Assessing the Sustainability of Urban Residential Development: An Effects Based Rating

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By

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Declaration

I, COURTNEY DICK, know the meaning of plagiarism and declare that all the work in this document, save for that which is properly acknowledged, is my own.

Signed: ……

Executive Summary

The effects of historically inefficient urban design have begun to create small negative consequences in urban environments. The aggregation of these small scale changes has led to increasingly recognised large scale impacts. These include, amongst others, climate change, decreasing species diversity, decreasing human health and increasing social inequalities. As the concentrated centres of human activity, urban environments are responsible for the majority of the negative impacts noted. It is not certain to what extent the environmental sinks can assimilate the externalised waste products of the city before a point is reached where the imbalance cannot be corrected.

This dissertation investigates what causes the urban environment to operate inefficiently and attempts to provide a manner in which this inefficiency may be recognised and corrected. The particular focus is on mixed income urban residential development in Cape Town, South Africa. This work attempts to develop the theory that effect-based systems of assessment are more useful than traditional technique-based assessment. This may be due to the perceived ease of creation, application and flexibility of effects-based systems.

The methodology for this process takes two distinct paths. Firstly it uses extensive literature review to identify urban problems, discuss ideal outcomes and critically assess the systems which attempt to judge these outcomes. Secondly, it attempts to create the new assessment system based on the examination of the evidence from critical review. The success of the processes used in the creation of this assessment system is an important outcome. The assessment system created is tested by applying it to a real development situated in the greater Cape Town area.

The findings of this work show that effects-based assessment systems are able to be created and successfully applied. Importantly, it also shows that the methods used to create the system are valid and may be up-scaled in future studies. This work concludes with a detailed review of the outcomes and a set of recommendations for future applications and improvements.

List of Terms

CLOSED ENDED QUESTIONS	These provide a fixed list of alternative responses and ask the respondent to select one or more of them as indicative of the best possible answer. (Rea and Parker, 2005:42)
CONFIDENCE INTERVAL	The range in which the true value of the population is estimated to be. It is expressed as a percentage. (Israel, 2003:1)
CONFIDENCE LEVEL	The level of certainty of the survey, or how likely it is that an interval contains the true measure of the parameter of interest. It is expressed as a percentage. (Israel, 2003:1)
DEGREE OF VARIABILITY	A statement of the inconsistency of answers from the population. The maximum degree of variability is 50% as the population is evenly split in their choices. Variability's of 10% or 90% are low. (Israel, 2003:2)
ERF	A formally defined plot of land with a surveyed boundary registered on a title deed and legally authorized to be bought and sold on the market. Erven is the word used to refer to two or more of these plots of land. (Swilling and Annecke, undated:2)
GLOBAL WARMING	The gradual warming of the Earth's climate as a result of the build-up of greenhouse gases in the atmosphere. (Department of Environmental Affairs and Tourism (2007:32)

GREENHOUSE GAS	Any gas (such as carbon dioxide, methane and nitrous oxide) that absorbs infrared radiation in the atmosphere, thus allowing more heat to enter the earth's atmosphere than is able to leave it. (Department of Environmental Affairs and Tourism, 2007:32)
GOVERNANCE	Governance is concerned with enhancing government's capacity to act by forging strategic interorganisational coalitions with actors in the external environment. (Peters and Pierre, 1998:231)
INDUCTION	A form of reasoning from statements about observed cases to statements about other, unobserved, cases or – more usually – to a general claim about most or all cases of the same kind. (Jupp, 2006:146)
NON PROBABILITY SAMPLING	Often called quota sampling and it entails choosing entities to be sampled in order to purposely attempt to recreate the population as closely as possible in terms of certain characteristics. (Buckingham and Saunders, 2004:294)
NON SAMPLING ERROR	Error built into the design or the mode of collection of data. (Sapsford, 2007:92)
OPEN ENDED QUESTIONS	These have no pre-existing response categories and permit the respondent a great deal of latitude in responding to them. (Rea and Parker, 2005:42)

POPULATION	The entire set about which we wish to make generalizations through a survey. (Sapsford, 2007:6)
PROBABILITY SAMPLING	Sometimes called random sampling and it entails that every entity to be sampled has an equal and known chance of being selected from the population. (Buckingham and Saunders, 2004:294)
RELIABILITY	A matter of whether a particular technique, applied repeatedly to the same object, would yield the same result each time. (Babbie and Mouton, 2005:118)
SAMPLE	A subset of the population – usually with the implication that the subset resembles the population closely on key characteristics. (Sapsford, 2007:7)
SAMPLING ERROR	The error of measurement due to the predictable variation between samples when drawn randomly from the same population. The sampling error decreases with the square root of the sample size. (Sapsford, 2007:92)
SAMPLING FRAME	The sequence of steps that moves the researcher from the general population to the sample. (Rea and Parker, 2005:25)
STANDARD DEVIATION	This measures the average amount by which each case differs from the group mean. (Buckingham and Saunders, 2004:72)

VALIDITY	The extent to which an empirical measure adequately reflects the real meaning of the concept under consideration. (Babbie and Mouton, 2005:122)

List of Abbreviations

BREEAM	Building Research Establishment Environmental Assessment Method
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
CFL	Compact Fluorescent Light
EF	Ecological Footprint
DEAT	Department of Environmental Affairs and Tourism
DOH	Department of Housing
GDP	Gross Domestic Product
HDI	Human Development Index
IID	Independent and Identically Distributed
LCA	Lifecycle Analysis
LED	Light Emitting Diode
LEED	Leadership in Energy and Environmental Design
MAV	Multi-Attribute Valuation
MLE	Maximum Likelihood Estimation
MNL	Multinomial Logit
RP	Revealed Preference
SDI	Sustainable Development Indicator
SP	Stated Preference
TERI-GRIHA	The Energy and Resources Institute Green Rating for Integrated Habitat Assessment
UN	United Nations

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1 Introduction

1.1 Background

There is an ever growing awareness of environmental issues in the general public. This has been driven by the media rightly expressing the almost consensus scientific view that environmental issues have been disregarded. The positive side of this coverage has been the increased interest in environmental protection and a more holistic approach to design. Increased interest has helped research to rise in prominence and funding to increase. There is no doubt that public outcry over the stark realities facing the planet will go a long way toward ensuring the situation is slowly improved.

Trends and Causes

Climate change is a now widely accepted phenomenon which has large potential impacts for South Africa. Large greenhouse gas emissions drive these changes across the world. Although South Africa is a small country with comparatively modest total emissions, reliance on coal based power generation means that the annual per capita emission of carbon dioxide (a major greenhouse gas) is disproportionately high at 6.91 tons per capita when compared to the African average of 0.82 tons per capita and the world average of 3.89 tons per capita (Department of Environmental Affairs and Tourism, 2007:32,33). The Department of Environmental Affairs and Tourism (DEAT) (2007:32) lists the following consequences of climate change:

- Diminishing water supply due to changing rainfall patterns
- Increased malaria risk areas
- Crop production declines
- Livestock reduction due to changes in grazing areas
- Fisheries reduction due to changing sea water temperatures
- Biodiversity loss with associated tourism impacts
- An average sea level rise of approximately 39 centimetres (Lomborg, 2007:1).

Reliance on imported oil and oil based products is identified by the DEAT (2007:35) as a problem not only in terms of environmental impact but also long term economic and social success. Price fluctuations have a large influence on profitability of

business as well as consumer spending security. Poor residents are the most affected, contributing negatively to social equity and equitable economic development. The dramatic fuel cost increases of 2008 have clearly demonstrated this.

The rapidly globalizing world economy has potential problems and opportunities for South Africa. Firstly, there is greater demand for the raw materials supplied. There is however the threat of cheap imports undermining local products and forcing less stringent business practices in order to lower costs (DEAT, 2007:36).

The energy intensive practices in South Africa have been enabled by an abundant, cheap coal supply (DEAT, 2007:37). This has created a high amount of energy use per unit of GDP. Cheaper energy prices do not necessitate the installation of efficiency measures (Winkler (ed.), 2004:29). This has caused high greenhouse gas emission rates. The power outages of 2006-2008 have highlighted the manner in which cheap fuel has increased energy demand to beyond the capacity for generation.

Water resources in South Africa are already stressed with a demand at 97% of possible supply. Even with supply increases through infrastructure, the DEAT (2007:39) forecasts a scenario where demand could rise as high as 113% of supply. Thus it is imperative that water resource efficiency improves.

Municipal solid waste is growing rapidly in the country with wealthy residents generating in excess of 2kg/person/day in comparison to the 0.16kg/person/day generation rates of the poor (DEAT, 2007:40). In Cape Town, waste generation is increasing at a greater rate than economic growth (DEAT, 2007:40).

The DEAT (2007:41) explains the state of the ecosystem in South Africa as follows:

> 34% of South Africa's terrestrial ecosystems are categorised as threatened, mainly due to loss and degradation of natural habitat, through, for example, cultivation, deforestation, urban and coastal sprawl, mining, and invasion by alien species. 82% of our main stem rivers are classified as threatened; it is estimated that 50% of our wetlands have already been destroyed; and 36% of freshwater fish are threatened. River ecosystems are under pressure from over-abstraction of water, for a range of uses, including agricultural, industrial and residential. Poor management of land also directly impacts river

> biodiversity. 65% of marine biozones are threatened, and eight of the 13 estuary groups are threatened.

Increasing vehicle emissions (2% per year) are contributing to lessening air quality in South African cities (DEAT, 2007:43). The DEAT estimate that air quality induced health problems will increase 20% over the next decade. The wide ranging consequences of ill health are severe enough to necessitate urgent action.

Affected Groups/Sectors

There are several groups affected by the development path of the country:

- The poor are affected the most as they have the highest risk. Service provision insulates wealthier urban dwellers from these risks, but the poor are often under serviced. It is estimated that 20% of urban inhabitants do not have access to electricity (Winkler (ed.), 2004:11) and these are the poorest residents. Transportation inefficiency and poor spatial layout increases relative spending and reduces wealth, global economic conditions lead to job losses for the least skilled, poor environmental amenity leads to illness and infrastructure failures lead to disasters on all scales.
- The economy is directly impacted by energy prices/supply, the loss of environmental amenity (with associated costs of substitution) and the loss of productive capacity due to declining human health.
- Natural environments and endemic flora and fauna are lost due to the lack of sustainable planning.
- Urban environments are most affected as they have the largest concentration of people and the greatest resource throughput and waste outputs.

A Good Development Path

The Department of Environmental Affairs and Tourism (DEAT) (2007:21) state the approach to good development which is needed in developing countries:

> Zero growth strategies like those adopted in some developed economies will not work in a developing country context where poverty eradication will of necessity entail substantial investments in material infrastructure, physical development and the material pre-conditions for a decent quality of life for all. In other words, increased household consumption for the poor majority and sufficient rather than over-consumption for the

> rest is a pre-condition for sustainable living in the longer-term. To achieve this, inequalities will need to be reduced and consumption systems and patterns will need to become more resource efficient and less wasteful.

The Department of Environmental Affairs and Tourism (2007:29) details a vision of what this good development path entails:

> South Africa aspires to be a sustainable, economically prosperous and self-reliant nation state that safeguards its democracy by meeting the fundamental human needs of its people, by managing its limited ecological resources responsibly for current and future generations, and by advancing efficient and effective integrated planning and governance through national, regional and global collaboration.

1.2 Problem Statement

1.2.1 The Urban Environment

The urban environment is largely responsible for the poor environmental and social state in South Africa and around the world. Hughes, (1974:120,123) describes the destructive features of its energy/resource/waste flows:

1. The energy flows in the city are many times greater than those in an equivalent size natural ecosystem.
2. The material cycles in the city may be considered to be broken. This is as many by-products are externalised beyond city limits. The anthroposystem is therefore an open system. (See Figure 1)
3. There is little or no feedback system between humans and the natural condition in the cities. Thus population dynamics are unaffected by changes in the state of the immediate environment.

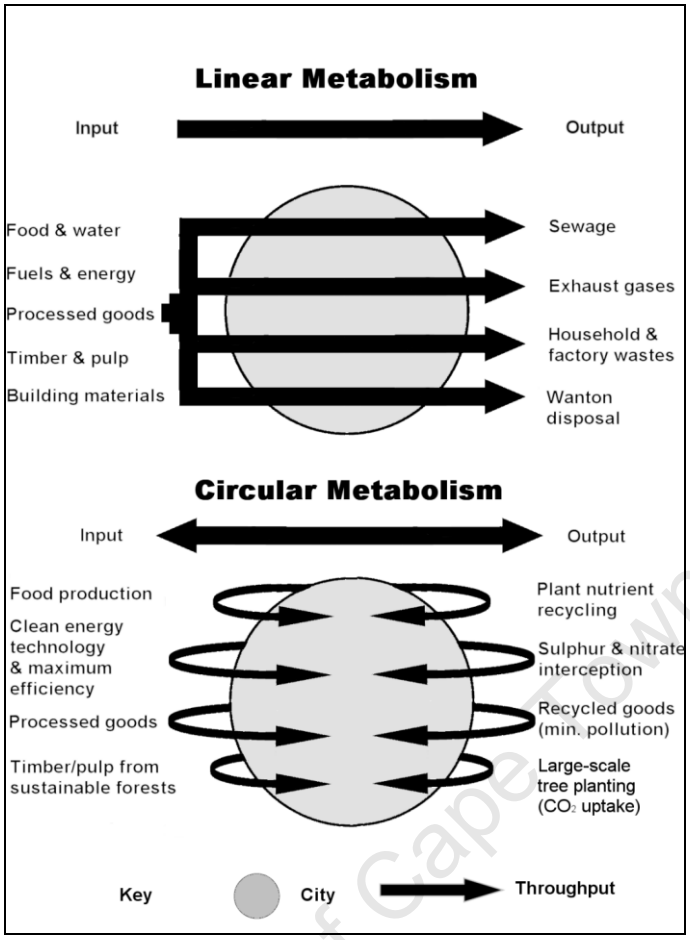


Figure 1: A linear city metabolism and the idealised circular sustainable metabolism.

Source: Development Education Project (2008)

Urban expansion, even without the added pollution element, is inherently destructive. Over 34,000 hectares of farmland is annually converted into urban area in South Africa (Rosenberg, 2007). Rosenberg (2007) therefore calculates that by the year 2050 there will be only 0.2 hectares of productive farmland per person in South Africa. This is well below international averages.

Urban poverty has a relation to the urban environment, although the nature of this link is often misunderstood. Satterthwaite (2003:74) dispels the myth that it is the urban poor and the prevalence of urban poverty that causes environmental degradation. Indeed it is the consumptive patterns and the linear metabolism of the non-poor which cause degradation and contribute to the worsening of urban poverty. This is as the environmental degradation caused by the over-consumption of the non-poor, creates environmental hazards which cause burdens on the poor (Satterthwaite, 2003:76). These burdens may be disease exposure or poor living environments. Thus to

significantly reduce urban poverty and lessen environmental damage, the structural bias toward linear consumptive patterns must be eliminated.

The combination of broken material cycles leading to environmental decay, expanding urban footprints destroying productive land and lessening regenerative capacity, and the cycles of structural poverty together create a continually worsening urban scenario. This urban scenario has global links which cross boundaries and affects people and the environment widely through the externalisation of negative effects and a widening wealth range fuelled by the unequal development enabled by globalization (McMichael, 2000:1121, 1122).

1.2.2 Assessment Processes

The vague definition of sustainable development does not lead itself easily to quantification. It is thus difficult to determine when sustainability has been achieved. The standard compromise is therefore to assign importance to sustainability promoting techniques and to aggregate these. Such methods are useful if they are applied in conditions mirroring those where they were created. However this is not often possible with their implementation. They are also too complex to be easily recreated in differing conditions. Thus there is currently no satisfactory manner in which to review and choose which techniques to implement in residential development to obtain the greatest net benefit.

1.3 Hypothesis and Objective

The central hypothesis in this work is that it is possible to create a transparent method of attaching importance to the effects of sustainability producing techniques.

The chief objective of this work is to develop a tool which may be used in decision making. This decision making is in the field of project planning and design and it is intended that designers may make use of this work in order to choose which techniques to implement to create the most sustainable outcome.

1.4 Application

This work is applicable in the Cape Town area of the Western Cape Province, South Africa. Although the process may be applied freely in other parts of the world, the quantitative results of the process are most applicable where they are produced. A general income range has been used to define the scope outside of which this work may not be applicable. Generally it does not apply to informal settlements or rural areas as well as to the extremely wealthy. The middle range from below to above average income settlements are the most applicable. A range is shown in Figure 2 with some well known Cape Town suburbs used to indicate the typical areas of relevance for this research.

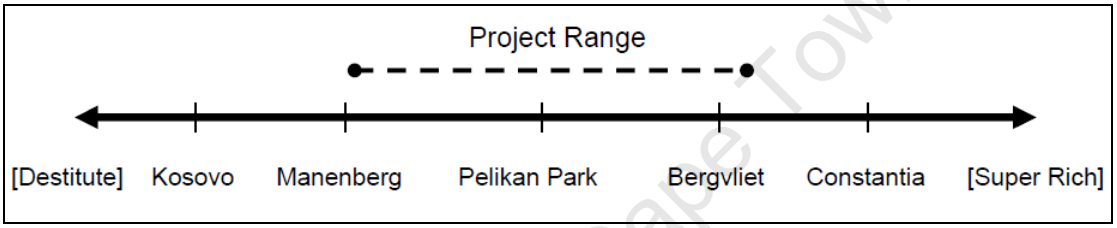


Figure 2: The range of development to which this research applies

1.5 What is expected in the text

This work is divided into several sections representing a natural progression from;

- information gathering and review,
- to critical assessment and problem identification,
- to developing a strategy for attempting to overcome recognised problems,
- to developing a strategy for collecting new data,
- to collecting, managing and analyzing the data
- and finally to test the results by applying them to a practical scenario.

Chapter 2 will begin by making clear the accepted definitions of urban sustainability. This is important in that achieving this standard is the goal of this work. This will be followed by a review and understanding of common sustainability assessment methods. This is important in order to present a method here to improve on these. Following on from this, the objectives and techniques of creating sustainability will be

reviewed. Survey research methodology will then be described in order to design appropriate data collection processes.

Chapter 3 will develop the methodology for the study. It will describe the important steps in this work. This will be followed by a review of the survey processes used and the data collected.

Chapter 4 will detail the analysis of collected data and present the results of the study.

Chapter 5 presents a case study procedure to test the usefulness of the data by applying it in a real development. The significance of the results will be tested in this process and conclusions may be drawn on any modifications that are necessary.

Chapter 6 presents the discussions and conclusions while **Chapter 7** gives the recommendations for further research on the topic.

2 Literature Review

2.1 Introduction

The purpose of the literature review is to understand and critically assess the current thinking in urban sustainability assessment. However to move to this point, it is first necessary to have a thorough understanding of the different concepts in urban sustainability and the basic assessment techniques. Also, the fundamental building blocks of sustainability (objectives, techniques and effects) must be understood in order to integrate these into an effective assessment system. Once all this literature has been compiled, it is possible to use the information to critically review assessment systems and design a method to improve on their shortcomings. Thus the survey, analysis and composition methods most relevant will also be discussed in detail.

2.2 Sustainability in the Urban Context

Some of the more popular definitions of sustainable development and sustainability are presented below and followed by commentary.

> Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (Brundtland Commission (World Commission on Environment and Development), 1987:43)

Although it is made clear in the Brundtland Commission (1987:43) report that the needs of the poor are those to which "overriding priority should be given", it does not clearly account for how the needs of the privileged should be considered. As Serageldin (1996:2) asks, "what does it mean for a family that already has two cars, three televisions, and two VCRs?"

Sustainability is commonly represented graphically. The three interacting spheres (Figure 3) or three sided triangle representations (Figure 4) are most common.

