrastructural development focus?

Yes, the study showed how a sustainability indicator was developed from the cumulative total per intervention area.

- Is it practical to determine the financial viability of cumulative infrastructural provision on the basis of individual sectoral sustainability ratings?

Yes, it was practical to determine the financial viability based on individual sectoral sustainability ratings as the financial viability framework for sustainable infrastructure provision was populated (see Table 5.1). Based on information contained within the framework, a guideline was formulated as to what components of sustainable infrastructure to invest in along with the extent thereof, although a guideline does not exist at this point in time. This results in an informed multi-year budgeting process with respect to the development of sustainable infrastructure.

- Can a framework be developed that attempts to guide capital investment with respect to alternative infrastructure provision based on relational sustainability criteria along with relational cost factors?

This study developed a framework that independent raters within the professions of quantity surveying, architecture, construction project management and economics confirmed that the application of the framework could be utilised in the determination of a possible budget split for sustainable infrastructure interventions.

A brief summary of the chapters is presented in the following sections.

6.3 SUMMARY OF CHAPTER ONE

Chapter One discussed the background to the study, the problem statement and the primary and secondary objectives of the study. Furthermore, this chapter provided an overview of the research design and methodology which was used to obtain the empirical data for the study. Concluding this chapter was an outline of the forthcoming chapters.

The primary objective of this research was to develop a framework that demonstrated the financial viability of pursuing collective sustainable infrastructural development across a university campus. To give effect to the primary objective of this study, the following secondary objectives were formulated:

- To devise a comparison between current conventional and alternative infrastructural interventions by means of:
    - Determining the relationship between sustainable planning, infrastructural development and an enhanced working environment
    - Providing an overview of conventional and alternative infrastructural interventions
    - Developing relational sustainability indicators for alternative infrastructural interventions
    - Developing relational cost factors for alternative infrastructural interventions
- To define financial viability within the context of integrated alternative infrastructural provision within a closed entity such as that of the NMMU
- To select an appropriate research methodology and research methods for the study
- To develop a framework for the NMMU where:
    - Possible infrastructural interventions could be measured against one another in the form of a sustainability indicator
    - Appropriate weightings per infrastructural intervention area could be devised based on the outcomes of the sustainability indicator process
    - Relational cost benefit framework could serve as the basis of determining the financial viability of specific infrastructural intervention areas
- To provide pertinent conclusions and recommendations based on the findings

Given the stated objectives of the research, a number of research questions needed to be addressed, namely:

a) How did cumulative cross-sectoral alternative infrastructural provision within a closed system such as a university campus contribute to sustainability of the campus?
b) Could a viable sustainability indicator per infrastructural intervention area be derived in relation to another that would serve as the basis for determining infrastructural development focus?
c) Was it practical to determine the financial viability of cumulative infrastructural provision on the basis of individual sectoral sustainability ratings?
d) Could a framework be developed that attempts to guide capital investment with respect to alternative infrastructure provision based on relational sustainability criteria along with relational cost factors?

The research process undertaken in this study included five steps, namely:

f) Step 1: Reviewed the delivery mechanisms and associated costs of conventional and alternative infrastructure provision.
g) Step 2: Developed a sustainability indicator per infrastructure sector for alternative infrastructure provision. The sustainability indicator was to be a relational indicator per infrastructural sector within a closed system, namely, a university campus.
h) Step 3: Determined a relational cost factor, namely, a weighted cost, per alternative infrastructure category based on the outcome of Step 3 above. This would be done by means of a calculation.
i) Step 4: Presented the results of the calculation as a framework so as to determine the relational cost–benefits of cumulative alternative infrastructure provisions on a university campus.
j) Step 5: Presented the framework to independent observers who acted as independent raters so as to evaluate and comment on the proposed framework.

Chapter Two outlined the research methodology applied in the study in more detail.

6.4 SUMMARY OF CHAPTER TWO

Chapter Two identified and described the processes followed during the research process. The nature of research and the various research classifications was described. The different research paradigms were discussed, and the specific paradigm, namely, a qualitative research design that was chosen was motivated. The data collection and subsequent analysis was addressed. The five steps in the research are described in the following sections.

Step 1: Review the delivery mechanisms and associated costs of alternative infrastructure provision.

To execute this step, a literature review was undertaken. The literature review provided the distinction between conventional and alternative infrastructure provision along with the components of:

- Demand side management
- Rationalising spatial growth
- Construction of green buildings
- Sustainable operation and maintenance of existing buildings
- Alternative wastewater treatment
- Alternative water provision
- Alternative energy provision
- Sustainable transportation

Step 2: Develop a sustainability indicator per infrastructure sector for alternative infrastructure provision

The sustainability indicator was to be a relational indicator per infrastructural sector within a closed system such as a university campus.

To execute this step, the following was done:

- A literature review outlined the attributes of sustainable infrastructure along with the components of corporate sustainability
- Data was collected by studying documentation from both external and internal stakeholders to Nelson Mandela Metropolitan University

- Data was analysed by coding information form documents as per the following themes:
    - Sustainable alternative infrastructure provision
    - Weighting parameters amongst alternative infrastructure sectors within a closed system
    - Parameters of infrastructural relational comparison

From this analysis, it was possible to determine a relational sustainable indicator.

Step 3: Determine a relational cost factor

The basis of cost determination for alternative infrastructure provision was done by analysing literature.