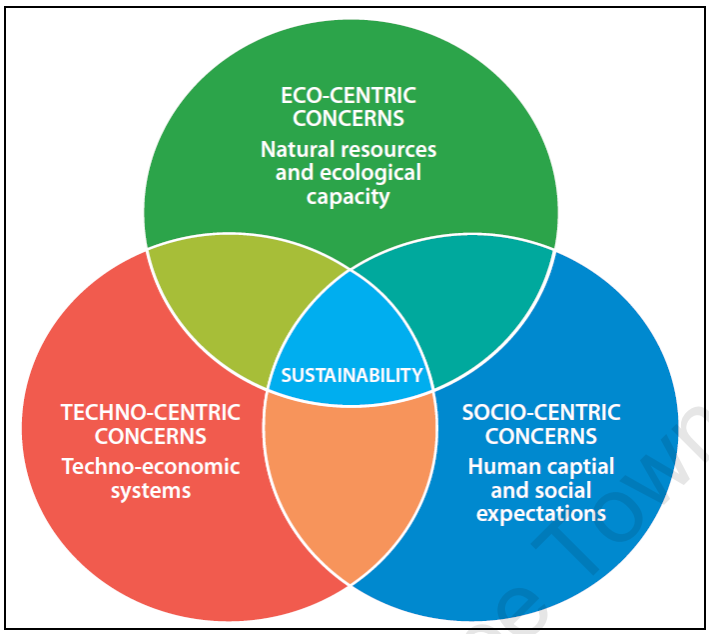


Figure 3: Venn diagram representing the interactive forces driving sustainability

Source: Dodds and Venables (2005:8)

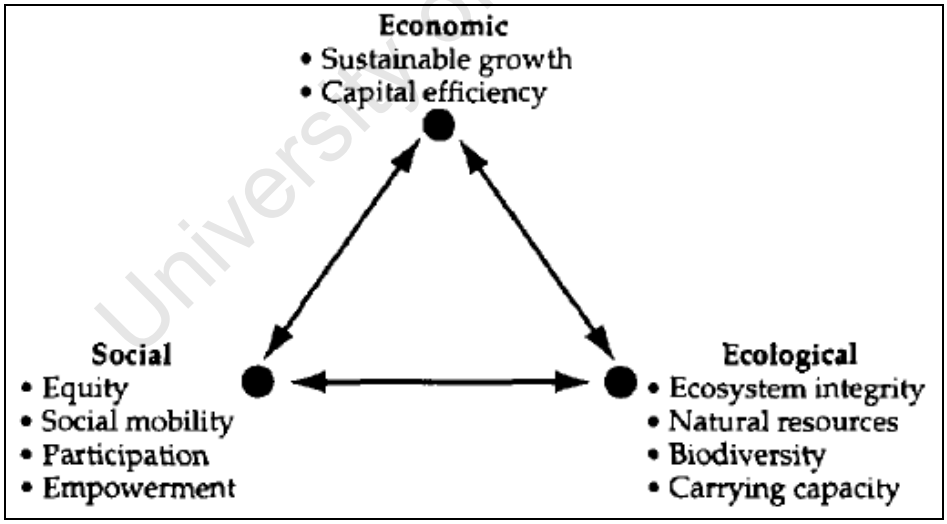


Figure 4: The sustainable development triangle.

Source: Serageldin (1996:2)

Dodds and Venables (2005:7, 8) explain the interacting spheres as follows:

> "Eco-centric concerns" represent the ability of the planet to sustain us – by providing material and energy resources and by accommodating us and our emissions and wastes.

> "Techno-centric concerns", which encompass techno-economic systems, represent human skills and ingenuity – the skills that engineers must continue to deploy – and the economic system within which to deploy them. "Socio-centric concerns" represent human expectations and aspirations – the need of human beings to live worthwhile lives."

Dodds and Venables (2005:9) further explain the concepts of inter-generational and intra-generational equity. Inter-generational refers to the obligation to maintain the standard of living through generations. Intra-generational equity refers to maintaining an equal standard of living for all those currently inhabiting the earth. It is conceded that while intra-generational equity is the most visible problem, inter-generational equity is as important.

Zimmermann *et al*. (2005:1148) describe sustainability as follows:

> Sustainability is defined as a state in which a stable social order underpinned by a suitable economic framework can prevail in the long term without overtaxing the earth's overall ecological capacity.

This definition places an emphasis on social stability, as without this order the other spheres of sustainability would be of no importance to humans.

The following definition by Serageldin (1996:3) is of sustainability as an opportunity to create and preserve as much as possible.

> Sustainability is to leave future generations as many opportunities as we ourselves have had, if not more.

Serageldin (1996:4) uses this definition in conjunction with an understanding of the concept of capital. He states that we should not deplete our per capita capital and any activity which reduces capital is not sustainable. Serageldin goes on to define the four types of capital we should not deplete (1996:4-7).

- **Man-made capital**: Assets created by humans and subject to traditional accounting methods.
- **Natural capital**: "…is basically our natural endowment and is defined as the stock of environmentally provided assets (such as soil, atmosphere, forests, water [and]

wetlands) that provide a flow of useful goods or services." It is important to note that accurate accounting must not confuse the depletion of natural capital as a form of income.

- **Human capital**: This form of capital is an investment in people, with emphasis on education and health.
- **Social capital**: This relates to social cohesion and "…common identification with the forms of governance and of cultural expression and social behaviour…". Strong social capital is therefore a society in which people feel included in governance and are able to participate freely, express their views and be mindful of the perspectives of others.

> Sustainability has several levels - weak, sensible, and strong - depending on how strictly we elect to hew to the concept of maintenance or non-declining capital. (Serageldin, 1996:8)

Serageldin (1996:8) describes the three levels of sustainability as follows:

- **Weak sustainability**: "…is maintaining total capital intact without regard to its composition (natural, man-made, social, or human)." This assumes that the four types of capital may be perfectly substituted for each other and arithmetically totaled.
- **Sensible sustainability**: This builds upon weak sustainability by recognizing that the capitals are interchangeable to an extent but not perfectly substitutable. It therefore advises that while the total capital should remain at a fixed level, care must also be taken to maintain certain ratios between them. Thus, a loss of one form must be substituted against an acceptable gain in another while not depleting any one capital below a predetermined amount.
- **Strong sustainability**: This concept aims to maintain and grow each of the four types of capital without the depletion of any capital. However it is not possible to avoid any drawdown in capital and therefore these losses must be replaced with an equal gain through investment in the same capital type.

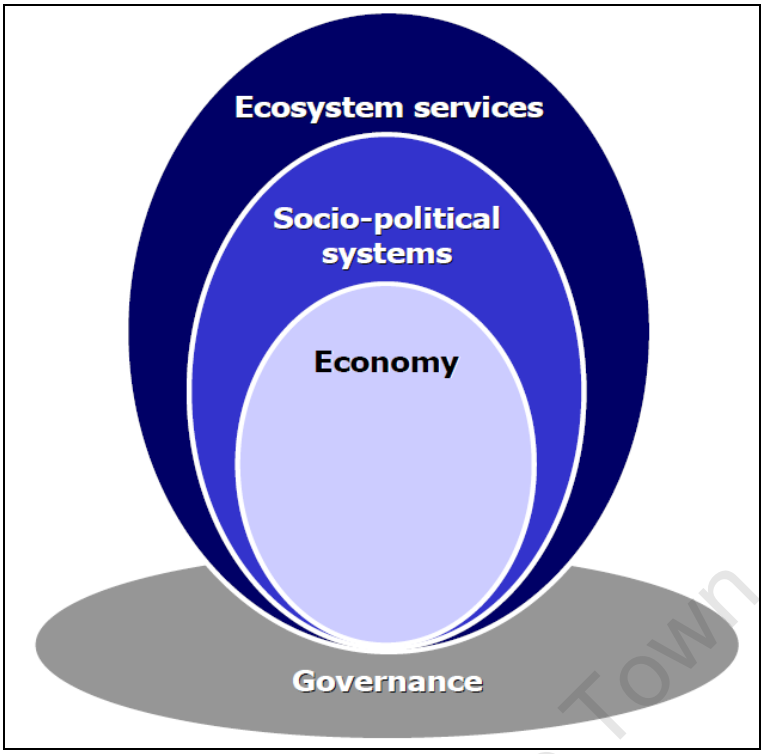


Figure 5: A systems approach to sustainability.
Source: Department of Environmental Affairs and Tourism (2007:21)

The Department of Environmental Affairs and Tourism (2007:21) prefer a systems approach to defining sustainability which acknowledges that the economy, socio-political (human) systems and ecosystem services are integrated within one another and that a functional relationship must be maintained (Figure 5). These relationships must be carefully regulated through governance. The DEAT (2007:21) further states that it is paramount to recognise certain "non-negotiable ecological thresholds". It further advises using a "precautionary principle" to prevent ecological damage which will undermine the other systems which depend thereon. This entails "pursu[ing] growth that respects the limits of our ecosystems".

Newman (1999:220) describes sustainability in an urban area as "…the reduction of the city's use of natural resources and production of wastes while simultaneously improving its livability, so that it can better fit within the capacities of the local, regional and global ecosystems".

Engel-Yan *et al* (2005:46) explain that the "essential public services of transportation, utilities (water, gas, electric), energy, telecommunications, waste

disposal, park lands, sports, and recreational and housing" are important aspects of urban neighbourhood sustainability. Engel-Yan *et al* (2005:46) also state that "the design of a sustainable neighbourhood involves creative arrangement of components and attention to details to meet a set of specifications subject to various other constraints." Thus the wide range of important aspects, coupled with the variety of constraints and specifications, creates a very different outcome in neighbourhoods. The difficulty lies in that all these design outcomes must be assessed against a standard of sustainability.

2.3 Sustainability Assessment

Indices and indicators are used to measure progress toward a predetermined goal and then to combine these individual progressions in some manner to measure overall progress (Singh *et al*, 2009:191).

2.3.1 Construction of Indices

There are many ways to create indicator systems, but Singh *et al* (2009:192) explain that they can be developed in two general ways:

- The 'top-down' approach, which means that experts and researchers define the framework and the set of SDI's [Sustainable Development Indicators].
- The 'bottom-up' approach that features the participation of different stakeholders in the design of the framework and the SDI selection process.

However the creation of indicators is not a simple process and Serageldin (1996:3) explains the difficulty in comparing sustainability across the environmental, social and economic fields as, "The units of measurement are different, the constructs are different, and the context and time scale are different."

Many authors describe the complex processes in creating composite indicator systems in a deceptively simple manner:

Böhringer and Jochem (2007:2) state:

> Firstly, in selecting input variables one should be conscious that themes determine the thematic aggregation method and units determine the technical aggregation method. Secondly, as there are no general rules for normalization of these variables and their weighting these procedures should be treated in a transparent way with great reserve and be subject to comprehensive sensitivity analysis. Thirdly, commensurability of input variables should be assured.

Singh *et al* (2009:195,196) explain that "…composite indexing remains an inherently value laden and subjective exercise. Based on the goal, the component will have to be selected whether it is of universal significance or for local conditions. The number and nature of the components that will make up part of the composite index need to be determined based on theory, empirical analysis, pragmatism or intuitive appeal, or some combination thereof".

Valentin and Spangenberg (2000:381-382) state that indicators need, "(a) to be simple, the number of indicators must be limited and the method of calculating them transparent; (b) directionally clear [which] means that they should indicate items and trends obviously relevant in terms of importance for sustainability, and that they are sensitive, i.e., able to signal progress or the absence of it".

There is popular criticism of the subjectivity of composite indicator creation due to the use of necessary assumptions, exclusion of components and the variety in weighting methods. However Singh *et al* (2009:197) recommend the use of sensitivity analysis or other testing of the systems to check validity.

To avoid the errors in measurement associated with using surveys to construct indices, Mega and Pedersen (1998:28) suggest:

- Adequate provision of information to make the context of the question fully understood by the respondent, in order to avoid mis-specification;
- Provision of information in a way not to predispose the respondent;
- The questions and information should not provide any incentive to the respondent to misrepresent his or her values.

2.3.2 Indicators in Practice

One study of indicators shows that there are over 500 indicator and rating systems worldwide (Böhringer and Jochem, 2007:1) with varying formats and emphasis and it is therefore difficult to assess the most useful features of each. Some of the better known, relevant, indicator systems are briefly described below.

Human Development Index (HDI)

The HDI was created by the United Nations (UN) with the aim of creating an index comprising social and economic development (UNDP, 2009). The index uses life expectancy, education level and per capita gross domestic product (GDP). The simple system uses maximum and minimum values (called goalposts) for each of these attributes and the performance in question is assigned a value between 0 and 1 depending on how it relates to these.

Ecological Footprint (EF)

This concept explains that humans and our economies are a subsystem of the environment on which we depend. Rees and Wackernagel (1996:226) explain that the environment has a carrying capacity, which is a "load that can safely be imposed on the environment". Rees and Wackernagel (1996:227) then conclude that "the critical question becomes: How large an area of productive land is needed to sustain a defined population indefinitely, *wherever on Earth that land is located*?" The ecological footprint is then an area (land and sea) which is required to provide the natural capital for people (Rees and Wackernagel, 1996:227). The compilation of what the different human requirements consist is the challenging part of the footprint calculation process.

Life Cycle Index

This index entails looking at the entire lifetime of the product, development, structure or any other process being studied. According to Craighill and Powell (1995:1), "This includes the extraction of raw materials, processing of materials, manufacture of the product, distribution, use and reuse or recycling, and final disposal." It is often difficult to gather lifecycle data due to the myriad of complex interactions which

occur. The strength of the system is therefore in selecting which interactions and resource uses to disregard as being insignificant.

Urban Sustainability Indices

These indicator systems have been developed in multiple locations around the world although the methodology for their construction is dissimilar. For example, a Chinese index was developed by Singh *et al* (2009:204) using a top-down, expert consultation approach, whereas the *Urban Sustainability Indicators* system developed in Europe used a population driven, bottom-up approach. Both the systems derived a set of indicators weighted according to the results of their respective surveys. The ambitious intention of these urban sustainability indices is to measure the progress towards sustainability of a large urban area.

Well-being Assessment

The well-being assessment tool is an interesting index which is derived from two separate indices, the Human Well-Being Index (HWI) and an Ecosystem Well-Being Index (EWI) (Singh *et al*, 2009:209). The well-being index assumes human well-being and ecosystem well-being are of identical importance and therefore the overall well-being index is the average of the two. The Human Well-Being Index (HWI) and the Ecosystem Well-Being Index (EWI) are comprised of several sub-indicators which are weighted (Singh *et al*, 2009:209). The interesting feature of the well-being assessment system is the equal importance explicitly given to human and ecological factors.

2.3.3 Shortcomings of Indicator Systems

Indicator systems often do not perform satisfactorily as they attempt to function as a set of rules to be followed precisely. However, as Collis (2009) explains, these rules are not of value if applied out of the context within which they were created. Thus a system may assume the existence of certain technological aids, natural resources or human skills which may not be present in all environments. Thus attempts to implement these sustainability rules will produce unintended and often undesirable results. Thus it is imperative that guidelines be developed which are flexible enough

to be applicable within reason and yet are stringent enough to produce the required result.

2.4 Urban Development Rating Tools

The sustainability rating tools most relevant to residential development are points based tools used to guide design. These design guides are well known worldwide and are used in many countries to assess the sustainability of large scale housing developments, commercial structures, schools, industrial buildings and similar developments. Some of the more accepted rating systems include:

- Building Research Establishment Environmental Assessment Method (BREEAM) – United Kingdom
- Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) – Japan
- Leadership in Energy and Environmental Design (LEED) – United States of America
- The Energy and Resources Institute Green Rating for Integrated Habitat Assessment (TERI-GRIHA) – India

These systems all function similarly by assigning a certain number of points for the fulfillment of certain preset conditions. If these are not satisfactorily completed, points are not assigned. Furthermore, many of the tools have certain "hurdles" which must be successfully passed or the entire rating is considered a failure. These "hurdles" may be in the form of certain development characteristics which must be present, or a certain number of points which must be achieved. Overall, the success of the development is measured by the number of points it accrues.

The systems listed are reviewed below. The purpose of this critical review is to objectively assess the strengths and weaknesses of the rating systems and use this information to compile the draft system. The draft system will then be further reviewed.

2.4.1 BREEAM: Multi-residential Pre-Assessment Estimator

(Building Research Establishment, 2006)

Description

The BREEAM system works by assigning points upon fulfillment of certain credit concepts and a certain number of points must be reached for the development to achieve a rating. The main sections are; Management (6 credit concepts), Health & Wellbeing (13 credit concepts), Energy (8 credit concepts), Transport (7 credit concepts), Water (5 credit concepts), Materials (9 credit concepts), Land Use and Ecology (6 credit concepts), and Pollution (8 credit concepts).

Credit Reference	WATER	Points	Points Achieved
W1	Where evidence provided demonstrates that water efficient fittings have been specified with: • All WCs are 6/4 litre dual flush capacity AND • Instructions are provided on operating the flushing device appropriately	0.625	
	OR • All WCs are 4/2 litre dual flush capacity or where all WCs have a vacuum flush system or are waterless AND • Instructions are provided on operating the flushing devices appropriately	1.25	
	NOTE: These point scores are not cumulative, simply award the appropriate points score corresponding to the predicted level of achievement.		
	• All taps are either one or a combination of timed turn off push taps, electronic sensor taps, spray taps or aerated taps AND • Where specified, all showers have a nominal flow rate the same as or less than 9 litres per minute at 1.5 bar pressure	0.625	
	OR • Where two or more of the following are specified: small baths (50 litres/use or less) excluding assisted bathrooms; domestic washing machines are 40 litres/use or less; domestic dishwashers are 12 litres/use or less, commercial scale washing machines reuse water; all urinals have infra-red proximity controls or are waterless.	0.625	
	NOTE: These point scores ARE cumulative.		
W2	Where evidence is provided to demonstrate the specification of systems that collect, store, and where necessary, treat rainwater or greywater for WC and urinal flushing purposes.	0.625	
W3	Where a water meter with a pulsed output is installed to all building supplies.	0.625	
W4	Where evidence is provided to demonstrate that a leak detection system is specified or installed.	0.625	
W5	Where evidence is provided to demonstrate that low-water irrigation systems are specified/installed, or where planting and landscaping is irrigated via rainwater or reclaimed water.	0.625	
	Total points achieved to carry forward:	(max. 5.00)	

Figure 6: An excerpt from BREEAM showing the WATER section credit concepts

Figure 6 shows an excerpt from BREEAM. This is a portion which is representative of the full rating system. The credit concepts are fulfilled either fully or not at all. There may be no partial awarding of points. In compiling an overall score, the total numbers of points accrued are simply summed with no minimum score necessary for any particular main section. The BREEAM assessment is usually carried out post-construction, although these guidelines are used to design the development with the necessary principles.

Critique

The BREEAM Multi-residential Estimator is not well suited to the rating of low income residential developments, as the credit concepts are more suited to higher income apartment or gated community developments. Despite the fact that several of the credit concepts are unsuitable to low and middle income developments, there is still a wide variety of credit concepts covering many important facets of the development. The main sections with the most useful credit concepts are Energy, Transport, Water, Materials, Land Use and Ecology, and Pollution. These contain the most specific and applicable goals and targets. These specific goals under smaller, more targeted section headings are the main strength of BREEAM.

The lack of lifecycle assessment or the inclusion of maintenance and upgrade concepts is a notable shortcoming of the system. This is as developments which are initially well designed may lose functioning over time and the sustainability would be affected. Another possible negative element in the BREEAM system's functioning is that it is possible to have a successful development while achieving low scores in some sections. This is as there is no minimum score (hurdle) for any of the sections. This promotes weak sustainability as opposed to sensible or strong sustainability.

Improvements

There may be improvements to the Health and Wellbeing section to include more social aspects relevant to lower income housing provision. At present the Health and Wellbeing section includes details on air-conditioning control and glare reduction, but these luxury aspects are less important in low income housing.

The environmental aspects are well covered with many credit concepts covering pollution, energy, ecology and materials. The system may be improved by including more specific details on aspects such as conservation. These details are not available in BREEAM. Finance is not explicitly covered in any form in the BREEAM system and this is a very relevant concept in local development. Financial matters must therefore be incorporated.

With regard to the use of lifecycle analysis, it is recommended that some credit concepts be included to ensure that proper maintenance and system checks are done over time. They may even be included as mandatory items for a successfully rated development. Mandatory items or hurdles must also be included so that a more sensible view of sustainability is presented.

2.4.2 CASBEE

(JSBC, 2004a,b and 2006)

Description

The CASBEE suite of rating tools includes CASBEE for Pre-Design, New Construction, Existing Building and Renovation. These cover the lifecycle of the structure with the exception of demolition. The New Construction (CASBEE-NC) is the most applicable to new residential development although even this application is limited. This is as CASBEE has purposely been designed in order to be applicable to a wide range of structures. The reason for the description of CASBEE here is to highlight the innovative qualities of the system.

CASBEE for New Construction provides prescriptions grouped into four main sections, namely; Energy Efficiency, Resource Efficiency, Local Environment and Indoor Environment. These are then arranged further into Q (building environmental **Q**uality and performance) and L (building environmental **L**oadings on the outside environment). These are divisions made to define the consequences of development both internally and externally. The system aims to improve Q and decrease L. These are then placed as numerator (Q) and denominator (L) to define a ratio. This ratio is the Building Environmental Efficiency (BEE) ratio.

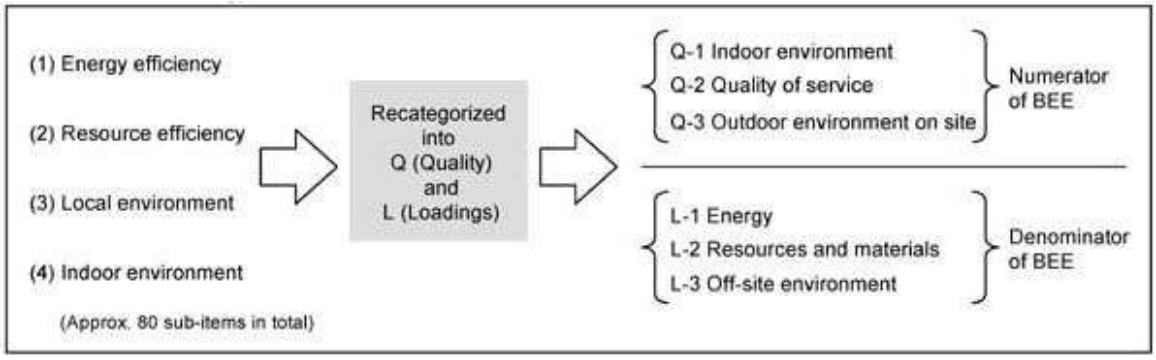


Figure 7: Representation of the ratio system defining Q and L.

Source: CASBEE (2006)

The BEE indicator is then displayed on a graph of Q vs. L and projected through the origin. The steeper the resulting line the more sustainable the structure. A representation of this graph is shown in Figure 8.

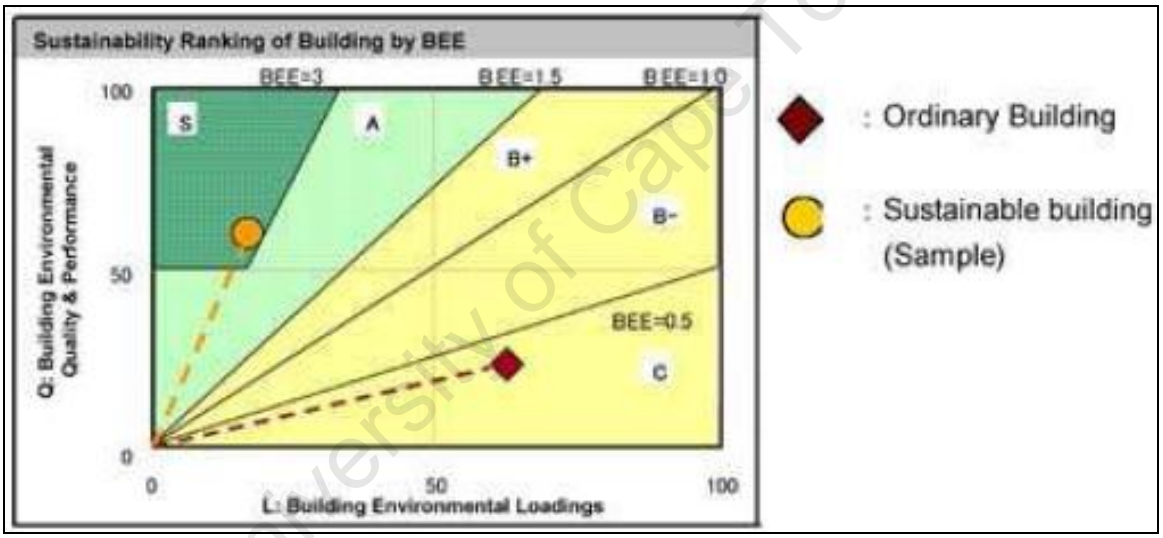


Figure 8: Graphical interpretation of BEE indicator.

Source: CASBEE (2006)

A slight complexity arises in the format when L is first assessed as LR (*level of performance in minimising building environmental loadings* OR **L**oad **R**eduction). This is to allow higher points to be gained for increasing the load reduction (LR) and this is later converted to L to use in the BEE ratio. This method means that the user must be careful in how results are recorded.

The Q and L (LR) are divided into three subsections each. These three subsections are weighted such that the totals of the weighting coefficients for Q and LR each equal 1. An excerpt from CASBEE showing one of the Q subsections as well as the

credit concepts is shown in Figure 9. The details of what is to be evaluated in each of the credit concepts are explained separately in the rating system. The scoring for each of the credit concepts (called *assessment items* in the original text) is on a positive integer scale from 1 to 5. 1 is given to an assessment item which merely satisfies the local laws or other such minimum standards. 3 defines an item which complies with common building practices and accepted average technologies. 5 is given to an item which performs excellently and innovatively or produces great benefit.

Q-1. Indoor Environment	1. Noise & Acoustics	1.1 Noise
		1.2 Sound insulation
		1.3 Sound absorption
	2. Thermal Comfort	2.1 Room temperature control
		2.2 Humidity control
		2.3 Type of air conditioning system
	3. Lighting & Illumination	3.1 Daylighting
		3.2 Anti-glare measures
		3.3 Illuminance level
		3.4 Lighting controllability
	4. Air Quality	4.1 Source control
		4.2 Ventilation
		4.3 Operation plan

Figure 9: An excerpt from CASBEE showing one of the three subsections for Q

The final step in this system is to multiply the scores by the weightings to achieve the final scores S_Q and S_{LR} which are then converted to Q and L using the equation:

$$BEE = \frac{Q}{L} = \frac{25 * (S_Q - 1)}{25 * (6 - S_{LR})} \qquad (1)$$

By calculating the BEE ratio, the development is assessed based on where it scores within five set ranges.

The three subsections for Q are; Q-1 (Indoor Environment), Q-2 (Quality of Service) and Q-3 (Outdoor Environment on Site). The three subsections for LR are; LR-1 (Energy), LR-2 (Resources& Materials) and LR-3 (Off-site Environment). An important point concerning the CASBEE system is that since it has been created for a developed country with adequate financial resources, it assumes a high order of

services. For example it assumes air conditioning will be fitted to all structures and thus recommends improvements to these systems. Such recommendations are not applicable to the local context and a more low cost approach.

Q

The subsections for Q are mostly not applicable to the local housing environment. They may be described as comfort items which are luxuries in low cost housing, or fall to the responsibilities of individual owners in high cost housing.

For example the indoor environment (Q-1) covers acoustics, thermal comfort, lighting and air quality. The control of these is by elaborate and expensive mechanical and electrical measures.

The Q-2 subsection has more applicable concepts such as continued serviceability of the structures, its flexibility in use and its ability to withstand environmental loads. These lean toward the Japanese context and thus describe earthquake resistance as an example of a severe load, but the overall concept is still applicable in the local context.

Q-3 describes the outdoor environment, but is not particularly strong on forcing compliance with strict environmental laws. Rather it encourages compliance with suggested area specific landscape styles. There is a particular section which deals with the environment but it stresses only evaluation of the finished and mature development to support wildlife. This is a noticeable weakness of the CASBEE system.

LR

The subsections for LR are on the whole more applicable to the housing environment and its development system. They consist of concepts which cover important topics such as Energy, Resources & Materials and Off-Site Environment.

LR-1 has subsections covering the building thermal load as well as efficient operation and maintenance of energy consuming elements. It also includes a section on utilising renewable energy sources. These are all relevant sections but once again the content

is unsuitable locally. It mainly describes the reduction in energy use possible through efficient design of air conditioning control systems.

LR-2 is related to two main components. The first is water efficiency. It deals with the saving of potable water and techniques for greywater reuse and water harvesting. The second component is broader and deals with lowering the environmental load caused by materials use. Thus it advocates recycling, natural materials from sustainable origins and reuse of components. These are all relevant topics which may possibly be adapted in the local context.

LR-3 describes impacts on the external environment and facilities. This includes pollution of various forms, irritants such as odour and noise, urban heat island (UHI) effect and the load placed on existing municipal infrastructure. These effects are not quantified but rather they are dealt with by consideration of the efforts and techniques implemented to reduce the external load. This measurement of effort rather than direct measurement of results may allow points to be gained for systems which ultimately do not function.

Critique

The majority of the credit concepts are not applicable to low or middle income housing development in South Africa. This is due to the expense involved in producing the technologies described as well as the questionable suitability of these in the local context.

CASBEE contains almost no reference to any social sustainability techniques or requirements. The only subjects relating directly to users are the requirements for user comfort and provision of user friendly facilities. This reflects the main aim of the system as guidance for commercial developments without a significant community upliftment component. This is therefore not necessarily a weakness of the system in its context, but it is an essential component of a locally referenced rating system.

CASBEE does not take a tough stance on environmental issues. Rather it focuses on monitoring and simple compliance with environmental laws. Besides the attempt to

encourage the use of sustainable resources and recycled components, there is little encouragement to impose innovative strategies to protect environmental integrity. While important, environmental laws do not cover the full range of possibilities open to the developer in terms of contributing positively to the external environment. Therefore it is important to suggest certain other actions to assist in this protection.

There is no financial recommendation given in the system. The local context may need such recommendations to improve financial efficiency.

The CASBEE system and the suite of assessment tools are innovative in their compilation and function. Firstly, use of the entire suite of tools allows lifecycle analysis to a great extent. This is an important feature in modern assessment. Also, the manner in which a ratio is used to assess quality is unique. It effectively compares human benefit to environmental disturbance. Many other rating tools do not explicitly give much attention to human benefit.

Improvements

The method of arriving at the final scores are rather complex and some mathematical manipulation is required. However the complexity is acceptable as the system uses a spreadsheet format which calculates the required output from simple inputs. However the disadvantage is that the user does not always have a clear idea of the inner mathematical manipulations of the system.

It may be possible to combine the multiple assessment tools of CASBEE in order to give a full lifecycle assessment more easily. This would greatly improve the result.

The CASBEE system does not prescribe techniques as clearly as other rating systems. Instead it allows the developer to insert techniques of their choice. This is both positive and negative. Firstly it allows flexibility and this makes the system more realistic in that all possible techniques may be included. However it is vague in its rating on a scale of 1 to 5 and this is open to interpretation. This lessens the integrity of the model. More rigid guidelines for achieving a score from 1 to 5 must be created.

2.4.3 LEED for Neighbourhood Development

(USGBC, 2007)

Description

LEED for Neighbourhood Development is the rating system within the LEED suite of tools which is most applicable to new housing developments. There are four main sections each containing credit concepts. The main sections of; Smart Location and Linkage, Neighbourhood Pattern and Design, Green Construction and Technology, and Innovation and Design take a widespread approach to the engineering design aspects of the project. The broad issues covered include water savings, energy savings, stormwater management, solid waste management, alternative transport modes, environmental preservation, mixed land use and good site selection.

The credit concepts are numerous (average 12 per section, totaling 49 credit concepts) and specific. The credit system consists predominantly of a set number of points for each credit concept to be awarded upon fulfillment. For the credit concepts with set numbers of points, there is generally only one option for their fulfillment. However there are certain credit concepts for which there are a range of points available and thus a range of options leading to achievement of the different numbers of points. Therefore the credit concepts are fairly prescriptive in the path that must be followed for their fulfillment. In addition to the credit concepts there are prerequisites. These are described similarly to the credit concepts with the difference being that the prerequisites must be fulfilled. If even a single prerequisite is not fulfilled, the development is not considered sustainable no matter the level of compliance with the credit concepts.

There are several instances where the prerequisite or credit concept directs the compliance with a particular policy or law. It however does not specify the contents of these policies and it is left to the developer to research the relevant portions. This is both a positive and negative feature of the system as it slows the certification process, but aids deeper understanding of requirements.

The non-technical, social engineering aspects are not specifically included as their own main section but are placed as credit concepts within the main sections. Social aspects include work and school proximity, access to public open spaces and community involvement. Universal access of a wide spectrum of people to the community facilities is stressed but the type of community facilities to be created is not stipulated. There is also a credit concept which encourages active public participation and the inclusion of the results of the public participation into the final design.

In order to derive the final score for the development, the points received are simply totaled. There is no hurdle for any of the main sections. However the requirement to fulfill each of the prerequisites acts as a hurdle. The number of points achieved determines the level of sustainability awarded.

Figure 10 and Figure 11 show an example of a typical prerequisite and credit concept from LEED. In this case, the prerequisite has two options for its fulfillment

SLL Prerequisite 2: Proximity to Water and Wastewater Infrastructure **Required**

Intent

Encourage new development within and near existing communities in order to reduce multiple environmental impacts caused by sprawl. Conserve natural and financial resources required for construction and maintenance of infrastructure.

Requirements

OPTION 1

Locate the **project** on a site served by existing water and wastewater infrastructure. Replacement or other on-location improvements to existing infrastructure are considered *existing* for the purpose of achieving this option;

OR

OPTION 2

Locate the project within a legally adopted planned water and wastewater service area and provide new water and wastewater infrastructure for the project.

Figure 10: An excerpt from LEED showing a typical prerequisite

SLL Credit 1: Brownfields Redevelopment
2 Points

Intent

Encourage the reuse of land by developing sites where development is complicated by environmental contamination, reducing pressure on undeveloped land.

Requirements

Locate **project** on a site, part or all of which is documented as contaminated (by means of an ASTM E1903-97 Phase II Environmental Site Assessment or a local Voluntary Cleanup Program) OR on a site defined as a **brownfield** by a local, state or federal government agency;

AND

Remediate site contamination such that the controlling public authority approves the protective measures and/or clean-up as effective, safe, and appropriate for the future use of the site.

Figure 11: An excerpt from LEED showing a typical credit concept

Critique

An excellent feature is that the LEED documentation prescribes certain policies and procedures called pre-requisites and these must be complied with. This is useful as it ensures that the developer follows several non-negotiable guidelines and therefore does not simply forego the challenging components and gain credits elsewhere. It is also not without flexibility and each of these prerequisites has a number of options for its fulfillment. However it may be argued that the use of prerequisites is too limiting and that the development should still be rated even if a certain number of prerequisites are unfulfilled. This may occur when a certain prerequisite is not applicable for whatever reason.

As the social aspects are included only as credit concepts there is no obligation to include them and a project may be successful without this social aspect. This is a shortcoming of the rating system.

Another shortcoming in the extent of the prescriptions is the lack of analysis of the financial implications of the project and the funding thereof. There is also no guidance on possible methods of cost minimisation. This is very relevant in the typical low to middle income housing projects in South Africa where subsidies are common and financing may be generated from diverse governmental and private sources and not a single developer.

There is no lifecycle analysis or inclusion of maintenance or upgrading in the credit concepts. LEED is typically applied pre-construction or closely follows construction. This therefore does not attempt to assess the long term performance of the development.

Improvements

A possible improvement to the system is a modification to the prerequisites to include more of the locally applicable aspects such as social involvement. Another possible improvement is a threshold or hurdle points system. For example a certain number of social points must be earned to get compliance no matter the number of points earned in other areas. This would apply to other sections as well. This then prevents the developer leaving out a particular important concept, earning points elsewhere and achieving a good rating.

The social portion needs to be more defined and perhaps form its own section or subsection. This is to allow the developer to focus more clearly on the social aspects and therefore effectively devote resources as a block.

The environmental aspects form the core of the rating system and are therefore well covered. The only point that needs to be more strongly stressed is the compliance of the project with relevant environmental laws and procedures such as *The National Environmental Management Act* and the EIA process.

There needs to be better prescription on the financial implications of varying funding sources and methods of best distributing and repaying funds. Options on how residents may repay their homes or part thereof should be included. Alternative finance schemes should also be investigated.

Lifecycle analysis needs to be introduced to the system in some form. This may either be through the introduction of credits or prerequisites. These will improve the value of the LEED system.

2.4.4 TERI-GRIHA

(TERI, 2007)

Description

TERI-GRIHA was designed after considering various rating systems worldwide. It was designed to be applied to residential and commercial buildings. A defining feature of TERI-GRIHA is that it was specifically designed to provide lifecycle analysis.

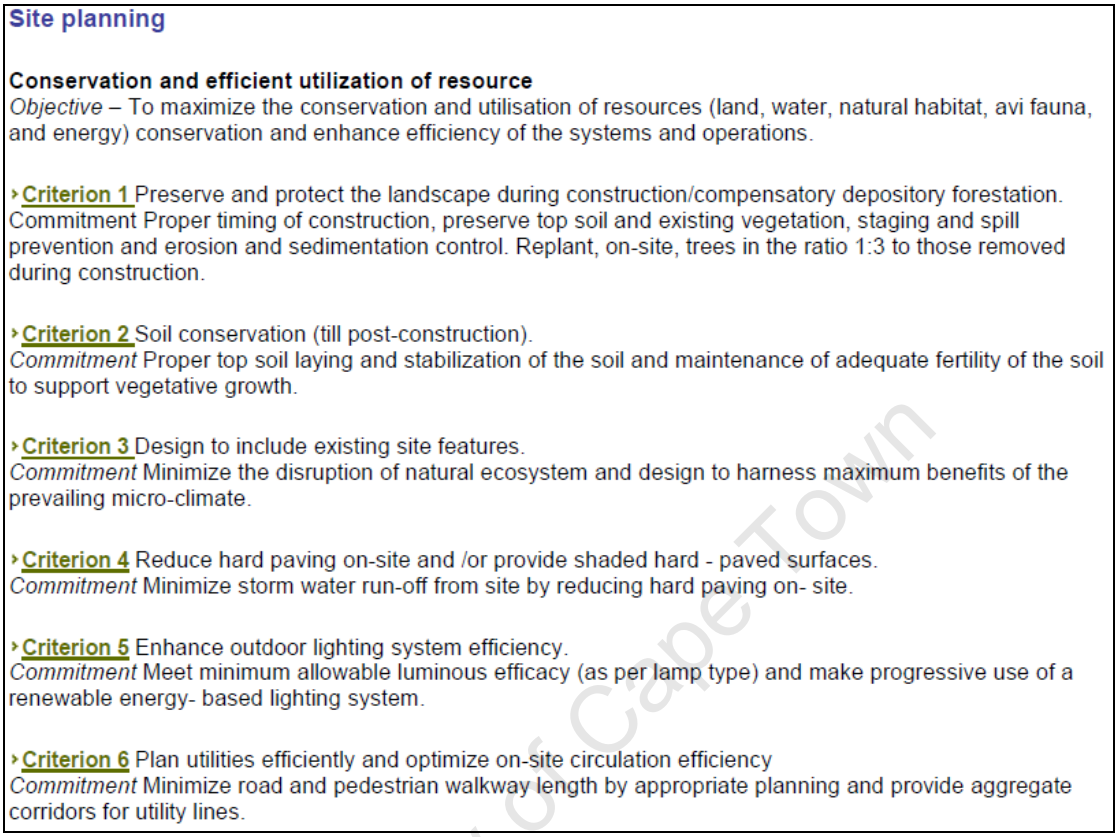
There are only three main sections in the GRIHA system, each focused on different project stages. The three main sections are; Site Planning, Building Planning and Construction Stage and Building Operation and Maintenance Stage. This classification focuses the developer on meeting criteria at each project stage. These are then sub-classified into sections dealing with relevant issues at each of these stages. Each of these sub-sections contains credit concepts (called *criteria* in the original documentation). There are a few credit concepts labeled as mandatory and which must be complied with for certification to be attained. After the fulfillment of the mandatory credit concepts, the final score is simply obtained by adding the number of points attained for each credit concept. There is no hurdle other than the mandatory concepts.