The literature overview resulted in the development of a framework that indicated the costs (see Table 3.2). Once the framework given in Table 3.2 was populated with the actual costs, a relational sustainable cost factor could be calculated. To populate the framework, data needed to be collected. To collect data, a review of documentation from both external and internal parties to the NMMU was done. This included data specific to recent and current infrastructure development at the NMMU. Where data did not exist within the NMMU, infrastructural data was sourced from external parties from which comparisons could be made relevant to the operations at the NMMU. To analyse the data, coding as per the following themes needed to be done:

- Sectors of alternative infrastructure provision, such as, water provision, energy provision, sewerage treatment and top structure provision
- Cost parameters of alternative infrastructure provision
- Operating costs of alternative infrastructure provision
- Sustainability parameters surrounding alternative infrastructure provision

Step 4: Determine the relational cost–benefits of cumulative alternative infrastructure provisions on a University campus

The framework was populated with actual costs at Nelson Mandela Metropolitan University in 2011. The relational cost factor of each of the components in the framework was assigned a relational sustainability indicator based on the attributes of green infrastructure along with the social, economic and environmental dimensions of sustainability. The application of the relational sustainable indicator was used with the relational cost factor per intervention area to ultimately calculate a relational cost benefit per intervention area.

Step 5: Present the framework to independent raters in the built environment to evaluate and comment on the proposed framework

Five independent observers who acted as independent raters were used to evaluate the framework. Table 5.2 showed that the interviewees agreed in principle with the concept and application of the framework. It could, therefore, be argued that the framework could be implemented at Nelson Mandela Metropolitan University.

In addition to the five steps, the following was also undertaken in support of the research process:

- To ensure the trustworthiness of the research, an audit trail was kept to complement the research process
- To ensure the reliability of the research, a review of the method of coding and the subsequent analysis of the data was performed by an external party to verify the appropriateness of the classifications
- To ensure the ethical practice of the research, it was important to consider the data needed in the research. As all the data used would be secondary in nature and most were freely available in the public domain, no ethical clearance needed to be obtained. In the case where NMMU data was used, clearance to use the data was obtained from management

6.5 SUMMARY OF CHAPTER THREE

Chapter Three distinguished between conventional and alternative infrastructure and the type of costs associated with alternative infrastructure provision. First, a distinction between conventional infrastructure and alternative infrastructure was made based on specific characteristics and attributes.

As sustainable infrastructure provision could not be categorised into an individual sector nor defined as consisting of a singular attribute, the premise behind this study, namely, viewing sustainable infrastructure provision from a holistic viewpoint consisting of a number of attributes. Green infrastructure attributes were not always applicable to this study's components of sustainable infrastructure provision, however, when the components of sustainable infrastructure provision were viewed holistically all the attributes of green infrastructure attributes might be achieved.

The assessment of sustainable infrastructure included the following cost components:

Cost benefit of the component

The cost benefit of the component could be calculated as follows:

Cost benefit of the component (C) = Resource utilisation without the sustainability intervention (B) – cost of the sub-components (A)

[C = B – A]

Sustainability indicator

The sustainability indicator was calculated as:

Sustainability indicator (E) = f (relation of intervention to the attributes of green infrastructure (D1) along with the social (D2), economic (D3) and environmental dimensions (D4) of sustainability)

[E = f(D1, D2, D3, D4)]

In undertaking the sustainability indicator calculation, the contribution made to the sustainability needed to be determined considering the attributes of green infrastructure along with the three pillars of sustainability, namely, the social, economic and environmental pillars. Each pillar related specifically to the following three pillars:

- Social pillar: socially desirable, culturally acceptable, psychologically nurturing

- Financial pillar: economically sustainable technologically feasible, operationally viable
- Environmental pillar: environmentally robust, generationally sensitive, and capable of continuous learning

It is important to note that the sustainability indicator per intervention area was a relational indicator, as this study examined the benefits of intervention areas in relation to one another within an isolated system, namely, on a university campus. The sustainability indicator for a university campus could be calculated by using the factors of relational sustainability to determine its contribution by each of the eight components of infrastructural provision. The factors of relational sustainability included:

- Green infrastructure attributes
- Environmental sustainability dimension
- Social sustainability dimension
- Economic sustainability dimension

Relational cost factor per intervention

The relational cost factor per intervention was calculated as follows:

Relational cost factor [(F) = f (C1, C2, C3, C4, C5, C6, C7, C8)]

Relational cost benefit

The relational cost benefit was calculated as follows:

Relational cost benefit (G) = Sustainability indicator (E) x Relational cost factor (F)
[G = E X F]

These costs were included in a framework for the assessment of sustainable infrastructure development. The framework (see Table 3.2) was developed to demonstrate the means of calculation with respect to the financial viability of sustainable infrastructure provision in relation to demand side management, rationalising university growth through appropriate planning, the construction of green buildings, the operation and maintenance of green buildings, the treatment of wastewater, the provision of water, the provision of energy and public transportation.

6.6 SUMMARY OF CHAPTER FOUR

Chapter Four quantified the costs associated with alternative infrastructure provision. Thereafter, a relational sustainable cost factor was calculated. The determination of a relational cost factor involved the quantification of the costs associated with alternative infrastructure provision. In particular, attention was paid to demand side management costs, rationalising spatial growth costs, green building development costs, operation and maintenance of existing buildings costs, wastewater infrastructure costs, water infrastructure costs, energy infrastructure costs and transport infrastructure costs. Once the actual costs of each intervention area were determined, a relational sustainable cost factor could be calculated. The actual costs of these intervention areas were determined using the costs and figures available at Nelson Mandela Metropolitan University. The total costs of the various intervention areas at Nelson Mandela Metropolitan University were:

- Initial demand side management costs: R12 672 260.
- Cost of rationalising spatial growth: R3 691 885
- Total cost of developing buildings of R263 000 000: R16 148 200
- Costs of upgrading existing buildings as per silver LEED certification: R16 924 203
- Initial wastewater management costs: R5 237 365
- Initial water conservation management costs total: R1 235 879
- Alternative energy provision total: R11 278 041
- Initial cost of undertaking an improved transportation system total: R6 376 170

Using the actual costs in the eight categories, a relational sustainable cost factor was determined. Thereafter, a relational sustainable indicator was calculated.