The sub-sections for the Site Planning section cover the basic environmental issues of water use, energy conservation, health and wellbeing of workers amongst others, but it does not cover any specific site selection principles. Figure 12 shows a portion of the Site Planning section. This is typical of the full rating system.

Building Planning and Construction Stage covers the necessary topics of water, energy, waste management, health and wellbeing. This gives guidelines which set out specific targets to be achieved.

The Building Operation and Maintenance Stage gives only a few guidelines and the purpose of these is to ensure that good processes are formulated to ensure that

maintenance of the infrastructure is carried out to maximise the efficiency of the project in the long term.



Site planning

Conservation and efficient utilization of resource
Objective – To maximize the conservation and utilisation of resources (land, water, natural habitat, avi fauna, and energy) conservation and enhance efficiency of the systems and operations.

› **Criterion 1** Preserve and protect the landscape during construction/compensatory depository forestation.
Commitment Proper timing of construction, preserve top soil and existing vegetation, staging and spill prevention and erosion and sedimentation control. Replant, on-site, trees in the ratio 1:3 to those removed during construction.

› **Criterion 2** Soil conservation (till post-construction).
Commitment Proper top soil laying and stabilization of the soil and maintenance of adequate fertility of the soil to support vegetative growth.

› **Criterion 3** Design to include existing site features.
Commitment Minimize the disruption of natural ecosystem and design to harness maximum benefits of the prevailing micro-climate.

› **Criterion 4** Reduce hard paving on-site and /or provide shaded hard - paved surfaces.
Commitment Minimize storm water run-off from site by reducing hard paving on- site.

› **Criterion 5** Enhance outdoor lighting system efficiency.
Commitment Meet minimum allowable luminous efficacy (as per lamp type) and make progressive use of a renewable energy- based lighting system.

› **Criterion 6** Plan utilities efficiently and optimize on-site circulation efficiency
Commitment Minimize road and pedestrian walkway length by appropriate planning and provide aggregate corridors for utility lines.

Figure 12: An excerpt from TERI-GRIHA showing several credit concepts

Critique

There are relatively few credit concepts in TERI-GRIHA. However they are varied and therefore cover all aspects reasonably well. However it is once again the case that social and financial aspects are not well represented.

The manner in which TERI-GRIHA has attempted to use lifecycle analysis is commendable. It adds depth to the analysis and brings it in line with modern methods of assessment. However the 32 credit concepts within TERI-GRIHA are perhaps too few when they are used to handle the entire lifecycle of the development.

The detailed manner in which each credit concept is explained lends itself to a more precise awarding of the points. An example of the detailed explanation is given in Figure 13.

Criterion 1 Preserve and protect landscape during construction

Objective
To preserve the existing landscape and protect it from degradation during the process of construction.

1.1 Commitment

1.1.1 Select proper timing for the construction activity to minimize site disturbance such as soil pollution due to spilling of the construction material and its mixing with rainwater.
1.1.2 Use staging and spill prevention and control plan to restrict the spilling of the contaminated material on site.
1.1.3 Protect the top soil from erosion. Use collection storage and reapplication of the top soil, sediment basin, contour trenching, mulching, soil stabilization methods to protect the top soil from erosion during construction.
1.1.4 Specify and limit construction activity in pre-planned/designated areas.
1.1.5 Preserve existing mature trees on-site during the course of construction by preserving and transplanting them.
1.1.6 Compensate the loss of vegetation (trees) due to the construction activity by compensatory plantation. Replant the same number of mature or fully grown trees as eliminated during the construction of the proposed landscape design. Replant the same, native and/or non-invasive species, which existed on the site before elimination in the proportion of 1:3.
1.1.7 Plant in excess of 25% to the minimum required (i.e. in addition to the requirement prescribed in commitment 1.1.6) within the site premises (plantation to follow same criteria as above).

1.2 Appraisal (maximum points 5)

Figure 13: The detailed requirements to fulfill a credit concept within TERI-GRIHA

Improvements

The lack of guidance on site selection principles is a major drawback of the system, as a poorly selected or unsuitable site for development will find it very difficult or expensive to develop many other aspects sustainably. Therefore some guidance on this principle must be introduced.

Management is another important aspect which is lost from the rating system. Management is critically important as without an effective management framework, the commitments to sustainability will inevitably not be followed by the necessary corresponding institutional structures.

There is no guidance on the aspects of social interaction in the community or any attempt to develop guidelines to create benefit to residents through community activities. There is also no emphasis placed on a public participation process. Thus the social issues are lacking in this rating system.

The major environmental issues are well covered with reference to protecting the environment by monitoring construction and design. However the lack of site selection guidelines is the drawback, as good environmental preservation techniques are null if the site itself is poorly selected.

There is no financial guidance given on any aspects of project funding or any other relevant short or long term costs. This needs to be added to the rating system.

2.4.5 Critical Summary

All the urban development rating tools must solve essentially the same problem of the conceptually discrete nature of sustainability aspects. At the simplest level, environmental, social and financial aspects are separate and sustainability may be achieved in each. However the question arises of how to manage them if one or more do not achieve sustainability. Two main options are utilized. The first is to deny the development that status of being sustainable if a certain level is not achieved within one or more of the aspects. TERI-GRIHA and LEED employ this technique. They each have certain credit concepts which must be fulfilled in order to achieve the mark of sustainability. The second option is to use a weighted system where a factor is applied to each aspect and the multiplication of the score achieved by that aspect and its factor determines it overall mark. The total of the marks for all the aspects then determines whether sustainability is achieved. BREEAM and CASBEE use such systems. Both these options have clear merits and are useful in assessment methodologies.

A well documented shortcoming of the urban development rating tools is that they do not provide lifecycle assessment of the structure. Cole *et al* (2005:2) contend that lifecycle assessments are "the only legitimate basis on which to compare alternative materials, components, elements, services and whole buildings." Another shortcoming of these systems is that they do not currently encourage a systems thinking approach to the assessment. This means that credits are given for the achievement of certain criteria but the interrelationship between criteria and how certain techniques contribute to others is not noted (Cole *et al*, 2005:4). These interrelationships are important in design. The final important shortcoming of the tools is their minimal reference to social and economic sustainability. Environmental factors are readily mentioned but the remaining two legs of sustainable practice are largely ignored or poorly represented. This may be due to the difficulty in accounting for them using quantifiable methods.

However the most important negative comment on the urban development rating tools is the inflexibility of their context due to the use of techniques as their smallest unit of measurement. This is not always well recognised when these tools are applied to particular developments. The weightings and aggregations were developed using specific data, at a specific point in time with a specific state of technology and environmental condition.

Table 1 below compares the four assessment systems described using the important categories discussed in this analysis.

Table 1: A comparison of four assessment systems

	BREEAM	CASBEE	LEED	TERI-GRIHA
Application	Multi-residential Medium to high income	Commercial, Schools, Residential	Residential Developments	Commercial and residential
Philosophy	Total Score & No hurdles	Ratio & No hurdles	Total Score & Prerequisites	Total Score & Prerequisites
Number of Credit Concepts	62	44	49	32
Lifecycle?	To an extent	NO	NO	YES
Flexible?	NO	To an extent	NO	NO
Positive/s	The inclusion of concepts of efficient management	Innovative approach to creating the final score	Prerequisites & A wide range of credit concepts	Lifecycle Analysis

2.5 Elements of Sustainability

2.5.1 Overview

A review of literature was carried out in order to note objectives of sustainability, performance measures, and techniques for creating sustainability as well as the effects of these techniques. A tabular summary was created as shown in Appendix A. The column headings from this tabular review are shown in Table 2 below.

Table 2: The most important columns in the tabular literature review

Objectives	Performance Measure	Technique	Effect/s

This table is the basis for the remainder of this work as it creates the collection of information from which, ultimately, extents of significance will be inferred. It is expected that the entire range of techniques available will not be covered in this tabular summary. However this is not to its detriment as it is likely that the most important, relevant objectives and effects will be established in such a wide ranging literature review. The results of the tabular review are stated below.

The tabular summary has several unfilled cells, indicating that the particular resource has no information on one or more aspects required. In fact, 45% of the rows have at least one aspect missing.

It is clear from the review that certain aspects of sustainability are common and appear regularly in literature while others are less frequent. The more common themes include those regarding energy, social and environmental factors. Financial factors are notably absent. In addition, Table 3 below shows the number of each aspect which was found from literature review. It must be noted that these are after repeated aspects have been removed.

Table 3: Summary of the results from the tabular review

	Objectives	Performance Measures	Techniques	Effect/s
Number	72	44	106	65

2.5.2 Objectives

The objectives are well covered in the literature with less than ten percent of the rows in the literature review table missing an objective.

It is evident from the literature review that many of the objectives are strongly linked to the most important positive effects of the technique they prescribe. Thus an ordering of objectives is akin to an ordering of positive effects. The objectives are however at times overly specific. For example an objective may refer to reducing

energy requirements for heating purposes. Such specific objectives may be generalised so as to reduce their number.

It is important to note which of the objectives may be influenced by the design process and which may not. The objectives which are not influenced by design are usually controlled by external factors, the most important being the attitudes and behaviour of people (both residents and other users). Also, many objectives may be only partially within the control of the designer. For example, the creation of multifunctional spaces is a valid objective; its actual usage however is beyond designer control. A reduction in public lighting energy however is an example of a fully designer-controlled objective. It is interesting to note that 60% of the objectives are partially controllable by design, with their efficiency residing largely with the users of the design. The remainder of the objectives is split evenly between those completely controlled and those completely uncontrollable by design.

The objectives are not explicitly either long-term or short-term in nature. Taken separately, they advocate strong sustainability as they do not propose the substitution of capitals. The sustainability objectives are not biased toward low, middle or high income developments and may be applied to any of these with suitable techniques. Therefore it is not necessary to disregard any objectives to suit the income ranges and designs assumed for this work.

It may be noted that several of the objectives may at face value be seen as the inversely stated equivalent of each other. For example:

Positive	Negative
To encourage the use of non-motorised transport.	To reduce the use of personal motorised transport.

However it is not possible to integrate these similar seeming objectives as they do not necessarily imply each other. For example, a reduction in personal motorised transport use does not necessarily imply (although it is likely) that non-motorised transport will be used.

2.5.3 Performance Measures

The overwhelming majority (75%) of missing aspects in the table are the performance measures. Thus it is clear that while techniques and their effects are well understood, it is a more difficult task to decide what constitutes a successful implementation of these. As an example of this, a certain performance measure would simply state that energy reduction is desirable but not the percentage decrease necessary to contribute meaningfully to sustainability. The performance measures which are given are mostly shown in numeric terms. However there are some performance measures more difficult to measure. These are typically the social measures such as happiness, cultural identity or community integrity.

Thus the performance measures are described at a conceptual level as "movement toward" sustainability. This is not to the detriment of the literature. This is as the extent of the "movement toward" which constitutes sustainability is set by the context in which it operates. The assumed extents of the "movements toward" which constitute sustainability are set in complete assessment tools such as those described earlier.

2.5.4 Techniques

Techniques are well documented in the literature and less than 10% of the objectives do not have a technique attached. The literature also shows that a single technique often contributes to more than one objective. This is as the effects they produce may be performance measures for several objectives.

Designer control is important to note in the techniques, as with the objectives. All of the techniques are designer controlled or partly designer controlled. Creating partnerships with communities or creating long term management plans are partial designer controlled techniques. It is also clear that strong social infrastructure is the foundation of the sustainability techniques. They require an understanding and an acceptance from the users of the physical infrastructure in order for successful long term efficiency.

The techniques listed are mostly physical modifications to standard design with relatively few being focused on the more esoteric elements such as social change. Also, there is a greater emphasis on implementation of techniques rather than the creation of management plans or setting long term targets. Applicability also varies with certain techniques being costly to implement and therefore possibly impractical in the lower income development arena.

2.5.5 Effects

Time and monetary cost are two inescapable effects in all the techniques regarding sustainability. All the techniques include these two effects to some degree. It is clear that the easiest method of comparison is to describe them in terms of the amount by which they differ to the outcomes when the usual (non-sustainability oriented) techniques are applied.

The majority of the effects are physical or easily quantifiable. They thus relate to improvements/decreases in function which are easily measured. However there are a small minority of social effects which are less readily measurable. Effects such as community involvement, preservation of cultural identity, integration, improving welfare and social equity are less easily measured but no less important. As is to be expected, certain effects are common to many objectives and techniques.

2.5.6 Proxies

It is possible for certain factors to stand as proxies for others. This is common in survey design where, for instance, car ownership is used as a proxy for income (Saltz, 1995:17). However the literature on sustainability does not describe these proxies to the extent that they may confidently be stated to be suitable representations of any particular aspect. It is therefore necessary to develop proxies for the purposes of this research.

2.6 Survey Research Methodology

Sapsford (2007:10) explains that the primary use of survey data is "to make planned comparisons".

2.6.1 Objectivity in Research

Babbie and Mouton (2005:10) describe rational science as "provid[ing] good or persuasive reasons for accepting or rejecting new scientific claims". Rational science is a result of a rational agent (researcher) making informed judgements and the outcome being ratified by a community of peers with particular expertise (Babbie and Mouton, 2005:11).

Objective evidence is what is required to make rational claims. Babbie and Mouton (2005:11) claim that objective methodologies lead to the production of objective evidence necessary to make rational judgements. Furthermore, an objective methodology is one which reduces error as far as is reasonably possible. Babbie and Mouton (2005:12) list some of the identifying features of objective research as:

- Unbiased sampling
- Consistent measurements
- Systematic observations
- Critical participant engagement and observation

2.6.2 Survey Planning and Decisions

The initial planning of a survey involves four fundamentals as described by Sapsford (2007:34):

1. **Problem Definition**: What kinds of answers are required?
2. **Sample Selection**: Who/what is to be counted?
3. **Design/Selection of Measurements**: What is to be measured and how?
4. **Social and Ethical Responsibilities**: Prevention of harm and discomfort.

Rea and Parker, (2005:23) list the stages in survey research, all of which usually apply to any particular survey as:

1. Identifying the focus of the study and method of research

2. Determining the research schedule and budget
3. Establishing an information base
4. Determining the sampling frame
5. Determining the sample size and sample selection procedures
6. Designing the survey instrument
7. Pre-testing the survey instrument
8. Selecting and training interviewers
9. Implementing the survey
10. Coding the completed questionnaires and computerizing the data
11. Analysing the data and preparing the final report

Furthermore, Sapsford (2007:111) lists the following three points which are necessary for a successful survey.

- Questions must not be ambiguous.
- A reduction in interviewer-caused variation, such that each respondent is asked the same questions in the same manner.
- An acceptable manner of collating and analyzing data from respondents.

2.6.3 Pre-survey testing

Focus Groups

Focus groups are meetings of individuals, chaired by the researcher, with the purpose of either establishing preliminary information in order to better design the survey, or debriefing after the survey and clarifying any difficulties encountered. They are qualitative research tools as opposed to the quantitative tools such as surveys. Rea and Parker, (2005:73) recommend that the focus group consist of eight to twelve members and the meeting take place over one to two hours. It is not necessary for the focus group to be completely representative of the population.

Rea and Parker, (2005:74-85) give the following points with regard to focus group uses, planning and implementation.

- To obtain background information in order to better structure research hypotheses and create survey questions.

- To gain a better understanding of areas which may be ambiguous or on which there is little research.
- To test forms of communication and the applicability of survey techniques to particular audiences.

- The focus group participants should be chosen such that they have certain common characteristics while simultaneously having a range of opinions and areas of expertise. Such a group will relate to each other and encourage idea sharing.
- If certain characteristics such as gender or education levels are important, several focus groups may be scheduled to incorporate each of these characteristics separately. No more than two to three characteristics should be regarded as critical in order to limit the number of focus groups.
- A minimum of two and a maximum of ten focus groups should be planned.

- The focus group session should be recorded with either video or voice recording unless this is deemed to interfere with the free exchange of ideas needed.
- The names of the participants in the focus group are to be recorded.
- The agenda for the focus group as well as any time restrictions and other guidelines for the discussion are to be presented to the participants at the outset.
- The discussion should begin with simple questions which each participant may easily answer in order to create a free speaking environment.
- After each question, the resulting answers must be summarized by the chairperson for the benefit of the group.
- At the end of the session, a short summary of the topics covered will serve as a closing to the meeting.

Pilot Surveys

Pre-tests and a pilot survey are a trial of the survey questionnaire. They are important in that any errors or ambiguity in the questionnaire must be rectified prior to the full scale survey being launched.

According to Buckingham and Saunders (2004:84), the pre-test is an informal test with people who may be knowledgeable in the field but not necessarily from the

target population. The aim of the pre-test is to obtain feedback on any errors in the questionnaire in terms of its explanation, layout or individual questions.

A pilot test is a more formal test where a sample must be found in the same manner as for the full scale test and the questionnaire must be completed by the respondents. The data collected must then be analysed in the chosen manner. However the sample for the pilot test is smaller than for the full scale survey. Rea and Parker, (2005:31) suggest that the pilot test must check for questionnaire clarity, comprehensiveness and acceptability by the participants. Further pilot tests must be carried out should large changes be made to the questionnaire post the initial pilot test.

2.6.4 Question Design

Buckingham and Saunders (2004:60, 61, 76) give guidelines for constructing questions for data collection.

- "…every item included in the questionnaire should be justified against the theoretical purposes of the research." Therefore, no question should be asked if it is not to be analysed and not relevant to the research question.
- Each question must test the variables which define a particular concept/category. The analysis of the answer must allow you to decide whether the respondent is classified within a certain concept or in a certain category.
- The questions must take note of the trade-off between reliability and validity. Open-ended questions which allow greater user input and interaction will create more validity, while closed-ended questions which call for simple structured answers will create reliability.
- Questions should be avoided which lead the respondent by either implying an answer or using emotive language.
- Closed-ended questions must allow for the entire range of possible answers.

Scales are often used for questions where a response may be between extremes and they may be used to measure the extent of a respondent's response. Examples of measurement scales are as follows:

1. **Likert Scales**. These scales measure the degree of agreement in response to a question (Sapsford, 2007:223).

I think that survey is important (ring one response)				
Strongly agree	Agree	Neither	Disagree	Strongly Disagree

2. **Semantic Differentials**. This scale asks for a response which is to be placed usually on a number scale between two clearly opposite adjectives (Sapsford, 2007:224).

I think that survey is: (ring one response)									
Interesting	1	2	3	4	5	6	7	8	Boring

3. **Visual Analogue Scaling**. This scale is similar to the previous scales however the respondent is not asked to choose from discrete answers but may mark their response anywhere along the continuum. The response must then be physically measured (Sapsford, 2007:224).

How important do you think that survey is? (ring one response)

Extremely Important ---------- Extremely Unimportant

4. **Guttman Scales**. The respondent is asked to choose the most applicable statement from a set of answers to a question. The statements are structured so that choosing a particular answer implies that the previous answers are also applicable (Sullivan, 2005).

Please select the most appropriate response:

- I am willing to spend 10 minutes completing a survey
- I am willing to spend 20 minutes completing a survey
- I am willing to spend 30 minutes completing a survey
- I am willing to spend 40 minutes completing a survey
- I am willing to spend 50 minutes completing a survey
- I am willing to spend 60 minutes completing a survey

2.6.5 Sample Size

It is accepted that the larger the sample size, the greater the accuracy it yields. However, Rea and Parker (2005:26) comment that, "The researcher must weigh the desired degree of accuracy against the increased time and cost that a larger sample size entails".

Rea and Parker (2005:142) as well as Israel (2003:1) state that the confidence level, the confidence interval and the degree of variability are the most important considerations in determining sample size. Incorporating these factors, Rea and Parker (2005:148) give the following formula for determining sample size as shown below. This formula is valid for large and small population sizes.

$$n = \frac{Z_a^2 p(1-p)N}{Z_a^2 p(1-p) + (N-1)ME_p^2} \qquad (2)$$

where n = Sample size

Z_a = Z score for various levels of confidence (1.96 for 95%; 2.575 for 99%)

p = Degree of variability expressed as an integer

N = Population size

ME_p= Margin of Error (Confidence Interval) expressed as an integer

Rea and Parker (2005:144) state that for most research, a 95% level of confidence and a 3% - 5% confidence interval is satisfactory.

2.6.6 Sampling Techniques

There are various techniques which are applicable to once-off surveys. These techniques describe how the sample is to be drawn from the population. The two important classifications of sampling methods are probability sampling and non-probability sampling. StatPac Inc. (2007) describes the following sampling methods.

Probability sampling methods include:

- **Random sampling.** This process selects respondents indiscriminately by using a particular relevant method so that each member of the population has the same chance of being selected.

- **Systematic sampling.** This method is similar to random sampling. However it is simplified in that once the sample size is selected, the population list is divided by the sample size and every n^{th} name is selected until the required number of samples is obtained.

- **Stratified sampling.** Strata are first selected from the population and these strata each contain a particular characteristic of interest such as males and females or scientists and non-scientists. The representation of each stratum in the population must then be found. Random samples are then taken from each stratum according to the proportion of the population which is represented in the stratum.

Non-probability sampling methods include:

- **Convenience sampling.** This form of sampling does not result in a random sample and respondents are chosen as they may be conveniently sampled. This method is often used in preliminary research.

- **Judgment sampling.** This method is related to convenience sampling but differs in that the researcher makes an assumption on which the sample is based. For example it may be assumed that the characteristics of a certain suburb represent the characteristics of an entire city and therefore only that suburb may be sampled.

- **Quota sampling.** This is similar to stratified sampling with the exception that convenience or judgement is used to fill the quota required from each stratum.

- **Snowball sampling.** This method is often used when the characteristic to be studied is rare and the researcher would like to save cost finding suitable respondents. Each respondent interviewed recommends a further respondent/s and the process continues until obtaining the desired number of respondents.

Table 4: Comparison of probability and non-probability sampling techniques.

Source: StatPac Inc. (2007).

	Advantages	Disadvantages
Probability Sampling	• The sampling error can be calculated.	• Expensive to select samples.
Random Sampling	• A representative sample is obtained.	• It is often difficult to include an entire large population in the sampling process and therefore certain members may be excluded from the possibility of being randomly sampled.
Systematic Sampling	• Simple technique for selecting samples from computerized lists.	• The population list may need to be randomized to remove any associations or any order.
Stratified Sampling	• Reduces sampling error. • Creates more representative random samples. • Creates greater convenience and enables easier survey administration.	• Difficult to identify the strata and the proportion of the population it represents.
Non-probability Sampling	• Sampling is often quicker and less expensive.	• The sampling error cannot be calculated.
Convenience Sampling	• Quick method • Inexpensive	• Does not usually represent the population.
Judgment Sampling	• Quick method • Inexpensive	• It is difficult to prove the underlying assumption and an incorrect assumption leads to incorrect results.
Quota Sampling	• The method ensures that important subjects or groups are surveyed.	• Errors in judgement or reasons for choosing certain samples will cause errors in the results.
Snowball Sampling	• The cost and time involved in locating respondents is reduced.	• The sample is not usually representative due to the bias introduced by the referral process.

2.6.7 Survey Administration

There are many methods of administering a survey. Salant and Dillman (2004:33) broadly list mail surveys, telephone surveys as well as face-to-face surveys as important types of interviewer-administered and respondent completed questionnaires.

Sapsford (2007:109-110) as well as Buckingham and Saunders (2004:69-71) describe the advantages and disadvantages of interviewer-administrated and respondent completed questionnaires. These are tabulated in table 5.

Table 5: Comparison of survey administration methods

	Advantages	Disadvantages
Interviewer-administrated	• Allows explanation of complicated questions which may be misinterpreted. • Allows interviewer to record aspects such as respondent behaviour and attitude without necessarily asking for these responses directly. • Removes biases which may be created through different degrees of fluency or writing ability of respondents. • Longer interviews are possible.	• It is time consuming for the researcher to administer many interviews. • Interviewer style and differing interactions with each respondent may lead to questions being phrased or emphasised differently. This may lead the respondent and cause varying responses.
Respondent completed	• Cheap to administer in terms of both interviewer time and traveling costs. • Creates standardization so that each question is phrased in exactly the same manner for all respondents. • Greater anonymity is possible and respondents may more freely share embarrassing or personal information.	• Higher non-response rates are likely. • Misunderstanding of questions by some respondents may lead to certain returns being invalid or useless. • Respondents are able to modify their responses after reading the entire set of questions.

2.6.8 Specialised Survey Techniques

There are two main categories of techniques used to get an understanding of preferences amongst people. These are Revealed Preference (RP) and Stated Preference (SP). Revealed Preference is first discussed.

Revealed Preference

Houthakker (1950:160) describes revealed preference theory as based on the concept that certain goods (X^a), bought at certain prices (P^a) are preferred to certain other goods (X^b) also potentially bought at prices (P^a). This shows that X^a is revealed to be superior to X^b and is expressed as:

$$P^a X^b \leq P^a X^a \quad (3)$$

From the construction of the theory it is clear that revealed preference deals only with use values and cannot handle non-use values.

Popp (2009) describes several important ways of valuing environmental amenity in terms of use values:

- **Aversion Costs**: These are the costs that people pay in order to avoid the problems a poor environment has on them. Thus they may pay for water filters, air filters or medicine. Thus the theory is that they would pay the same amount in order to avoid the poor environment.
- **Travel Cost Method**: This is a method more limited in its use. It uses the costs that people carry in order to travel to and use a facility as an estimate of the value they place on the amenity. However the method has drawbacks in that it cannot easily account for the opportunity cost of time, the relative burden of the financial cost on different people and the many reasons people may have to visit an area (not only for the amenity being measured).
- **Hedonic Pricing Techniques**: These techniques work based on the value that people place on the attributes of a good. The example stated is that of a house, where the house is valued for its attributes (number of bedrooms, style of bathroom etc) rather than for the quality of simply being a house. Thus environments are valued for their attributes and qualities. Thus the decrease in house prices or the

increase in wage demands in a polluted area can be used to derive a monetary value placed on the pollution attribute.

Stated Preference

The methods discussed here which form part of Stated Preference techniques are Contingent Valuation, Conjoint Analysis and Choice Methods.

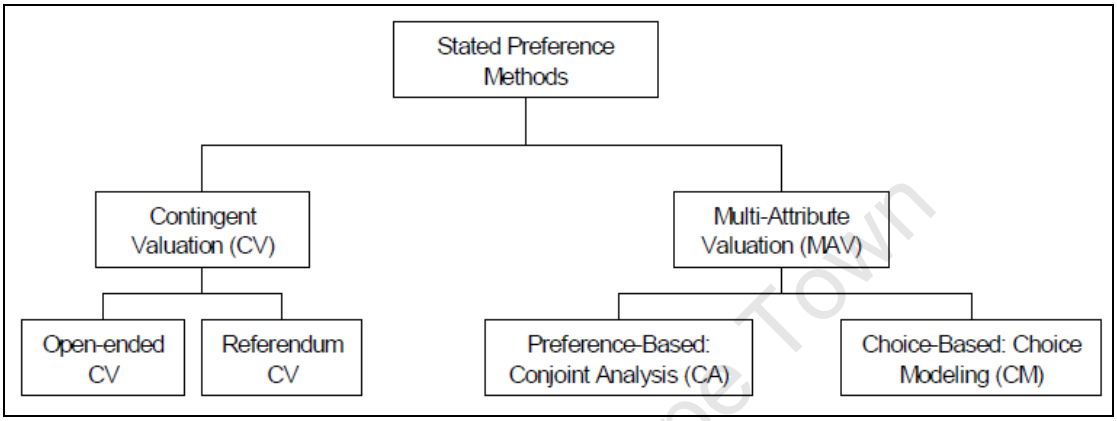


Figure 14: Representation of stated preference methods.

Source: Merino-Castelló (2003:5)

Contingent Valuation

Contingent valuation is a technique used to derive what may be called *non-use* values or *passive-use* values. These are typically environmental services or public goods for which the general public does not pay fully, equally or even directly. Arrow *et al* (1993:2) use the example of a public beach damaged by oil spills. Even those who may not make direct use of the beach give it some value, perhaps merely due to its symbolism. These attached values may need to be totaled and play a significant role in the assessment of the significance of the beach.

Contingent valuation surveys use probability sampling and avoid self administered surveys in order to increase reliability (Hanemann, 1994:22). The process involves asking respondents about the financial value they may be prepared to pay for certain environmental services. However according to Hanemann (1994:22) the questions must be structured so that they:

- Avoid general unfocused terms. For example; What would you pay for environmental safety? Such a question creates no immediate reference point for respondents. Questions must be related in terms of benchmarks such as taxes.
- Avoid hypothetical questions based on past events, as these are illogical to the respondents. For example, it is not recommended to ask how much the respondent would be prepared to pay to avert a disaster which has already occurred in the past.
- Use closed ended questions such as; Would you be willing to pay increases in taxes of (*x)* dollars? These are preferable to open ended questions asking how much the respondent would be willing to pay.

In order to derive the willingness-to-pay, it is necessary to ask a single respondent if they are willing to pay a certain amount for the service in question. This process is then repeated with each new respondent being asked their willingness to pay a certain different amount. The distribution of the "yes" responses then gives an idea of the average willingness-to-pay of the population.

There are four main objections to contingent valuation processes which must be noted (Hanemann, 1994:26-30):

- Response effects: These occur when the wording of the question, the ordering or questions or the time involved create problems with the responses. They may cause confusion or fatigue in the respondent, leading to poor answers. These may be prevented through careful pre-survey testing and question design.
- The creation of values by the survey: The argument arises that respondents may have no real idea of the value of an item but simply create one based loosely on the choices in the survey. This may be tested by conversing with the respondent and gaining an appreciation for how they may come to their response.
- People are not trained to value environmental goods: A lack of background in environmental valuation need not be a disadvantage in answering the questions posed as it is only their own willingness-to-pay which is important.
- Impossible to verify survey responses: The survey results cannot be completely verified, however they may be tested through repetitions of the survey, a comparison of the result with similar work elsewhere and a comparison with revealed behaviour.

Conjoint Analysis

Conjoint analyses, along with choice methods, are what (Merino-Castelló, 2003:3) labels Multi-Attribute Valuation (MAV) techniques. The contingent valuation method may therefore be conversely labelled as a single attribute valuation technique.

Conjoint analysis is described by Merino-Castelló (2003:9) as a preference technique and the respondent completes the survey by either rating or ranking each product/attribute being studied. Rating would involve giving the attribute a score on a scale with a predetermined minimum and maximum. Ranking would involve placing the attributes in order from the most to the least desirable. From the rating or ranking of these it is possible to determine the importance of each attribute.

The utility function for conjoint analysis is as follows:

$$U_i = \phi [V_i (X_i)] \qquad (4)$$

where U = Utility

Φ = *A transformation function*

V= A deterministic (objective/non-random) utility function

X = The attribute being studied

Choice Method

This technique does not involve ranking or rating as with conjoint analysis but rather a choice between two or more alternatives each comprising a set of attributes with certain assigned values. Each question set may have different sets of attribute values and the status quo attribute values are often included. The utility function for choice methods is as follows:

$$U_i = V_i (X_i) + \varepsilon_i \qquad (5)$$

where U = Utility

V = A deterministic (objective/non-random) function

X = The attribute being studied

ε = A stochastic (random) unobserved function

The choice method has the advantage that it can be used to measure non-use values. Also, the hypothetical construction and range of attribute values used in the question sets allow more room for uncertainty in that the true attribute values may not be perfectly known, but the results will still be applicable (Boxall *et al*, 1996:244). As multiple attributes can be easily analysed, choice methodology is useful in the study of environmental amenity where multiple impacts or effects are likely.

Selection for this work

Firstly, it is necessary to choose between stated and revealed preference methodology. Stated preference methods are able to be used when appropriate information on past choices is not available (Merino-Castelló, 2003:3). Also, stated preference methods are able to be used to measure non-use values. Revealed preference techniques cannot accomplish this. Revealed preference also has the disadvantage that if past choice data is available; it may not necessarily still be relevant. The argument that a well designed revealed preference study is necessarily more representative of the truth than a stated preference survey is countered by Boxall *et al* (1996:244) who cite studies showing that the two methods produce similar results. However this may not necessarily always be the case. Due to this research concerning attributes for which there is insufficient historical choice data, it is not possible to conduct a revealed preference study. Thus the stated preference methods are applicable.

Amongst the stated preference methods, contingent valuation has several drawbacks. The first is that only one attribute can be presented per scenario and therefore multiple scenarios must be created (with cost and time implications) in order to value multiple attributes (Merino-Castelló, 2003:7). The second problem is the system being open to strategic responses when the interviewee foresees an advantage to themselves to provide misleading information (Merino-Castelló, 2003:7). The third is the tendency to overestimate the value of the attribute. Merino-Castelló (2003:7) ascribes this to the respondents avoiding the embarrassment of answering "no" to a question about their finances for fear of seeming less financially secure. Based on the drawbacks of contingent valuation (the most important being that only one attribute may be handled) it may be concluded that the MAV techniques are most appropriate to this work.

Choice methods have the distinct advantage over conjoint analysis (preference methodology) in that choice methods more closely resemble real life situations (Merino-Castelló, 2003:8). In this work it is important to represent reality in order to gain more accurate responses. Also, the ease with which a wide variety of attribute levels may be incorporated makes choice methods superior to preference methods. This is as attributes levels are widely variable and a range must be accounted for. Choice methods are therefore to be used in this work.

2.7 Choice Theory

It may be noted that people have difficulty accurately describing the attributes (and the relative importance of these) that they find significant in a product or service. It is therefore difficult for producers to design products which will have the most favorable combination of attributes.

Choice analysis is the method which creates combined sets of attributes from which respondents conclude their preferences. (Birol *et al*, 2006:5) explain that in stated preference methods, "consumer preferences are elicited directly based on hypothetical, rather than actual, scenarios". Based on the stated preferences, a coefficient is calculated for each attribute and this coefficient describes the importance the respondents place on each attribute. Choice methods do have certain disadvantages and they "are commonly criticized because the behaviour they depict is not observed" (Birol *et al*, 2006:5). This means that it is possible that the stated preference design does not take into account the true factors leading to decisions being made. However this error should be minimized by thoroughly investigating the attributes at the pre-design stage.

2.7.1 Theoretical and Mathematical Basis

Hensher *et al* (2005:62) show that while individuals make choices, the process of expanding the observed choices to create data for the entire population is difficult given the variability amongst people. Also, all the information relevant to an individual's choice may not be observed in any survey but is no less relevant. Therefore the task is to minimize the amount of unobserved information while still

recognizing that some information will always be unobserved and unknown. The information to be observed are called attributes. These attributes may be either positive or negative (constraints).

Choice experiments function by taking two or more alternatives, assigning relevant attributes to each, and asking respondents to identify which of the alternatives they prefer. The attributes and attribute levels are identified by preliminary surveys which gauge the most important attributes from respondents and the range of values which is possible within these. For example the choice of car may take into account price, model, fuel economy or colour. Thus by using multiple combinations of attribute levels it is possible to calculate the importance (part/marginal utility) applied to each attribute by the respondents.

The total utility of an alternative (U_i) is composed of the part utilities of each of the attributes. The contributions of the observed utility are denoted as (V_i) and the unobserved utility as (ε_i).

$$U_i = V_i + \varepsilon_i \qquad (6)$$

Hensher *et al* (2005:76) describe that the observed utility (V_i) is made up of the sum of the marginal utilities of all the attributes. Each attribute (X_i) is scaled by a factor (β_i). It is also possible to have an alternative specific constant (β_0) which is related to the average unobserved utility. Thus the observed utility is shown by Hensher *et al* (2005:76) as:

$$V_i = \beta_{0i} + \beta_{1i} f(X_{1i}) + \beta_{2i} f(X) + \cdots + \beta_{Ki} f(X_{Ki}) \qquad (7)$$

where V_i = Observed Utility

X_i = The particular attribute

β_0= The alternative specific constant

The unobserved utility (ε_i) is present in all alternatives. Two types of assumptions are used to calculate the unobserved utility. Hensher *et al* (2005:77) describes *maintained*

assumptions as those assumptions which cannot be tested and *testable assumptions* as those whose behaviour can be discovered. Hensher *et al* (2005:77) explain that the first maintained assumption is that the distribution of the unobserved utility is unknown and a distribution must therefore be assumed and randomly assigned to each individual respondent. The testable assumption is that every alternative has a unique unobserved utility which is independent from the unobserved utilities for the other alternatives. However, these unobserved utilities, while independent and unique, all have the same distribution. This is known as the *Independent and Identically Distributed* (IID) principle.

In order to move from the utility for a single alternative to a rationale for the choice of one alternative over another, it is necessary to make a further assumption. Hensher *et al* (2005:80) state that "an individual acts as if they are maximising utility". This means that they are acting rationally and they consider all the important attributes and use the information which they have at hand. Hensher *et al* (2005:82) therefore explain:

> …the probability of an individual choosing alternative *i* is equal to the probability that the utility of alternative *i* is greater than (or equal to) the utility associated with alternative J after evaluating each and every alternative in the choice set of j = 1, . . . i, . . . J alternatives.

This is represented mathematically as follows:

$$P_i = P\left[(V_i + \varepsilon_i) \geq (V_j + \varepsilon_j)\ \forall j \in j = 1,\cdots,J; i \neq j\right] \qquad (8)$$

where P = Probability

$\forall$ = for all

$\in$ = is an element of

Using the assumptions for the unobserved utility explained earlier, it is possible to derive the distribution of this utility. The most commonly used distribution is Extreme Value Type 1 (EV1). The combination of the EV1 distribution and the

observed probability leads to a choice model called the Multinomial Logit (MNL) model (Hensher *et al*, 2005:86)

$$P_i = \frac{e^{V_i}}{\sum_{j=1}^{J} e^{V_j}}; \qquad j = 1, \cdots, i, \cdots\cdots J \qquad i \neq J \qquad (9)$$

Hensher *et al* (2005:82) describe this in words as follows:

> …the probability of an individual choosing alternative *i* out of the set of J alternatives is equal to the ratio of the (exponential of the) observed utility index for alternative *i* to the sum of the exponentials of the observed utility indices for all J alternatives, including the *i*th alternative.

2.7.2 Design

Harrell (1993:2) recommends the number of attributes to be combined in a single question to be between three and eight. Greater than eight attributes may create irritation with respondents as greater time and effort is required. This may increase the non-response rate or result in poorly considered answers. Intangible attributes are those which are often difficult to quantify using traditional scales such as money or time. They may include comfort, satisfaction, service or similar themes. They may be included in the choice design but a scale must be created which will allow the respondent to understand it and make useful judgements. Likert or Semantic Differential scales may be appropriate.

A large number of questions are unlikely to be answered accurately by the respondent due to the time inconvenience as well as the mental fatigue caused by complex testing. Therefore Harrell (1993:3) recommends that no more than twelve questions are asked of a respondent without adequate reward as a motivation for their time.

Hensher *et al* (2005:100) explain the process of completing a choice based experimental design.