A relational sustainable indicator showed how a university could collectively determine the contribution made to sustainability by various sectors of infrastructure. This was developed by means of a secondary study. Two components were important for calculating the relational sustainability indicator, namely, green infrastructure attributes and the basic elements of sustainability systems such as the environmental, economic and social dimensions of sustainability.

The relational cost factor of each of the components in the framework was then assigned a relational sustainability indicator based on the attributes of green infrastructure along with the social, economic and environmental dimensions of sustainability. The application of the relational sustainable indicator was used along with the relational cost factor per intervention area to ultimately calculate a relational cost benefit per intervention area.

6.7 SUMMARY OF CHAPTER FIVE

In Chapter Five, the framework was populated with:

- Costs of sustainable infrastructure provision as per the eight defined categories
- Resultant relational cost factor per the eight categories of sustainable infrastructure provision
- Relational sustainability indicator per the eight categories of sustainable infrastructure provision
- Resultant relational cost benefit as per the eight defined categories of sustainable infrastructure provision derived from the relevant costs of sustainable infrastructure provision, the resultant relational cost factors and, finally, the relational sustainability indicators.

The resultant relational cost benefit per category of sustainable infrastructure provision, by implication, quantified the financial implication of sustainable infrastructural interventions in relation to one another and, in turn, provided a basis for the determination of budget split between the various interventions.

The actual costs of the infrastructural intervention areas were determined using the costs and figures available at Nelson Mandela Metropolitan University. The total costs of the various intervention areas at Nelson Mandela Metropolitan University were:

- Initial demand side management costs: R12 672 260.

- Cost of rationalising spatial growth: R3 691 885
- Total cost of developing buildings of R263 000 000: R16 148 200
- Costs of upgrading existing buildings as per silver LEED certification: R16 924 203
- Initial wastewater management costs: R5 237 365
- Initial water conservation management costs total: R1 235 879
- Alternative energy provision total: R11 278 041
- Initial cost of undertaking an improved transportation system total: R6 376 170

Using the actual costs in the eight categories, a relational sustainable cost factor was determined. A resultant relational cost benefit as per the eight defined categories of sustainable infrastructure provision was derived from the relevant costs of sustainable infrastructure provision, the resultant relational cost factors and, finally, the relational sustainability indicators.

The resultant relational cost benefit per category of sustainable infrastructure provision would by implication quantify the financial implication of sustainable infrastructural interventions in relation to one another and, in turn, provide a basis for the determination of budget split between the various interventions. The proposed framework that was evaluated by independent raters confirmed percentages that would guide what components of sustainable infrastructure to invest in as well as the extent of the investment at Nelson Mandela Metropolitan University. It was proposed that that the following percentages be applicable to the various interventions included:

- Demand side management interventions: 15.97%
- Rationalising spatial growth: 6.72%
- Construction of green buildings: 24.37%
- Operations and maintenance: 21.85%
- Wastewater: 7.56%
- Water: 1.68%
- Energy: 12.61%

- Transport: 9.24%

6.8 CONCLUSIONS

Given the outcomes of the framework, along with the associated testing thereof, the proposed framework could be utilised to:

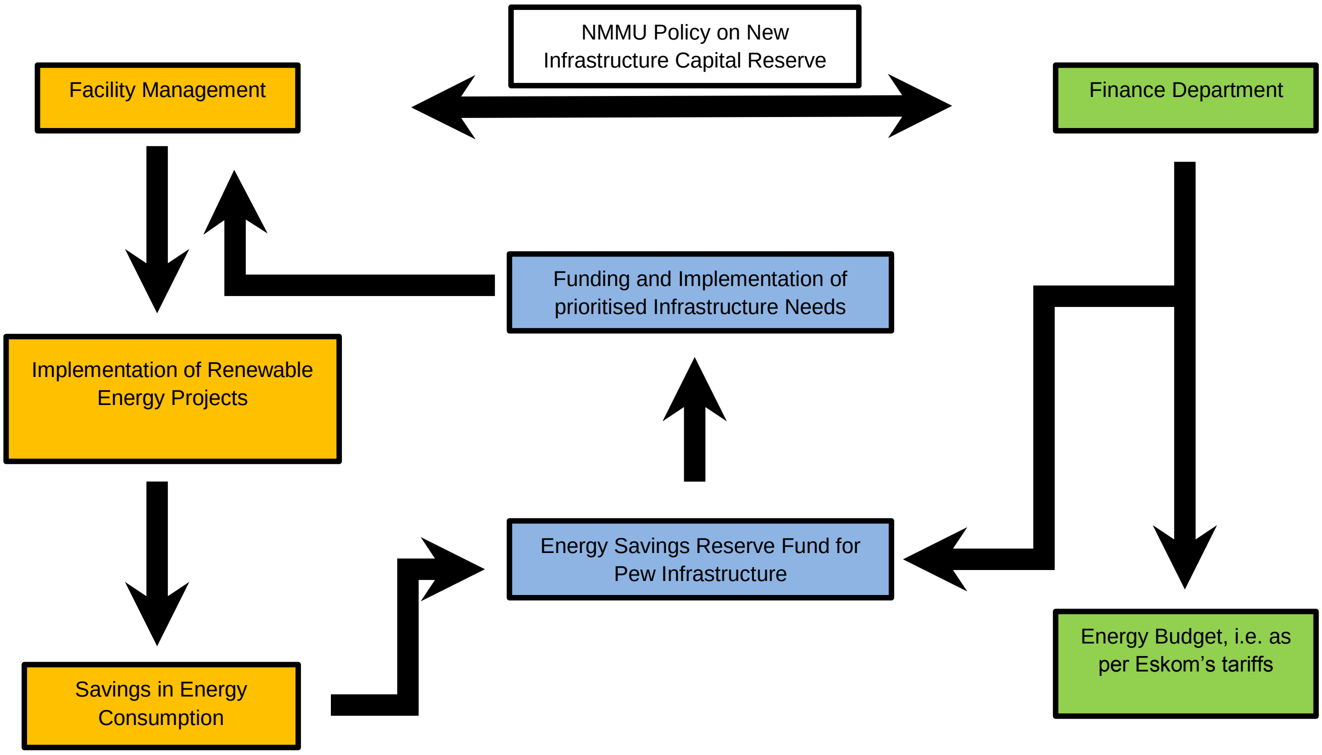
- Assist in determining a budget split per sustainable infrastructure intervention areas
- More appropriately invest in sustainable infrastructure based on pre-determined indicators thereby ensuring the appropriate scale of investment in sustainable infrastructure
- Assist an institution in determining its strategic focus with respect to sustainable infrastructure development given that the relational cost factor component is indicative based on the nature of sustainable infrastructure development that an institution may wish to undertake