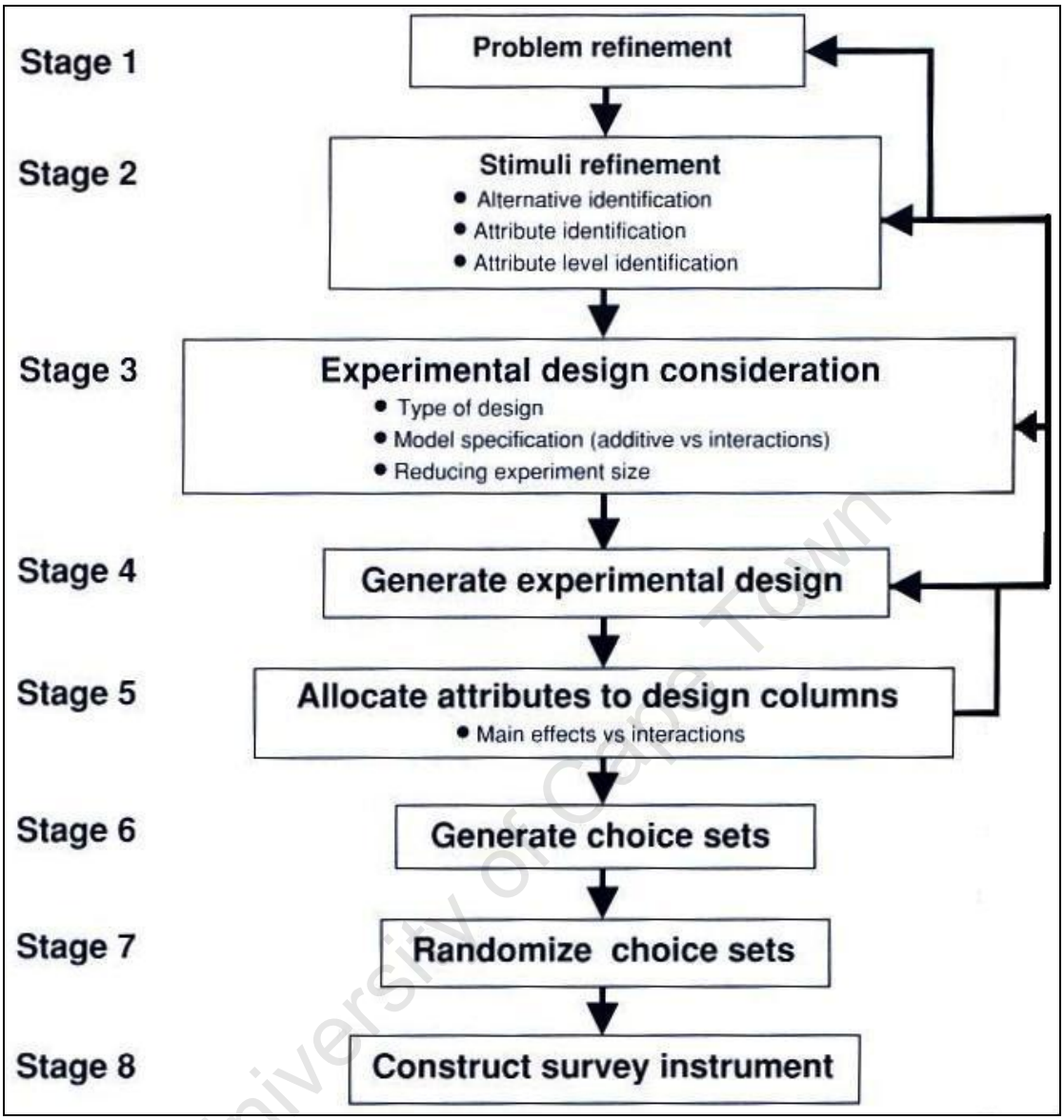


Figure 15: Representation of the design process for stated preference questionnaires.

Source: Hensher *et al* (2005:102)

Stage 1: In the first stage it is important to define the central question or questions. This is done by questioning the motives for the research and what it intends to uncover. Naturally, this leads to a decision on the questions to be asked in order to answer these central hypotheses. The value of this process is that it creates a more in-depth knowledge of the subject with the researcher.

Stage 2: This involves considering the full list of alternatives as well as the full list of attributes from which the respondents may ultimately choose. An alternative contains attributes at specific levels.

Firstly, it is imperative that the researcher defines the full set of alternatives available before this extensive list is reduced by removing certain alternatives. The reason for reducing the number of alternatives is that a list which is too long may make the questionnaire cumbersome and difficult to both administer and analyse. There are several methods of removing alternatives.

- Firstly, a random selection of alternatives may be added to constitute the question set to be given to each respondent. Therefore the full set of alternatives will be studied without a single respondent being asked to complete an unduly large set. It is important that the random selection of alternatives do not violate the *Independent and Identically Distributed* (IID) principle. This principle states that attributes must be uncorrelated and independent.
- The researcher may use judgement to exclude certain alternatives deemed less important. However this is problematic due to the judgement of the researcher being placed before the results of the survey.

It is important in defining attributes that there is no ambiguity. Hensher *et al* (2005:105) give the example of the attribute "comfort" on a journey. This may mean different things to different people and its definition will differ on various transport modes. Thus if a survey result shows that respondents perceive comfort on a train to be poor, it may not be useful if the researcher is not clear whether the respondents are referring to overcrowding, seat design, temperature or any other factor. Alternatives may or may not contain common attributes, and if they do, these attributes will usually be at different levels.

The concept of inter-attribute correlation is a potential difficulty in stated preference design. The problem lies in that respondents often create intrinsic linkages between attributes which may not always be understood by the researcher. The example given by Hensher *et al* (2005:106) is that of price and quality. A respondent may see a higher price for a service as indicative of quality. Therefore if an alternative has a high price and a certain low quality, the respondent may see this as a conflict. This

may cause a rejection of the question or cause a skewed decision. Hensher *et al* (2005:107) recommend that the researcher be wary of such surrogate attributes and remove them from the alternative.

Attribute levels are descriptions of the attributes used in the alternative. The attribute levels may be numbers or descriptions. The number of attribute levels to use is a trade-off between the accuracy required and the time and cost of the survey. The outcome of the survey will eventually be a marginal utility assigned to each attribute level and therefore the greater the number of attribute levels, the more accurate a marginal utility relationship may be established. The extremes of the attribute levels are to be determined from literature or preliminary interviews. Hensher *et al* (2005:108) recommend that once these practical extremes are recorded, the values used for the survey should be slightly outside this range. This is because statistical models will predict poorly near the edges of the data range used in the questionnaire. Therefore it is important that the real data range is reasonably within the questionnaire data range.

Stage 3: A full factorial design is, "a design in which all possible treatment combinations are enumerated" (Hensher *et al*, 2005:109) or, alternatively stated, in which the full range of attributes, no matter how numerous are presented (Harrell, 1993:2). Therefore in a full factorial design, all the possible combinations of attribute levels are created. In a full factorial choice analysis where the respondent must choose between alternatives, the formulae L^{MA} (for labeled questionnaires) and L^{A} (for unlabeled questionnaires) describe the number of combinations possible where L is the number of levels, M is the number of alternatives and A is the number of attributes (Hensher *et al*, 2005:112). Labeled questionnaires are where each alternative is given a meaningful title while in unlabeled questionnaires generic headings are used (e.g. Option 1, Alternative 1). The advantage of unlabeled questionnaires is that the principle of IID is less likely to be violated as an alternative name may be correlated by the respondent to certain of the other attributes.

The equations L^{MA} and L^{A} show that even for a small number of attributes and levels, a large number of combinations are possible and a full factorial design will overburden a single respondent with this large number of choices. Fractional factorial

designs are those "which use only a fraction of the total number of treatment combinations…" (Hensher *et al*, 2005:115). They are useful in reducing the number of questions a single respondent must answer. The treatment combinations used in the fractional factorial design are usually created using reference tables such as those maintained by Sloane (2008) although designs from first principles are demonstrated by Raktoe *et al* (1981).

Stage 4 and Stage 5: These stages are usually completed simultaneously through the use of statistical software which assigns attribute labels to the design columns generated earlier. This creates a matrix of the treatment combinations and coded attribute levels assigned to attribute labels.

Stage 6: The choice sets are simply the treatment combinations already created, with the coding structure replaced with the attribute levels as they will be used in the final questionnaire.

Stage 7: A complete randomization of the choice sets, where each respondent receives an individually randomized set of questions, is preferable. However, this has a high administration cost and it may also be acceptable to generate a smaller amount of randomized sets such that each respondent obtains one of these (Hensher *et al*, 2005:171). This lessens the administration required.

Stage 8: The final construction of the survey is different for each survey requirement although the following points must be taken into consideration as described in Hensher *et al* (2005:173-175):

- The context in which the respondent chooses is important. Therefore it may be necessary to guide the respondent into placing themselves within a certain context through a brief description. This description may be placed before the questions.
- As respondents usually only fully grasp the concept after answering a few choice sets, it may create less useful data for the first questions answered. Therefore it is useful to create an example question with greater explanations of the expected mode of answering in order to better prepare the respondent.
- Another note which may be necessary on the survey is that which advises the respondent to treat each choice set as independent from all others. This avoids the

problem of sets being answered only once others have been considered. This would lead to bias in the questionnaire.

2.7.3 Bias

Bias in stated preference work is a noteworthy source of error and must be investigated. Geurs *et al* (2006:16) as well as Wardman (1988:78) describe common forms of respondent bias:

- **Hypothetical Bias**. This error comes as people often answer questions untruthfully. Thus what they say they prefer is not always what they would prefer in reality. It is important to have the attributes and attribute levels as realistic as possible in order to minimize this bias.
- **Strategic Bias**: Respondents may attempt to influence the survey results in order to benefit themselves. For example, they may untruthfully state that they would use an improved train service in order to ensure it is upgraded and thus redirect commuters to the train and create less road congestion for themselves. Reduction of this bias may be done through not revealing the purpose of the survey to respondents.
- **Order Bias**: To reduce the influence of the order of the choice sets on respondent behaviour it is necessary to randomise the order in which they are presented. Fatigue while completing the questionnaire may cause results to be less useful in the later choice sets and randomizing these will reduce the error.
- **Justification Bias**. This bias occurs with respondents who already have a predetermined preference and who use false internal justifications in order to continue selecting this preference as the best option even when evidence in the choice set does not support this.

2.8 Literature Review Important Findings

A summary of the literature review is presented here in order to highlight the most important points to be carried forward.

Urban Sustainability

The concept of sustainability refers to a broad interpretation of the interaction between the environmental, social and financial/technical spheres. While the significance of each of the spheres may not be identical, they are all nonetheless important. New sustainability thinking assumes that the three spheres are integrated within one another with the environmental/ecosystem sphere as the most important. The others may therefore be undermined simply through the degradation of the environment. Weak, sensible and strong sustainability are concepts which explain the interchangeability of the spheres and whether the degradation of one can be perfectly substituted by improvements in another.

Sustainability Assessment

Assessment in urban sustainability consists of indicators aggregated into rating tools. The complexity of creating indicators is described and two approaches (top-down and bottom-up) are developed. These are either expert driven or developed with a range of stakeholders including those without recognised formal expertise. There are over 500 relevant indicator systems worldwide with the most significant being; the Human Development Index, Ecological Footprint, Life Cycle Indices, Urban Sustainability Indices and Well-being Assessment. The most important shortcoming of the indicators is that they are often inflexible and are a set of strict rules without easy adaptation to fit specific circumstances.

Urban development rating tools are specialised assessment tools designed for the urban development context. The most widely used are BREEAM, CASBEE, LEED and TERI-GRIHA. They broadly function by assigning a number of points for the implementation of certain sustainability techniques in a development. The total of these points (manipulated in some fashion) determines whether sustainability has been achieved. The points assigned to each technique and the manner in which they are added presents the greatest test of their relevance. The lack of lifecycle assessment in

these tools represents a noticeable negative point. Without lifecycle assessment and the inclusion of long term monitoring and evaluation, they are less useful. Also, as with the simpler assessment systems, their inflexibility and narrow range of implementation makes their results less relevant.

Elements of Sustainability

The basic elements of sustainability examined were the objectives, performance measures, techniques and effects. Performance measures were the least well documented in literature. Objectives of sustainability and the techniques to achieve these objectives are however well covered. It is possible to conclude from this that while the methods of moving toward sustainability are well understood; the extent of change required is specific to the context in which it is applied. This need for task specific flexibility in sustainability, ties in with the criticism of the assessment tools described earlier. The effects of sustainability are also well documented although there is less discussion on the extent of change which occurs.

Effects in Sustainability

The consideration of effects for assessment stems from the shortcomings of technique-based rating systems. Effects-based systems may overcome drawbacks in traditional technique-based systems as follows:

- Costs/Finances: Lifecycle costs in particular are not adequately covered and related adequately to the project specifics. With the introduction of cost as an effect, it is easier to introduce considerations of lifecycle cost as well as capital cost.

- Applicability: Many credit concepts in the rating system may not be applicable to a particular project, region or budget. As they are not removable from the rating system, it inappropriately affects the result. The use of effects as the most basic comparative tool transcends time, location, technological and environmental boundaries. This is as an effect is a common unit of measurement even when its significance changes. The ability to relatively easily change this significance within limits, allows for the applicability to be greater for any particular development.

- Scale: The credits in the rating systems are based on the assumed scale of the results which occur when applying them. If they are applied with differing results (better or worse), the credits awarded are no longer appropriate. It is very likely that techniques implemented by different developers in different circumstances will have outcomes not expected by the rating system planners. This compromises the result. If effects are used, it eliminates the error due to this assumption.

- Substitutability: In a development, it is possible to include techniques which are not listed in the rating system. When a development rating tool does not take into account certain techniques, or awards too many or too few credits for a technique, the result is compromised. This often occurs when the rating tool is used out of context. However it is not easy to develop rating tools quickly enough to incorporate all possible techniques. Therefore it is assumed that any alternative techniques used are insignificant in the calculation of sustainability. This is not always the case. Effects solve the problem of substitutability as a new technique simply has its effects recorded and these are included in calculations.

- Flexibility: This means the ability to change the system within limits. Effects-based systems are far more flexible due to the ease of construction and revision. And this may occur without necessarily reducing the validity of the result.

Survey Research

The most relevant survey method for this work has been established to be a form of stated preference survey. The particular form chosen is the choice survey. This is because of the ability of the choice questionnaire to represent plausible real life situations and to cover a range of attribute levels makes it well suited to this work.

3 Methodology

3.1 Introduction

Determining the importance of effects within sustainability requires a combination of literature review and the use of survey instruments. The choice of these two methods relates to the initial hypothesis that it is possible to (as objectively as possible) attach importance to the effects of sustainability producing techniques.

The research methodology involves the use of induction. This is as a claim is to be made about the general notions of sustainability based upon the importance given by a sample population. The particular type of induction used here is *enumerative induction* which Jupp (2006:146) describes as follows:

> This involves generalization from a sample whose features have been studied to a larger, finite population of cases many of which have not been studied.

The methodology description which follows here will consist of three portions; the detailed work plan, the generation of attributes for the final questionnaire, and the creation and implementation of the final questionnaire.

3.2 Work Plan

The work plan below briefly describes the processes which will be followed in the preparation of this work. Secondary data analysis as well as primary data collection was done including both numeric and textual data. The research may be described as partly descriptive and partly explanatory in nature. The units of analysis are individuals and groups. The time dimension of the study is cross-sectional.

3.2.1 Phase I: Theoretical Review

The initial process is an extensive literature review. This literature review was first used to develop sufficient relevant knowledge on the subject of sustainability in the urban context. General assessment methods as well as urban sustainability assessment tools (both local and international) were critically discussed.

Specific objectives, performance measures, techniques and effects are central to discussions of urban sustainability. These were therefore reviewed with the aim of creating a library of these elements to be later re-organised as necessary. While it is not possible to review all the myriad possibilities, a large amount of literature was used to ensure that the most important topics are sufficiently covered.

Survey methods are to form an important function in this work. They were therefore reviewed in depth, beginning with the most general techniques and following with specific methods used for relevant environmental, engineering or social surveys. The most relevant survey method were then chosen and studied sufficiently such that a full survey could be designed for this work.

3.2.2 Phase II: Attribute Generation

Attribute generation involves the creation of the attributes and attribute levels which are to be used in the final survey. The first portion of this generation was concerned with organising the data from the theoretical review. The objectives were separated and organised concisely with redundancies removed. The objectives, the related effects and performance measures were then organised into a preliminary survey. This preliminary survey was used to determine the most important effects according to professionals in the urban and environmental related professions.

Once the most important effects were found, they formed the attributes in the final survey questionnaire. The attribute levels to be used were determined from a further literature review regarding the implementation of sustainability techniques and the extent of change that they have produced. From this a range of possible extents of change for each of the performance measures was determined.

3.2.3 Phase III: Questionnaire Generation and Implementation

The final questionnaire to be used was generated by using the survey methodology studied as well as the attributes and attribute levels generated. A series of pre-survey tests was performed in order to determine the final form of the questionnaire and the

most effective survey administration methods. Following on from this, the survey was conducted as necessary.

3.2.4 Phase IV: Data Analysis

The analysis of the survey data was conducted on a suitable statistical analysis package. The data was checked for validity and used for the determination of the importance attached to each performance measure. Other factors such as correlation were also determined where they were deemed important. Errors in the data as well as possible improvements were also determined.

3.2.5 Phase V: Application: Case Study

A case study process was used in order to check the validity of the results in a real scenario. Comments were also made on the outcome of the case study process and possible improvements suggested.

3.3 Generating the attributes

3.3.1 Desktop Study

The desktop study was completed in order to form the foundation of the survey processes. The desktop study has taken the results of the initial literature review and condensed these results, removing redundancies and reorganizing the data. The initial literature review was organised according to objectives and effects.

Classification of Objectives

The objectives were organised and certain objectives modified/removed according to the following criteria:

a. The statement of the objective must not consist of more than one part. If greater than one part is referred to, the objective statement must be separated and written as more than one statement.
b. The objective must not be limited to any overly narrow application.
c. The objective must not be too general in its meaning and such objectives may be subdivided to become more specific.
d. The objective must not state a technique within it.

The classification of objectives through the use of criteria is a reliable method of repeatedly getting the same result from a raw set of objectives. Validity is a more difficult concept although it is maximised through the creation of strong criteria. However the criteria used may be challenged as the point in the classification most open to error. The revised list of objectives created following the criteria prescribed, are shown in Appendix B.

Classification of Effects

The effects were more simply organised with the only manipulation being the removal of those effects stated more than once. The effects are considered the most important result of the literature review and the reason for their simple compilation is to present as comprehensive a list as possible to be further explored in the survey process.

3.3.2 Preliminary Survey

The preliminary survey was designed in order to decide which effects would ultimately form part of the stated preference survey. As a prelude to the preliminary survey, a pilot test was completed. This pilot test used the survey questionnaire in an electronic form and each respondent was informed that a pilot test was being carried out. Respondents were asked to complete the survey and report their comments. Responses were received electronically and several respondents were also contacted telephonically. The results of this process were used to produce the form of the preliminary survey to be widely distributed.

This preliminary survey took the form of an electronically distributed mail survey. Potential respondents were introduced to the study and the basic methodology. The respondents were then asked to consider a table created from the results of the desktop study and which contained objectives, effects and relevant selected performance measures from literature review. The nine objectives used in the preliminary survey were created by examining the revised objectives from literature review as shown in Appendix B. The most common objectives were then classified into the nine themes used for the survey. These nine themes are:

- Time
- Water

- Energy
- Social Integrity
- Financing
- Materials and Waste
- Environmental Health
- Human Health
- System Function

The creation of the nine themes is not as important as the effects and performance measures are represented irrespective of whichever themes may have been used. The most relevant and second most relevant performance measures were then selected by each respondent for each objective. A spreadsheet was developed in order to organise the collected data. The question in tabular form, from which respondents were asked to select, is shown in Appendix C.

The sample was constructed from a database of professionals in the fields of engineering, town planning, environmental management, architecture, government and the like. In excess of two hundred surveys were mailed to potential respondents. Due to the large number of diverse potential respondent's contacted, all with interest in urban, policy and environmental issues, it was assumed that there would be adequate variety in professions represented. The range of respondents which complete the electronic survey is an important factor in determining its validity.

The drawback of electronic surveys is the potential for non-response as well as responses which are incorrect due to the respondent not fully understanding aspects of the survey. In order to minimize the errors in understanding, the preliminary survey was sent to several respondents and comments were received in order to improve the final form of the instrument.

The preliminary survey showed the following results with respect to the most important performance measures:

Table 6: Results of the Preliminary Survey

Objective	Performance Measure Chosen
Time	Percentage change in time in comparison to the use of traditional non-sustainability oriented techniques.
Water	Percentage change in potable water consumption in comparison to the use of traditional non-sustainability oriented techniques.
Energy	Average change in electricity use per household.
Social Integrity	Job-days created on average per person per year over 10 years.
Financing	Extent of local economic development.
Materials and Waste	Amount of recyclable waste recovered before being landfilled.
Environmental Health	Percentage retention of valuable natural environments and systems
Human Health	Change in work absenteeism per individual per year due to illness.
System Function	Cost of annual maintenance required as a percentage of capital cost.

It is necessary to further explore the performance measures chosen in order to find a realistic range within which they occur in project developments. This is necessary to formulate the attribute levels for the stated preference questionnaire.

Time: Percentage change in time in comparison to the use of traditional non-sustainability oriented techniques.

The change in time as a result of sustainability techniques may come as a result of construction/installation, operation, maintenance or deconstruction. These changes may also increase or decrease the time spent. Therefore many combinations are possible depending entirely on the proportion in which techniques are used in the development as well as whether they are efficiently installed, used and maintained.

Water: Percentage change in potable water consumption in comparison to the use of traditional non-sustainability oriented techniques.

Thompson (1998:265) cites research indicating that average household use in metropolitan areas ranges between 98 litres per capita per day to 193 litres per capita per day. Mah *et al* (2008:117) estimate that 60% to 90% of water used in households may be recycled in some way. However the City of Cape Town (2008:85) estimates that low to middle income homes use up to 46% of supplied water for gardens (where present) and between 73% (low income housing) and 37% (middle income housing) of supplied water for toilet flushing. These represent the most significant areas for saving. Mah *et al* (2008:118) observe water savings due to reuse as high as 45%, while the City of Cape Town (2008:82) has set a water reduction target for households of 20% by the year 2020.

Thus potential savings of between 20% and 50% of potable water consumed are possible in residential developments.

Energy: Average change in electricity use per household.

There are large variations in the energy use profiles of homes. Factors such as climate or income greatly affect the energy use profile as well as the range of savings which are possible and cost effective. However the City of Cape Town (2008:46) indicates that typical mid-income homes in the city use on average 774kWh/month. Herring (1999) warns that historically, energy efficiency gains have been overtaken by increased energy use due in part to monetary savings used to fund additional energy driven processes. This rebound effect may therefore cause energy uses to increase after efficiency measures are introduced.

Below, the scale of savings possible in homes in developing countries is given.

Table 7: Possible electrical energy savings of middle income homes.

Electrical energy savings	Reference
10% or greater	Marechal et al (2005:248)
20% to 30%	City of Cape Town (2008:45)
Up to 30%	Dincer and Rosen (1999:438)

Social Integrity: Job-days created on average per person per year over 10 years.

The job-days created can vary widely depending on the size of the project and the length of time for which intensive work persists. For example, McCutcheon (1995:339) reports very high work creation on labour intensive construction sites in Kenya where an average of 290 job days were created per worker each year over ten years.

However Gaude *et al* (1987:428) cite construction programmes involving building works at a moderate scale where in the region of 200,000 job days over 5 years (40,000 job days per year) were created. Subbarao (1997) shows that in some cases these labour intensive schemes have produced 60 job days per year over the long term. These are insufficient to sustain families in the long term.

Freedman (1990:168) as well as Gaude *et al* (1987:428) infer that approximately 10% of the job days created for the construction period is sustained into the future through the maintenance phase of the project.

Financing: Extent of local economic development.

As the extent of local economic development is dependent greatly on the size and nature of the development, it is not possible to assign a figure which would constitute a sustainable development. It is therefore useful to use a proxy measure. Ladd (1994:203-207) has used increases in jobs created as a proxy to measure the economic development of a region. These jobs must be from new businesses created and excludes businesses which relocate to the area in question. Ladd (1994:203-207) cites several studies showing job increases of 8%, 13%, 76% and 19%. Therefore it is clear that a wide range of scenarios are possible depending on the unique situation of the development.

Materials and Waste: Amount of recyclable waste recovered before being landfilled.

The State of New Jersey, in the United States of America, has set a target of recycling 50% of all household solid waste generated (Otegbeye *et al*, 2008:647). This target is derived from studies indicating that over 50% of waste generated is recyclable by industrial or natural processes.

The Norwegian government has published a target indicating that 75% of the recyclable content of its municipal waste must be recycled by the year 2010 (Refsgaard, 2008:761).

Wilson *et al* (2008:629) show evidence from developing countries of the informal sector contributing significantly to recycling efforts, with 20% to 50% recycling of municipal solid waste being achieved.

The City of Cape Town (2008:10) has set fairly low targets and aims to recycle 25% of municipal waste by the year 2012.

These sources offer a clear indication that recycling rates in a sustainably oriented development may range from below 20% through to in excess of 60%. This must be placed in the context of household generation rates.

Table 8: Waste reduction rates recorded

Waste Generation Rate	Context	Reference
1.24kg/capita/day	High income South African cities	Mbande (2003:6)
1.85kg/capita/day	Western Cape, South Africa	Fiehn and Ball (2005:6)
0.7kg/capita/day	High Income Rural Western Cape, South Africa	van der Merwe (1997:201)

Environmental Health: Percentage retention of valuable natural environments and systems.

Beatley (2000:7), writing on biodiversity reduction and species loss in the United States of America, notes that much of the damage "could have been avoided through careful, land use planning and growth guidance." Beatley (2000:11) further describes that land of ecological value must be integrated and the creation of small islands of protected areas with no linkages must be avoided.

It is not possible to apply a prescription as to how much natural environment must be retained as this is specific to each development. However several other authors describe methods on how best to implement this selection:

- Shoup (1996) recommends regulating the land use at sale and thus forcing the purchaser to develop within certain guidelines.
- Arnold *et al* (1996) state that any previously natural environment will become damaged as impervious surfaces exceeds 10% of the total area. Above 30% coverage, degradation is almost irreversible.
- Grant and Manuel (1996) view the process not in terms of the percentage natural environment retained, but the extent to which natural system functions are retained. Thus it is important that systems existing on site, as well as their connections to other systems, are understood and maintained.

Thus it is clear that on-site environmental protection can be measured in many ways.

Human Health: Work days lost per individual per year due to illness.

Reduced working days for an individual is harmful to a company and the economy of a region when aggregated over time. Whitaker, (2001:420) describes these costs as follows:

> As well as the salary costs for the person who is absent there are the costs of replacement staff or overmanning of the organisation to take account of a specific level of absence, costs associated with lost productivity, or reduced quality of services, as well as the management, human resources, and occupational health time spent dealing with absence that could be used for other purposes.

The poor socioeconomic circumstance of a neighbourhood "has negative effects on likelihood of smoking, physical activity, depression, hostility, and mortality risk" Harpham (2008:108). Furthermore, a "sense of inequality and position in the social hierarchy, psychological stress, higher crime, poor housing, lack of transportation, and greater exposure to environmental contaminants" contribute significantly to poor resident health (Harpham, 2008:108).

Housing improvements are related to improvements in human health, with Northridge *et al* (2003:562) citing studies which indicate that health and perceived wellbeing improvements result from these measures.

Johnson (2007) notes that low income South African workers (earning less than R5000 per month) have an absenteeism rate of 2.3%, which drops to 1.3% in those earning R10000 or more per month. The following table shows rates of reduction in absenteeism as a result of measures introduced to improve social or working conditions in line with sustainability principles.

Table 9: Reductions in absenteeism recorded.

Reduction in absenteeism	Reference
15%	Roper and Beard (2006:94)
15%	Linzmeyer (2008)
40%	City of Seattle (2008)

System Function: Cost of annual maintenance required as a percentage of capital cost.

It is clear that different systems will have a wide range of maintenance regimes depending on their type and complexity. Therefore it is best to examine several systems in order to discover the range of maintenance costs applicable.

Table 10 shows various systems with attached maintenance requirements.

Table 10: Maintenance costs of typical sustainability techniques

System	Annual maintenance cost as a percentage of capital cost	Reference
Small wind energy generation plant	30%	NWCC (2008)
Sustainable Urban Drainage Systems	4% to 9%	City of Colorado Springs (2007)
Photovoltaics	2%	Lenardic (2009)
Small scale sorting plant for recyclables	17% to 30%	Sherif (1998:6)
Bicycle/Cycling Pathways	15%	Wang *et al* (2004)

Confluence of Social Integrity and Financing

Research indicates that the measurements of social integrity as well as financing are similar in that they both relate directly to the creation of sustainable long-term jobs. Thus it is possible to remove one of these attributes from the list of attributes to be studied. However there is no objective manner to remove either of the attributes (social integrity of financing) and the eventual result of the surveys must be applicable to both. Therefore it is necessary to create a new variable to replace both these attributes. This new variable must be named so that it applies fully to both social integrity and financing but it must not indicate these directly.

3.4 Generating the Stated Preference (Choice) Questionnaire

The attributes for the stated preference questionnaire have been decided upon, and the attribute levels have been initially investigated. Therefore it is possible to design the final questionnaire and test it before its final implementation. The process is discussed below with the attribute levels choices first described. Following this is the description of the pilot tests. The final portion details the actual form and implementation of the choice survey.

3.4.1 Attribute Level Choices

The attributes and attribute levels described in this section were used in the first pilot stated preference survey. The earlier literature review process, as well as further investigation/reasoning (as indicated below) has been used to create the attribute levels. Several attributes have been renamed in order to allow for easier understanding in the stated preference survey although the concepts, as chosen in the preliminary survey, have been maintained. The attribute levels have been represented per household where possible in order to create a standard which can be applied to any project. Where this is not possible they have been represented per person or per development. Furthermore, the attribute levels have been described not in terms of change from the average, but simply in terms of usage/generation/cost per relevant unit. This is as it is easier for the respondent to compare between the options and it reduces the possibility of an error in understanding when increases and decreases from average are present.

In order to set the context for the stated preference survey, certain selected site and housing parameters were stated below which may be relevant to the respondents' considerations. These parameters have also been used so that the attribute levels assigned may be related to them.

- The total development area is 40 hectares
- The site includess 10 hectares of environmentally important, conservation-worthy land

- An average household produces 30kg of solid waste per week
- An average household uses 775kWh of electricity per month
- An average household uses 500 litres of potable water per day
- An average household spends 80 hours per week on household upkeep and maintenance

- The average working resident experiences 4 lost work days per year as a result of illness

Domestic Upkeep

Bittman et al (2004:408) concludes from extensive surveys that the average urban household spends approximately 80 hours per week on household work. Household work is assumed to be the main area affected by sustainability techniques. It is not possible to ascertain with any accuracy the time change caused by improving sustainability as the techniques used as well as the characteristics of each household vary widely, causing very different effects. However it is likely that time will not be significantly saved by implementation of sustainability techniques. Thus levels were selected to represent the likely time increases experienced.

Levels	84 hours per household per week upkeep required	95 hours per household per week upkeep required

Potable Water Use

The average daily per capita water consumption stated by Thompson (1998:265) is 166 litres. An assumption of a three person household allows an estimation of approximately 500 litres per household per day. Mah *et al* (2008:118) cite water savings systems reusing as much as 45% of household water. The City of Cape Town (2008:82) describes water reduction targets for households of 20% by the year 2020. These are used as guidelines while also allowing for water use increases due to the rebound effect or other systems requiring more water.

Levels	250 litres per household per day used	550 litres per household per day used

Electrical Energy Use

The City of Cape Town (2008:46) indicates that a typical mid-income home in the city uses on average 774kWh/month. This is therefore a good approximation for the energy used in the development. The attribute levels were then chosen using the 30% maximum observed saving noted by Dincer and Rosen (1999:438) and a 5% increase in electricity which is possible should energy intensive equipment be installed to meet other household goals.

Levels	545kWh per household per month used	815kWh per household per month used

Job Creation

The research by Gaude *et al* (1987:428) as well as the assertion by Freedman (1990:168) that 10% of construction job days are carried forward to long term upkeep may be used to calculate equivalent jobs created. Thus the 40,000 construction job days per year are translated into 80 full time jobs over the long term.

Ball and Wood (1995:317) found that home building creates 29 construction jobs for every £1 million (in 1992) spent and that general civil engineering work (roads, sewerage, water) create approximately 13 jobs per £1 million (in 1992) spent. Thus allowing for inflation and a R250 million construction for a 40 hectare site (assumptions), this translates into 45 long term jobs created.

These approximations will be used as attribute levels with upward and downward adjustments.

Levels	35 long term jobs created	100 long term jobs created

Solid Waste Recycling

The average waste generation rates of Mbande (2003:6) as well as Fiehn and Ball (2005:6) result in an average generation rate of 1.6kg per person per day. Once again, assuming a three person household creates a weekly rate of approximately 30kg per household.

The ambitious targets (75% reduction in waste to landfills) of European countries were used along with the City of Cape Town target of 25% reduction. Furthermore, the data from Wilson *et al* (2008:629) was used as a guideline. This showed between 20% and 50% recycling of municipal solid waste being achieved. These were then applied to the calculated generation rates.

Levels	24kg per household per week sent to landfill	10kg per household per week sent to landfill

Environmental Health

It is important that the land conserved is measured in terms of the amount of environmentally important land on site. The hypothetical site has 10 hectares of environmentally important land. It is not easy to choose levels due to the fact that each development is unique and thus levels of 0% retention and 70% retention are used to cover the most probable outcomes.

Levels	Zero hectares of valuable natural environments and systems retained on site	7 hectares of valuable natural environments and systems retained on site

Personal Illness

Using an average of 1.7% absenteeism rate inferred from Johnson (2007) along with an average work year of 250 days it may be assumed that the average worker misses approximately 4 days per year due to illness. Data from various authors indicate the possibility of reducing absenteeism by between 15% and 40%. Application of this (with rounding of the numbers) leads to either no change or a reduction of two days per year in absenteeism.

Levels	2 sick days experienced per person per year	4 sick days experienced per person per year

Additional Equipment Maintenance

A statement of annual maintenance must be linked to the equipment in the household and the level of savings produced by them. Thus an inventory of possible equipment affecting water, electricity and solid waste was compiled:

- Potable Water Recycling: R3000 (GardenResQ, 2008)
- Solar Water Heating: R10,000 (Eskom, 2009)
- Domestic Recycling System: R600 (Take2, 2009)

Each of these equipment systems may or may not be present in the household and their presence is indicated by the changes which occur in the other attributes of that particular alternative. Each equipment system also has a particular annual maintenance indicated by the literature. Thus taking into account whether certain equipment is present (as seen by its effect) as well as the annual maintenance of that equipment, it is possible to calculate a maintenance requirement which is specific to that alternative.

Levels	Variable	Variable

3.4.2 Pilot Test 1

A pilot test was conducted with a survey size of 10 respondents randomly selected. The aims of the first pilot survey were as follows:

- To investigate the clarity of the explanations both verbal and written
- To investigate whether the question format is acceptable
- To get feedback on the appropriateness of the attributes and their levels

Results

The first significant result was related to the layout of the questionnaire. Many of the respondents would have preferred the development statistics to be more readily available beside the alternative outcomes. This reduces the constant referral required and speeds up the process. Also it sets the context of the results more clearly.

The attributes which accounted for the most confusion were Domestic Upkeep and Annual Additional Maintenance. Respondents felt that these were not clear and some asked for additional explanation of these.

Several respondents commented that the displaying of the alternative numbers used in the coding was unnecessary for the survey and added confusion.

Changes Instituted

In response to the results of the first pilot survey, the questionnaire was modified as follows:

- The attribute *Annual Additional Maintenance* was modified to *Annual Additional Maintenance per Household* in order to create more clarity. *Domestic Upkeep* was modified to *Domestic Upkeep Required*.
- The display was changed, thereby removing the coding from view and displaying the background information and summary simultaneously to the choice sets for easier reference.

3.4.3 Pilot Test 2

A second pilot test was conducted once again with a survey size of ten respondents selected. The respondents were asked to complete the entire survey. The aims of the second pilot survey were as follows:

- To gauge the time involved in administering the survey
- To investigate the clarity of the explanations both verbal and written
- To investigate whether the question format is acceptable
- To get feedback on the appropriateness of the attributes and their levels

Results

The full survey, including explanation, took 20-30 minutes to complete.

There was a notable improvement in the readability of the survey instrument due to the layout changes instituted.

Changes Instituted

- The description of the household averages was more clearly stated.

3.4.4 The Stated Preference Questionnaire

The stated preference survey was designed to be administered individually with the surveyor being present in order to better facilitate understanding of the survey. In the final survey, material explaining stated preference surveys, the process, as well as the research objectives was prepared and presented to the respondents. These preparations were important as the survey must be correctly understood, and all the choice sets must be answered, for the results to be valid. Each question set consisted of two scenarios from which the respondent was asked to choose the one they preferred as well as state any additional comments that they may have. Information was also collected regarding the gender, age range as well as profession of the respondent. Age range (below or above 45 years) was used in order to assess whether the perceptions of respondents are affected by the period during which they were likely to have been educated and formed their strongest opinions. Gender and profession were noted in order to investigate the changes in opinion (if any) between these groups. The sample used for the questionnaire is shown in Table 11.

Table 11: The sample used for the SP questionnaire

	Engineer	Non-Engineer	Below 45	Above 45
Male	11	11	12	10
Female	9	9	10	8
Below 45	15	7		
Above 45	5	13		

A fractional factorial design was used and designed in accordance with the catalogues set out by Kocur *et al* (1982). The minimum number of tests required by the design was 16. However many repetitions of the entire test were performed beyond this requirement. In total, 40 interviews were conducted. The participants were selected according to a stratified sampling protocol and participants indicated their willingness to participate.

4 Data Analysis

4.1 Introduction

In this chapter, analysis of the collected data is discussed and the final coefficients presented. A practical use of these coefficients is attempted in the following chapter. The data was analysed using the *Limdep Econometric Software Version 7.0*.

4.2 Results

4.2.1 The Survey Process

There were few instances of respondent confusion in the survey and any confusion was explained when necessary. The face-to-face survey approach was therefore successful. The planned number of surveys was completed.

4.2.2 Appraisal of Reliability and Validity

Reliability is concerned with the repeatability of the experiment and whether the same results would be found with a repeated application. Validity is concerned with whether the result found reflects the true situation.

The closed-ended nature of the survey, with the respondent simply choosing the preferred alternative, increases the reliability of the experiment. Also, the face-to-face survey approach increases reliability as the respondents are able to receive explanation of the process in order to clarify any confusion.

In assessing validity it is worthwhile to recall the statement by that Buckingham and Saunders (2004:72) that to achieve validity, the questionnaire must actually measure what it is designed to measure. This is fairly difficult to appraise, although the well constructed pre-survey testing process is likely to have identified and solved the major problems in this regard.

Theoretical Constructs

As Birol *et al* (2006:5) describe, a common criticism of choice surveys is that the survey may not take into account the true attributes that respondents find important. Thus, in this survey process, an extensive preliminary survey process was carried out in order to find, as correctly as possible, the most important attributes.

Survey Process

Harrell (1993:2) states that between three and eight attributes be used per combination. This is to minimize the chance of the respondent being overwhelmed with information and creating errors in the responses. Following this guideline, eight attributes were used. Harrell (1993:3) also recommends that no more than twelve questions are asked per respondent. In this survey, eight choice sets were presented to each respondent.

The four types of respondent bias described earlier (hypothetical, strategic, order and justification) were noted in the survey design process and should not significantly affect the survey outcome. Hypothetical bias was minimized through using realistic attributes and levels. Strategic bias was unlikely due to the respondents not having a vested interest in the survey outcome. Order bias was completely removed due to the choice sets being presented in random order. Justification bias is the most difficult to control, as the internal justifications of the respondent are impossible to ascertain. However, any clearly biased responses were not observed.