In addition, the framework, although applied to the set of circumstances as applicable to Nelson Mandela Metropolitan University, could be utilised by other institutions that invest in infrastructure across various infrastructural segments. This is, however, based on the premise that those institutions want to invest in infrastructure that is ‘green’.

6.9 RECOMMENDATIONS

Although a framework is proposed with respect to determining the budget split per area of sustainable infrastructure, a mechanism is required in which to fund the preferred identified areas of sustainable infrastructure. The nature of sustainable infrastructure development provides an opportunity to establish a new infrastructure reserve fund to be funded from operational savings that would occur as a result of reduced costs in the form of alternative energy provision. Such a reserve may be created, if the NMMU continues to budget as per conventional water and energy tariffs, but utilises the surplus which would occur, owing to reduced operational costs through the utilisation of sustainable infrastructure, for new infrastructure. Such an approach is represented diagrammatically in Figure 6.1.

Figure 6.1: Potential establishment of a sustainable infrastructure reserve fund



Source: Author's own compilation

6.10 LIMITATIONS OF THE STUDY

This study seeks to quantify the financial implication of sustainable infrastructural interventions in relation to one another and, in turn, provide a basis for the determination of budget split between the various interventions. The limitations of the study include:

- The study presumes that funding is available to invest in sustainable infrastructure. Although the public might exist to promote sustainable forms of development, the resources to do so might not always exist
- The various forms of sustainable infrastructure development as defined in the study are not exhaustive. Other forms of sustainable infrastructure development might be developed
- The study presumes that the management of the institution views the development of the various categories of infrastructure equally. A management

directive might exist which prioritises and / or relegates certain forms of infrastructure development given an institutions strategic thrust at a given point in time

6.11 FURTHER RESEARCH

This study seeks to quantify the financial implication of sustainable infrastructural interventions in relation to one another and, in turn, provide a basis for the determination of budget split between the various interventions. The application of the framework in determining a budget split between various forms of infrastructure interventions could potentially be applied to other institutions / organisations which develop and manage infrastructure such as local municipalities. Further research on the applicability of the relational cost factor, context specific relational sustainability indicators and subsequent relational cost benefits to the local municipality environment could be investigated.

6.12 FINAL CONCLUSION

The leadership role that South African universities possess within society dictates that sustainable environmental practices and interventions need to be integrated into a university's operations thereby allowing universities to become learning institutions rather than just teaching institutions. Given that universities function within financial constraints with varying priorities across both administrative and educational functions, a platform which seeks to guide how and where to invest in sustainable infrastructure might be beneficial so as to provide direction in determining a budget split between various categories of infrastructure development. This study may potentially form the basis for that platform.

REFERENCE LIST

Association for the Advancement of Sustainability in Higher Education. (2012). The Sustainability Tracking, Assessment & Rating System [online] Available at: https://stars.aashe.org/ [Accessed 16 February 2012].

Agudelo-Vera, C.M., Mels, A.R., Keesman, K.J. & Rijnaarts, H.H.M. (2011). Resource management as a key factor for sustainable urban planning. *Journal of Environmental Management*, 92, 2011, pp. 2295-2303.

City of Seattle. (2009). *Sustainable infrastructure initiative: Interdepartmental planning for better capital projects*. City of Seattle: Department of Planning and Development.

Collis, J. & Hussey, R. (2003). *Business research: A practical guide for undergraduate and postgraduate students.* 2nd edition. Basingstoke, Hampshire, England: Palgrave Macmillan.

Construction Industry Development Board. (2009). *National Infrastructure Maintenance Strategy (NIMS), Infrastructure Maintenance Budgeting Guideline.* Report prepared by the Construction Industry Development Board, South Africa.

Cooper, D.R. & Schindler, P.S. (2008). *Business research methods*. 10th edition. London, England: McGraw-Hill.

Cost Comparison- LED Lamps. (2012). Richard Nzuza and Associates. Internal Document of the NMMU.

Cram, K.G (2007). *Occupancy sensors- The promise, the delivery, the cost*. Electro Sense (Pty) Ltd.

Davis Langdon (An AECOM Company). (2012). *Africa- Property and Construction Handbook.*

Delai, I. & Takahashi, S. (2011). Sustainability measurement system: A reference model proposal. *Social Responsibility Journal*, 7 (3), pp.438-471.

Eskom. (2010). *Mind your own business- Energy efficiency in commercial properties.* Report prepared by Eskom, South Africa.

Eskom. (2012). *Load management pilot project*. [online] Available at: http://www.eskom.co.za/c/article/560/load-management-pilot-project/ [Accessed 3 February 2012].

Federation of Canadian Municipalities. (2004). *Demonstrating the economic benefits of integrated, green infrastructure*. Report for Sustainable Edge Inc. Canada: FCM Centre of Sustainable Community Development.

Godfrey, S., Labhasetwar, P. & Wate, S. (2009). Greywater reuse in residential schools in Madhya Pradesh, India- A case study of cost-benefit analysis. *Resources, Conservation and Recycling,* 53, pp. 287-293

Green Building Council of South Africa. (2011). What is a green building? *Green Building Council SA.* [online] Available at: http://www.gbcsa.org.za/home.php [Accessed 16 February 2012].

Green Building Council of South Africa. (2011). Public and Education Building rating tool. *Green Building Council SA.*

Green infrastructure North West. (2011). Our natural life support system. [online] Available at: http://www.greeninfrastructurenw.co.uk/html/index.php?page=index [Accessed 3 February 2012].

Heijer, A. (2008). *Managing the university campus in an urban perspective: theory, challenges and lessons from Dutch practice*. Delft University of Technology: Corporations and Cities.

Kulatunga, K., Amaratunga, D. & Haigh, R. (2011). Client's championing characteristics that promote construction innovation. *Construction Innovation: Information, Process, Management*, 11 (4), pp. 380 – 398.

Joubert, J. & Keen, J. (2011). Economic viability of wind turbines for Western Cape farms, using Germany's example.

LEED. (2009). *LEED 2009 for existing buildings operations and maintenance rating system*. USA: U.S. Green Building Council.

Leonardo Academy. (2008) *The Economics of LEED for Existing Buildings.* Report prepared for the Leonardo Academy Inc. Madison.

Moore, L., Post, H. & Mysak, T. (2005). *Five years of operating experience at the Springville PV generating plant*. Sandia National Laboratories, Albuquerque.

Mun, J.S., Ki, J.H. & Han, M.Y. (2008). *Economical Analysis on Rainwater Harvesting (RWH) System of Buildings and Residential Complex in the Republic of Korea*. Rainwater Research Center in Seoul National University, College of Engineering.

Nelson Mandela Metropolitan University, (2010). Mission, Vision and Values. [online] Available at: http://www.nmmu.ac.za/default.asp?id=163&bhcp=1 [Accessed 3 February 2012].

Nelson Mandela Metropolitan University's Draft Transportation and Mobility Framework. (2012). Internal Document of the NMMU.

Nelson Mandela Metropolitan University's Urban Design Framework. (2011). An Urban Design Concept for Nelson Mandela Metropolitan University (NMMU), Port Elizabeth and George. Internal Document of the NMMU.

North West Development Agency. (2007). *Economic value of urban design.* Report prepared by AMION Consulting and Taylor Young in association with Donaldsons and Dave Shaw, University of Liverpool.

Oates, B.J. (2006). *Researching information systems and computing*. London, England: SAGE.

Price, I., Matzdorf, F., Smith, L & Agahi, H. (2003). The impact of facilities on student choice of university. *Facilities*, 21(10), pp.212-222.

Randor, Z.J. & Barnes, D. (2007). Historical analysis of performance measurement and management in operations management. *International Journal of Productivity and Performance Management*, 56 (5/6), pp. 384-396

Rankin, R. & van Eldik, M. (2008). An Investigation into the Energy Savings and Economic Viability of Heat Pump Water Heaters Applied in the Residential and Commercial Sectors- A Comparison with Solar Water Heating Systems. M-Tech Industrial (Pty) Ltd. North-West University.

River and Associates. (2005).*Primer on demand-side management.* Report prepared for the World Bank. Washington DC.

Roebuck, R.M., Oltean-Dumbrava, C. & Tait, S. (2011). Whole life cost performance of domestic rainwater harvesting systems in the United Kingdom. *Water and Environment Journal,* 25, pp. 355-365.

Roosa, S.A. (2004). Planning for Sustainable Urban Development Using Alternative Energy Solutions. *Strategic Planning for Energy and the Environment*, 24(3), pp.37-56.

Scott, R.A. (2010). Introduction to exploring critical issues in American higher education. *On the Horizon*, 18 (4), pp21-32.

Sharp, L. (2002). Green campuses: the road from little victories to systematic transformation. *International Journal of Sustainability in Higher Education*, 3 (2), pp. 128-145.

Sustainable infrastructure, (2012). *Norwegian University of Science and Technology.* [online] Available at: http://www.ntnu.edu/ivt/sustainability [Accessed 3 February 2012].

Sustainable Infrastructure Engineering. (2001). *Sustainable Infrastructure, Research in the Department of Civil Engineering*. [online] Available at: http://www.civ.utoronto.ca/sir/default.htm. [Accessed 3 February 2012].

Tasol. (2012). Proposal for Solar PV System-Grid Tie. Unpublished document submitted to Nelson Mandela Metropolitan University. Port Elizabeth: Tasol.

The Real Estate and Infrastructure Division of the Deutshe Bank. (2007*). Performance Characteristics of Infrastructure Investments*. PREEF publication, USA: San Francisco.

Tsihrintzis, V.A., Akratos, C.S., Gikas, G.D., Karamouzis, D., & Angelakis, A.N. (2007). Performance and Cost Comparison of a FWS and a VSF Constructed Wetland System. *Environmental Technology, 28:*6 (2), pp. 621-628.

Turner & Townsend. (2012). *International construction cost survey.* [online] Available at: http://turnerandtownsend.com [Accessed 3 April 2012].

Victoria Transport Policy Institute. (2009). *Transportation Cost and Benefit Analysis- Techniques, Estimates and Implications.* Report prepared for the Victoria Transport Policy Institute, Australia.

Volksman, S. & Candidate, M.S. (2003). Sustainable Wastewater Treatment and reuse in Urban Areas of the Developing World. Michigan Technological University: Department of Civil and Environmental Engineering

Wadley, D. & Smith, P. (1998). If planning is about anything, what is it about? *International Journal of Social Economics*, 25 (6/7/8), pp. 1005 – 1029.

Walton, S.V. & Galea, C.E. (2005). Some considerations for applying business sustainability practices to campus environmental challenges. *International Journal of Sustainability in Higher Education,*.6 (2), pp. 147-160.

Welman, C., Kruger, F. & Mitchell, B. (2010). *Research methodology*. 3rd edition. Cape Town, South Africa: Oxford.

World Summit. (2005). The 2005 World Summit Outcomes. [online] Available at: http://www.who.int/hiv/universalaccess201/worldsummit.pdf. Accessed 16 February 2012].

Zikmund, W.G., Babin, B.J., Carr, J.C. & Griffen, M. (2010). *Business research methods*. 8th edition. Mason, Ohio: South-Western, Cencage Learning.

APPENDIX A: INTERVIEW SCHEDULE

INTERVIEW GUIDE

PRE-INTERVIEW PREPARATION

A) What are the research objectives for the study? Are they aligned with the questions in the interview guide?
B) Knowledge on the type of interview to be conducted and how to implement such an interview.
C) Location and scheduling of the interviews

IDENTIFYING INFORMATION

A) Transcribe the interview manually.
B) Name of interviewer and participants.
C) Interview date
D) Purpose statement of interview – to verify the process used and results achieved to quantify the financial implication of sustainable infrastructural interventions in relation to one another and in turn provide a basis for the determination of budget split between the various interventions.

OPENING

A) Introduction to the participants on the objectives of the research and what will be discussed during the interview.
B) Establishing – the researcher will state to the participants what information needs to be established.
C) Orientation – these are guidelines that shall be set out for the interview. For this interview during, open ended questions will be asked to the participants and response will be written down.

PURPOSE OF STUDY

- This study seeks to quantify the financial implication of sustainable infrastructural interventions in relation to one another and in turn provide a basis for the determination of budget split between the various interventions.
- Collectively determine the financial benefits of sustainability interventions in a manner that will provide a more holistic yet detailed perspective on sustainability.

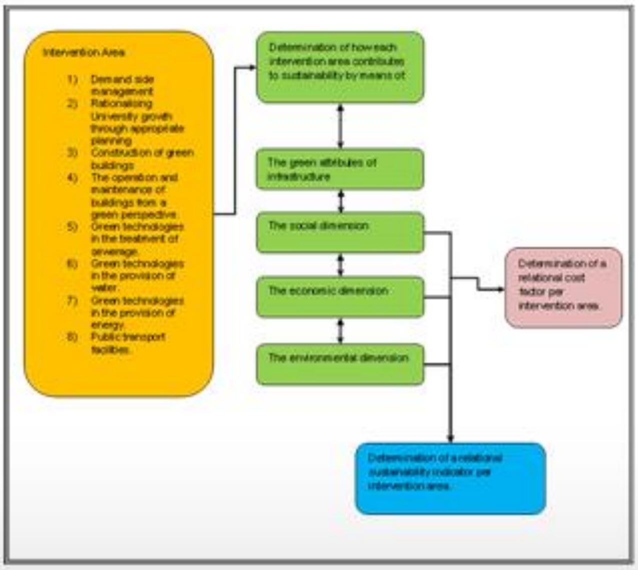
DEFINITION OF SUSTAINABLE INFRASTRUCTURE

- CONTEXT:
  - Demand side management with respect to end user utilisation of infrastructure;
  - Rationalising University growth as per an approved University growth plans;
  - The construction of new Green Star rated buildings as per the Green Building Council of South Africa's (GBCSA) rating tool for public and educational buildings;
  - The operation and maintenance of existing buildings as per the United States Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system. Currently no such rating system exists within South Africa hence the use of the United States Green Building Council's operation and maintenance of existing buildings rating tool;
  - The application of green technologies in the treatment of sewerage;
  - The application of green technologies in the conservation of water;
  - The application of green technologies in the provision of energy; and
  - The provision and utilisation of public transport facilities.

QUESTIONS

- *Comment on the elements contained in the definition*
- *Are there additional elements that should be considered?*

FRAMEWORK FOR THE STUDY

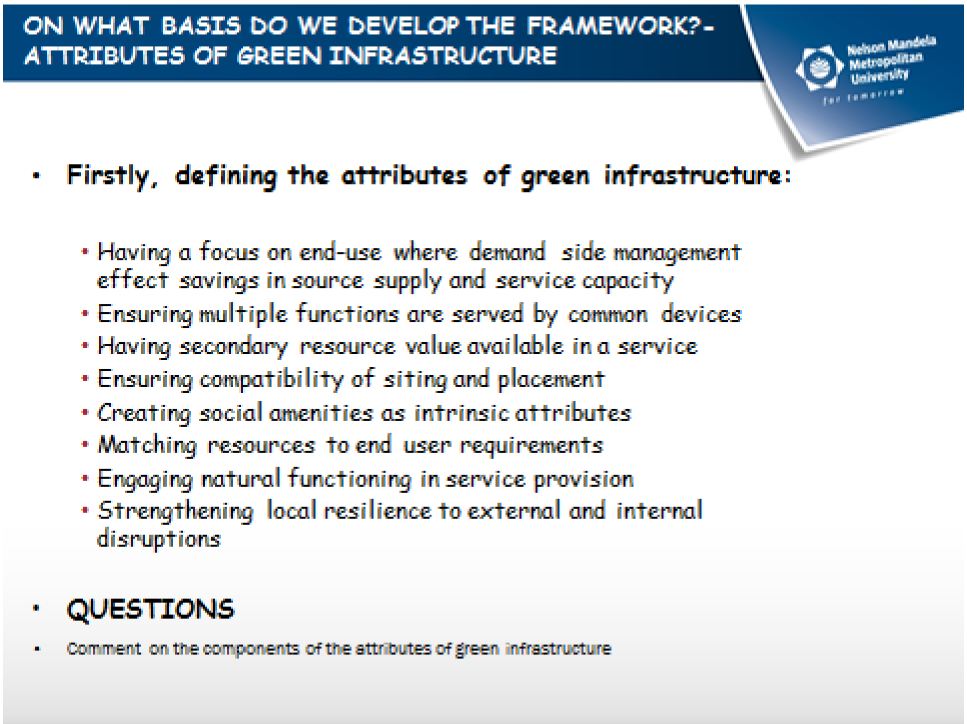


Source: Author's own compilation

- QUESTION: Give your opinion of this framework?

ON WHAT BASIS DO WE DEVELOP THE FRAMEWORK? - AN INTERNAL SUSTAINABILITY INDICATOR

- **Develop a sustainability indicator, relevant to infrastructure development, based on:**
  - The attributes of green infrastructure
  - The environmental dimensions of sustainability
  - The economic dimensions of sustainability
  - The social dimensions of sustainability

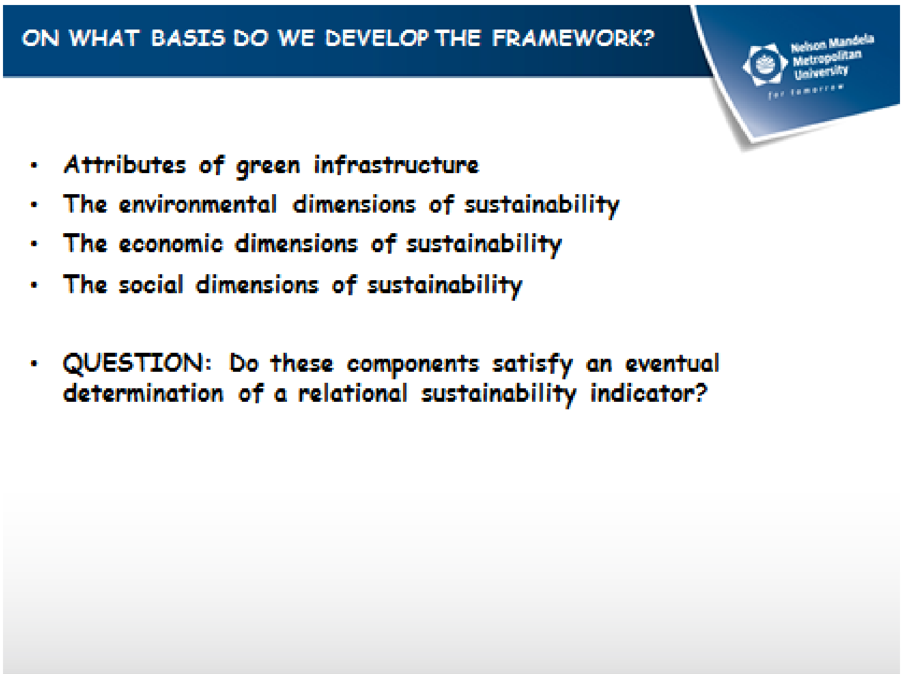


QUESTIONS **What do the allocations look like?**		**GREEN INFRASTRUCTURE ATTRIBUTES**							
		A focus on end use where demand side management and efficiency measures effect savings in source supply and service capacity	Multiple functions served by common devices	Secondary resource value available in a service	Compatibility of siting and placement	Creation of social amenities as intrinsic attributes	Matching resources to end user requirements	Engaging natural functioning in service provision	Strengthening local resilience to external and internal disruptions
STUDY'S COMPONENTS OF SUSTAINABLE INFRASTRUCTURE PROVISION	Demand side management	X					X		X
	Rationalising University growth through appropriate planning				X	X	X		X
	Construction of green buildings		X				X		X
	The operation and maintenance of buildings from a green perspective		X				X		X
	Green technologies in the treatment of sewerage		X	X			X	X	X
	Green technologies in the provision of water		X	X			X	X	X
	Green technologies in the provision of energy		X				X	X	X
	Public transportation facilities				X		X		

QUESTIONS How do the allocations look?	ENVIRONMENTAL DIMENSION																			
	AIR					LAND		MATERIALS		ENERGY	WATER					BIODIVERSITY			PRODUCTS AND SERVICES	
	Global warming emissions	Ozone depletion emissions	Atmospheric acidifcation	Human health effects	Photochemical ozone formation	Usage	Waste generation	Consumption	Consumption of hazardous materials	Consumption	Consumption	Acidification	Aquatic oxygen demand	Ecotoxicity to aquatic life	Eutrophication	Ecosystems	Protected areas	Species	Products recyclability	Ecofriendly products
STUDY'S COMPONENTS OF SUSTAINABLE INFRASTRUCTURE PROVISION																				
Demand side management	x	x						x		x										x
Rationalising University growth through appropriate planning						x		x		x						x	x	x		
Construction of green buildings		x		x		x		x		x	x								X	x
The operation and maintenance of buildings from a green perspective		x		x						x	x									x
Green technologies in the treatment of sewerage											x					x			X	x
Green technologies in the provision of water											x					x			X	x
Green technologies in the provision of energy										x										x
Public transportation facilities	x	x		x		x		x		x										x

QUESTIONS What do the allocations look like?	ECONOMIC DIMENSION					
	INVESTORS		INVESTMENTS		PROFIT AND VALUE	CRISIS MANAGEMENT
	Corporate governance	Shareholders' remuneration	Capital employed	Research and development		
STUDY'S COMPONENTS OF SUSTAINABLE INFRASTRUCTURE PROVISION						
Demand side management			x			
Rationalising University growth through appropriate planning						
Construction of green buildings						
The operation and maintenance of buildings from a green perspective						
Green technologies in the treatment of sewerage				x		
Green technologies in the provision of water			x	x		
Green technologies in the provision of energy			x	x		
Public transportation facilities						

QUESTIONS What do the allocations look like?		SOCIAL DIMENSION																				
		LABOUR PRACTICES AND DECENT WORK						CUSTOMER RELATIONSHIP MANAGEMENT					CORPORATE CITIZENSHIP					SUPPLIERS AND PARTNERS		PUBLIC SECTOR	
		Employees' education, training &development	Diversity and opportunity	Health and safety	Job creation	Talent attraction and retention	Human rights	Customer satisfaction	Customer health and safety	Products and labels	Advertising	Respect for consumer privacy	Social actions	Political contributions	Codes of conduct, corruption and	Competition and pricing	Society communication	Selection, evaluation, development of	Contracts	Subsidies	Taxes
STUDY'S COMPONENTS OF SUSTAINABLE INFRASTRUCTURE PROVISION	Demand side management																				
	Rationalising University growth through appropriate planning		x			x		x													
	Construction of green buildings																				
	The operation and maintenance of buildings from a green perspective									x											
	Green technologies in the treatment of sewerage																				
	Green technologies in the provision of water																				
	Green technologies in the provision of energy																				
	Public transportation facilities												x								



OUTCOME OF RELATIONAL SUSTAINABILITY INDICATOR

		FACTORS OF RELATIONAL SUSTAINABILITY					
		GREEN INFRASTRUCTURE ATTRIBUTES	ENVIRONMENTAL DIMENSION OF SUSTAINABILITY	SOCIAL DIMENSION OF SUSTAINABILITY	ECONOMIC DIMENSION OF SUSTAINABILITY	TOTAL	
STUDY'S COMPONENTS OF SUSTAINABLE INFRASTRUCTURE PROVISION	Demand side management	3	5	0	1	9	0.111
	Rationalising University growth through appropriate planning	4	6	3	0	13	0.160
	Construction of green buildings	3	8	0	0	11	0.136
	The operation and maintenance of buildings from a green perspective	3	5	1	0	9	0.111
	Green technologies in the treatment of sewerage	5	4	0	1	10	0.123
	Green technologies in the provision of water	5	4	0	2	11	0.136
	Green technologies in the provision of energy	4	2	0	2	8	0.099
	Public transportation facilities	2	7	1	0	10	0.123
	TOTAL						1.0

- **QUESTION:** What is your interpretation of the resultant relational sustainability indicators considering the elements of the various components of sustainable infrastructure provision?

OUTCOME OF A RELATIONAL COST FACTOR

COMPONENT	ESTIMATED COST	RELATIONAL COST FACTOR
Demand side management	R12,672,265	0.172
Rationalising spatial growth	R3,691,885	0.050
Construction of green buildings	R16,148,200	0.220
Operation and maintenance costs	R16,924,203	0.230
Wastewater costs	R5,237,365	0.071
Water costs	R1,235,879	0.017
Energy cost	R11,278,041	0.153
Transport costs	R6,376,170	0.087
Total	R73,564,008	1.000

- **QUESTION:** What is your interpretation of the resultant relational cost factors considering the elements of the various components of sustainable infrastructure provision?

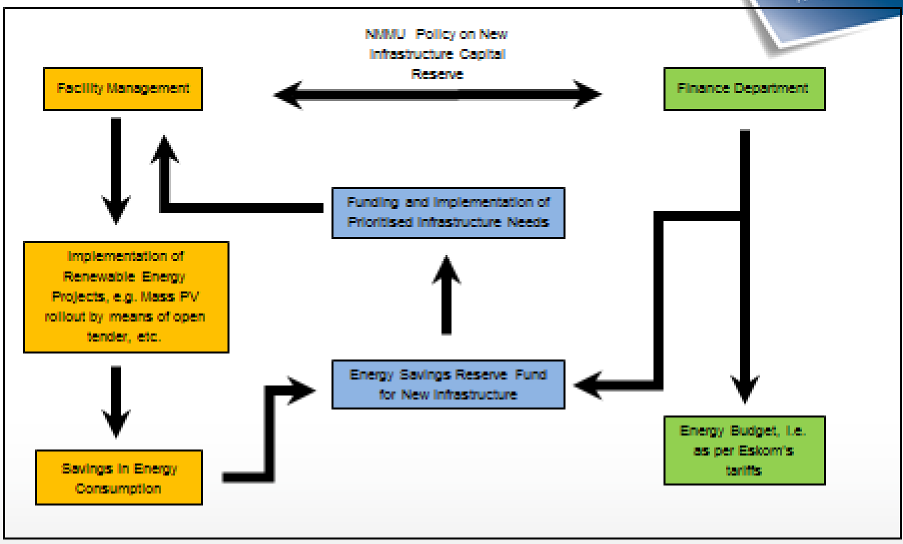
FINANCIAL VIABILITY FRAMEWORK

COMPONENT	INITIAL COST OVER AND ABOVE COVENTIONAL INFRASTRUCTURE	RELATIONAL COST FACTOR E	RELATIONAL SUSTAINABILITY INDICATOR F	RELATIONAL COST BENEFIT G = EXF
Demand side management	R12,672,265	0.172	0.111	0.019
Rationalising spatial growth	R3,691,885	0.050	0.160	0.008
Construction of green buildings	R16,148,200	0.220	0.136	0.029
Operation and maintenance costs	R16,924,203	0.230	0.111	0.026
Wastewater costs	R5,237,365	0.071	0.123	0.009
Water costs	R1,235,879	0.017	0.136	0.002
Energy cost	R11,278,041	0.153	0.099	0.015
Transport costs	R6,376,170	0.087	0.123	0.011
TOTAL	R73,684,008	1.000	1.000	-

- Demand side management interventions: 15.97%
- Rationalising spatial growth: 6.72%
- Construction of green buildings: 24.37%
- Operations and maintenance: 21.85%
- Wastewater: 7.56%
- Water: 1.68%
- Energy: 12.61%
- Transport: 9.24%

- **QUESTION: Do you think the envisaged budget split is achievable and realistic?**

MAKING IT REAL



- **QUESTION: Is this realistic?**