4.2.3 The Model

The *Limdep* software uses a Maximum Likelihood Estimation (MLE) method in order to calculate the results from the data. This model "calculates the parameters for which the observed sample is most likely to have occurred" Hensher *et al* (2005:318). Therefore it uses an iterative process to find the probabilities for each attribute which maximise the likelihood that getting the observed data.

4.2.4 Correlations

A correlation matrix was generated in order to determine the correlations amongst attributes and between the choice and the other attributes. The matrices are shown below.

Table 12: Correlation matrix

	JC	SW	EE	P	PW	DU	EH
JC	1.00000	.00000	.00000	.00000	.00000	.00000	.00000
SW	.00000	1.00000	.00000	.00000	.00000	.00000	.00000
EE	.00000	.00000	1.00000	.00000	.00000	.00000	.00000
P	.00000	.00000	.00000	1.00000	.00000	.00000	.00000
PW	.00000	.00000	.00000	.00000	1.00000	.00000	.00000
DU	.00000	.00000	.00000	.00000	.00000	1.00000	.00000
EH	.00000	.00000	.00000	.00000	.00000	.00000	1.00000
AAM	.02551	.00000	-.54426	.00000	-.16328	.00000	.00000
CHOICE	.39375	-.01250	-.08125	-.14375	-.05000	.06250	.15000
MALE	.00000	.00000	.00000	.00000	.00000	-.63522	.00000
BELOW45	.00000	.00000	.00000	.00000	.00000	-.63522	.00000
ENGINEER	.00000	.00000	.00000	.00000	.00000	-.57735	.00000

	AAM	CHOICE	MALE	BELOW45	ENGINEER
AAM	1.00000	-.08672	.00000	.00000	.00000
CHOICE	-.08672	1.00000	-.04833	-.04143	-.05052
MALE	.00000	-.04833	1.00000	.38978	.39864
BELOW45	.00000	-.04143	.38978	1.00000	.58998
ENGINEER	.00000	-.05052	.39864	.58998	1.00000

The *Limdep* coding is representative of attributes from the choice survey as follows:

JC: Job Creation

SW: Solid Waste

EE: Electrical Energy

P: Personal Illness

PW: Potable Water Use

DU: Domestic Upkeep

EH: Environmental Health

AAM: Annual Additional Maintenance

CHOICE: The chosen alternative

MALE: Male Respondent

BELOW 45: Respondent Below 45 Years of Age

ENGINEER: Respondent from the Engineering Profession

The first noticeable correlation statistic is the low correlation (-0.0125) between the choice of preferred alternative and the solid waste attribute. The negative sign indicates the expected result that the higher the solid waste generated; the less likely the respondent is to choose that alternative. This correlation is four times lower than that between the next lowest choice correlations of male, below 45 and engineer.

The correlations between gender (male/female), age (below 45/above 45) and profession (engineer/non engineer) are interesting to note. Firstly it must be noted that the correlations between choice and these variables are low. Thus these different groups did not choose remarkably differently to each other. From this it may be inferred that despite different training styles and periods of education, the perceptions of the important themes in sustainability is similar across the groups.

There are also reasonably low correlations between choice and Electrical Energy, Potable Water Use, Domestic Upkeep and Annual Additional Maintenance. However these are much higher than the low correlations noted earlier. Conversely, the highest choice correlation is with Job Creation.

4.2.5 Coefficient Calculations

Limdep was used to calculate the coefficients using the maximum likelihood method. In order to judge the outcomes, it is necessary to use statistical significance. There are several outputs which must be noted in order to judge the statistical significance of the model and the individual attributes. These are described below:

- Hensher *et al* (2005:324) state that for normal models, greater than 25 iterations before a solution converges, indicate that there may be a problem with the attributes (called variables in the output) included.

- The Log Likelihood Function is used to determine the significance of the model and how well it fits the data. A number closer to zero represents a better model fit. However, just how close this particular statistic is to zero can only be ascertained by comparing it to another model.

- The pseudo-R^2 (R-sqrd in the output) and the pseudo-R^2 adjusted (RsqAdj in the output) are used to indicate the fit of the model. The pseudo-R^2 is similar to the R^2 used in linear regression models. However it is not identical as the Multinomial Logit (MNL) model used for the analysis of choice experiments is not linear. However it is possible to compare the pseudo-R^2 to the more familiar R^2 for linear models. Hensher *et al* (2005:338) state that a pseudo-R^2 of 0.3 is an indicator of a good model fit. A pseudo-R^2 of 0.3 is approximately equivalent to a linear R^2 of 0.6.

- The standard error measures the amount of error, or the standard deviation, in the coefficient calculated.

- The Wald Statistic is analogous to the t-test used in linear regression to check the confidence assigned to regression coefficients. In this format, an absolute value of 1.96 for the Wald Statistic indicates a 95% confidence in the coefficient found through the maximum likelihood method.

- The Probability Value (P-value), at a confidence interval of 95%, should be less than 0.05 in order to determine than the coefficient found is not statistically irrelevant. Both the Wald Statistic and the P-value will give the same indication (at the same confidence level) of the acceptability of the coefficient calculated.

Three alternative outcomes were gained from the analysis. These outcomes represent different approaches to selecting and rejecting attributes.

Option A

Option A retains all the attributes regardless of their statistical properties.

Table 13: Option A

	1		2	
Iterations	101		101	
Log Likelihood	-221.8071		-221.8071	
Pseudo-R^2	0		0	
Attribute	Coefficient	Wald Stat.	Coefficient	Wald Stat.
JC	56.6764	error	1.5832	534.067
SW	832.4229	error	4.9741	222.775
EE	47.2054	error	0.2944	234.095
P	7157.3495	error	7.9799	50.840
PW	68.2514	error	0.5374	388.495
DU	-332.2663	error	-1.3827	-136.038
EH	1838.0069	error	24.8006	384.108
AAM	5.4581	error	0.0331	197.684
Male	-3.9393	-17.379		
Below 45	1.6088	6.647		
Engineer	-7.1646	-29.907		

- Run 1: In the first run, 101 iterations were completed and this is not satisfactory. The log likelihood function obtained here (-221.8071) shall therefore be used as the standard for comparison with later results achieved. The pseudo-R^2 of 0.0 achieved in this first run is not sufficient.
- Run 2: The descriptor variables are not important in the assessment of sustainability and their inclusion is merely to test the attitudes of different groups of respondents. Therefore they were removed in Run 2, leaving only the eight attributes.

The results of Option A indicate a model which does not easily converge due to the large number of iterations and it may therefore be problematic. Also, the log

likelihood and pseudo-R^2 are unchanged from the base result. Solid Waste, Electrical Energy, Personal Illness, Potable Water and Annual Additional Maintenance should intuitively have negative signs as increasing values reflect less sustainability. For these reasons, Option A must be rejected.

Option B

Option B first removed Annual Additional Maintenance (AAM) which was the least popular attribute in the preliminary survey. Thereafter, attributes were removed based on their statistical weakness.

Table 14: Option B

	1		2		3		4		5	
Iterations	101		7		6		6		6	
Log Likelihood	-221.8071		-158.0643		-158.3006		-158.3006		-158.9758	
Pseudo-R^2	0		0.28738		.28631		0.28631		0.28327	
Attribute	Coefficient	Wald Stat.	Coefficient	Wald Stat.	Coefficient	Wald Stat.	Coefficient	Wald Stat.	Coefficient	Wald Stat.
JC	56.6764	error	0.243	5.76	0.0229	6.36	0.2289	6.55	0.0212	7.07
SW	832.4229	error	0.0122	0.68						
EE	47.2054	error	0.0013	1.30	0.0010	1.13	0.0010	1.13		
P	7157.3495	error	-0.4473	-2.47	-0.5105	-3.30	-0.5110	-3.32	-0.4857	-3.19
PW	68.2514	error	0.0029	2.43	0.0029	2.36	-0.0028	-2.38	0.0021	2.13
DU	-332.2663	error	-0.0025	-0.17	-0.0006	-0.04				
EH	1838.0069	error	0.3016	4.94	0.2889	5.14	0.2880	5.65	0.2761	5.69
AAM	5.4581	error								
Male	-3.9393	-17.38								
Below 45	1.6088	6.65								
Engineer	-7.1646	-29.9								

- Run 1: This is identical to Option A.
- Run 2: In the second run, Annual Additional Maintenance was removed. This is as it was the least popular attribute in the preliminary survey. The number of iterations necessary to arrive at convergence has decreased to 8. Furthermore, at -

158.0643, the log likelihood function has improved toward zero. Also, the pseudo-R^2 is 0.287. This is close to the 0.3 which is acceptable as a measure of model fit.

- Run 3 to Run 5: In these runs, first Solid Waste followed by Domestic Upkeep and finally Electrical Energy was removed. This is as in each run these had the weakest statistical significance. The final log likelihoods and pseudo-R^2 statistics remain constant through the final runs (-158 and 0.28)

Option B is statistically relevant. However there are only four attributes remaining after the analysis. Four attributes may be too little to use for a meaningful system. Also, there is no financial element to Option B. Therefore the result of Option B is possibly not useful.

Option C

This option retains only those which meet requirements for statistical significance.

Table 15: Option C

	1		2		3		4		5	
Iterations	101		8		8		8		7	
Log Likelihood	-221.8071		-157.0379		-157.2504		-157.2546		-157.5899	
Pseudo-R^2	0		0.29201		0.29105		0.29103		0.28952	
Attribute	Coefficient	Wald Stat.	Coefficient	Wald Stat.	Coefficient	Wald Stat.	Coefficient	Wald Stat.	Coefficient	Wald Stat.
JC	56.6764	error	0.0259	5.07	0.02593	5.07	0.0259	5.04	0.0237	6.52
SW	832.4229	error								
EE	47.2054	error	-0.0001	0.09	-0.0001	0.09				
P	7157.3495	error	-0.4330	-2.55	-0.4321	-2.55	-0.4272	-2.66	-0.4588	-2.99
PW	68.2514	error	-0.0017	1.19	-0.0017	1.19	-0.0016	1.63	-0.0016	-1.59
DU	-332.2663	error	-0.0248	-0.83	-0.0147	-0.73	-0.0153	-0.78		
EH	1838.0069	error	0.2862	4.28	0.2858	4.28	0.2849	4.28	0.2573	4.96
AAM	5.4581	error	-0.0003	-1.27	-0.0003	-1.28	-0.0003	-1.61	-0.0002	-1.65
Male	-3.9393	-17.37	-0.0889	-0.32						
Below 45	1.6088	6.647	-0.0364	0.12						
Engineer	-7.1646	-29.90	-0.1616	-0.54						

- Run 1: This is identical to Option A and B.
- Run 2: In the second run, the Solid Waste attribute/variable was removed. This is as it had been shown to have the lowest correlation to choice. It was therefore not a largely relevant variable for respondents. It is evident that the number of iterations necessary to arrive at convergence has dramatically decreased to 8. This is an acceptable figure at less than 25 iterations. Furthermore, at -157.0379, the log likelihood function has improved toward zero. Also, the pseudo-R^2 is 0.29. It is preferable to remove the Male, Below 45 and Engineer variables as it is possible that the statistics for the remaining variables may improve subsequent to this.
- Run 3: The third run was altered simply by the removal of the descriptor variables. The number of iterations, log likelihood function and pseudo-R^2 are effectively unchanged from the previous run. The least statistically significant of these is Electrical Energy.
- Run 4: The fourth run was attempted after excluding Electrical Energy due to its low statistical significance. The number of iterations, log likelihood function and pseudo-R^2 are once again effectively unchanged from the previous run. Domestic Upkeep has the lowest statistical confidence.
- Run 5 was completed after the removal of Domestic Upkeep. Potable Water Use and Annual Additional Maintenance are still below the 95% confidence level. However Annual Additional Maintenance is above the 90% confidence level and Potable Water is above the 85% confidence level. Therefore the removal of these variables is likely to be unnecessary and it may detract from the overall usefulness of the system. The five remaining variables are therefore the most significant.

Option C is the preferred option due to the correct signs being present and generally good statistical significance. It also has five attributes (one more than Option B) and it includes financial, social and environmental characteristics.

4.2.6 The Final Coefficients

The final coefficients from analysis are presented in Table 15 with the unit to which they apply. When these attributes are applied to real techniques, the coefficient is multiplied by the number of relevant units.

Table 16: The final coefficients

Attribute	Coefficient	Unit
Job Creation	0.0237	per long term job created
Personal Illness	-0.4588	per sick day experienced per person per year
Potable Water Use	-0.0016	per litre per household per day used
Environmental Health	0.2573	per hectare of valuable natural environments and systems retained on site
Annual Additional Maintenance	-0.0002	per rand

It is interesting no note the comparison between the top five most popular effects found in the preliminary survey and the five attributes which remained after this analysis. Personal Illness, Potable Water Use and Environmental Health were the three most popular effects in the preliminary survey and they are represented in the final attribute list. However Solid Waste recovery and Electrical Energy Use, the two next most popular effects are not included. Annual Additional Maintenance was the least popular during the preliminary survey but was well correlated to choice in the analysis of the stated preference survey. Job Creation was also not popular in the preliminary survey however it was highly correlated to choice in the stated preference survey.

5 Application: Case Study (Lynedoch Eco Village)

5.1 Introduction

This case study will attempt to apply the coefficients obtained to a setting similar to that for which they were developed. The purpose of this is to test the applicability of the coefficients and whether they function as intended. As there is not enough information, even in a case study with such unusually detailed documentation, certain assumptions about the site will need to be made.

5.2 Reasons for Selection

The Lynedoch development was selected for the following reasons:

- Its situation near to Cape Town
- It is a predominantly housing development
- Sustainability techniques have been purposefully included
- There is some documentation on the processes followed and techniques implemented

5.3 Overview

The Lynedoch Eco Village is situated near the town of Stellenbosch in the Western Cape. It is approximately thirty minutes by car from Cape Town. It has been purposely designed in order to be a mixed community with sustainability techniques included as the main features of its design. Swilling and Annecke (undated:1) describe the village as follows:

> The most significant aspect of the Lynedoch case from a sustainable design and construction point of view is that it provides a working example of an *integrated sustainable development: integrated* because it connects social, economic and ecological objectives and because it incorporates technologies that span the energy, water, sanitation, and building materials fields; *sustainable* because of the commitment to a long-term vision of social, economic ***and*** ecological sustainability; and *developmental* because of the anti-poverty and local economic development objectives.

The development was created with three express goals in mind:

- The Lynedoch Eco Village should be a socially mixed community (both in terms of race and class) organized around a child-centred learning precinct;
- It should strive to be a working example of a liveable ecologically designed urban system;
- It would be a financially and economically viable community that would not require external funding to sustain itself.

Swilling and Annecke (undated:2) describe the key development features:

- the site is 6 hectares
- a primary school for 450 children drawn mainly from the families of local farmworkers (completed December 2001);
- a pre-school for 40 children (completed in February 2002);
- a large multi-purpose hall (completed in December 2001);
- offices and classrooms for the Sustainability Institute (completed in December 2001);
- conversion of the old Drie Gewels Hotel and an existing residential house into 18 residences that will provide accommodation for participants in the programmes of the Sustainability Institute, as well as a conference venue for general use;
- 42 new residential sites with 15 earmarked for purchase at a price of R20 000 by people who qualify for a government housing subsidy (10 of which were completed in March 2006), with the remainder sold at a commercial rate ranging from R90 000 to R275 000 per erf, and that this has been done by means of an urban design layout that does not spatially separate the subsidy erven from the commercially priced erven;
- commercial space for offices or small manufacturers and crafters;
- a village green and landscaped areas that will eventually be planted with indigenous plants;
- a traffic environment that limits the number of cars that can move around the village, and restricts the parking of cars to designated communal parking areas, which, in turn, secures the space for children and pedestrians.

5.4 Sustainability Features

5.4.1 Water and Stormwater

(Swilling and Annecke, undated:5-6) and (Posma, 2003:8)

- A variety of housing types ranging from subsidised homes to homes sold at commercial grades in order to raise the capital necessary for the cross subsidisation. There is an almost 50:50 split between commercial and subsidised housing units (Swilling and Annecke, undated:5)
- Recycled water is used for toilet flushing (reduces household consumption by 40%) as well as irrigation (reducing potable water use in market housing by up to 60%). Residents are then charged for the potable water and a nominal fee to maintain the water recycling equipment. (Swilling and Annecke, undated:6)
- Stormwater channels are lined with natural grasses and convey runoff from hard areas and roofs into a storage dam. (Swilling and Annecke, undated:6)

5.4.2 Household Effluent

(Swilling and Annecke, undated:7) and (Posma, 2003:8)

- Effluent from the households passes via septic tanks into a wetland system. After natural filtration processes the water moves to a reservoir from where it is pumped to supply the water described earlier for toilet flushing and irrigation.
- Due to the recycling system, no stormwater of effluent leaves the site boundaries (with the exception of groundwater flows).

5.4.3 Energy

(Swilling and Annecke, undated:8) and (Posma, 2003:9)

- All houses are connected conventionally to the national grid.
- Solar water heaters are installed on all dwellings and it is estimated that a 60% reduction in household electrical use is achieved.
- Passive heating and cooling has been encouraged through solar orientation, proper shading of windows, thermal stores and some geothermal energy systems.

- Compact fluorescent lights (CFL) as well as Light Emitting Diodes (LED) have been used throughout the development.

5.4.4 Refuse

(Swilling and Annecke, undated:8)

- Residents are required to separate solid waste into organic and non-organic. This is then collected by the home owners association and further separated.
- The aim of the development is to send only 5% of waste generated to landfill.

5.4.5 Governance

(Swilling and Annecke, undated:9-10)

- The Lynedoch Home Owners Association (LHOA) is tasked with the running of the community. This includes ensuring that the bulk charges are paid and the community runs in accordance with its constitution.
- There is a Code of Conduct binding on all residents of the development. It provides guidance on:

  > litter, waste disposal (including separating waste at source), the number of pets each owner is allowed, noise pollution, traffic control, building extensions, use of energy and water, use of common areas, planting of vegetation and food gardens, disposal of compostable organic waste, safety and security matters (especially for children), use of the community hall, conflict resolution, air pollution, external appearance of buildings, procedures for managing community events (e.g. parties, marriages, funerals, etc), behaviour of temporary residents (e.g. students, etc), and the right to privacy in a context that is already inundated by visitors.

- One of the conditions of development is that the cash equivalent of 1% of all land sales is deposited into a fund to be used for the protection of the natural environment.

5.4.6 Social

(Swilling and Annecke, undated:10-11)

- Funding mechanisms were put in place to afford those who did not qualify for bank loans to have the means to pay for the subsidized homes. This was to ensure the social mix of the development.
- A school was built on site with an emphasis on foundational learning and creating an environment which is safe for the children who attend there.

5.4.7 Financial Mechanisms

(Swilling and Annecke, undated:12)

- Poorer residents were financially empowered by being offered plots at far lower than market rates.
- The LHOA aims to prevent a quick resale of property at lower than market prices. Therefore its constitution prescribes that the plot must first be offered to the LHOA and thereafter to the general market at a price not lower than that stated by the LHOA.
- The LHOA also stipulates that a percentage of the sale be contributed to the LHOA in order to fund social sustainability endeavours.

5.5 Application of Coefficients

Each of the five attributes will be dealt with in turn. The total effects from the development which contribute to that attribute will be totaled and multiplied by the relevant coefficient.

Job Creation

There are no direct figures for the jobs created on site. Thus it is necessary to use the earlier assumptions to construct a likely figure. From Ball and Wood (1995:317) it may be calculated that general civil engineering work creates approximately 0.18 jobs per R1 million spent.

Data is available on the plot sales figures can be used to calculate the approximate housing costs. This makes use of the rule-of-thumb that the construction of a house generally costs four times the value of the plot on which it stands. Thus using the plot prices and an additional nominal amount for the extra sustainability equipment, the total housing cost is approximately R25 million. Allowing for the construction of basic engineering infrastructure, the total project cost may be estimated at R40 million.

From this, the long term jobs created would be 8. However due to the intentional manner in which jobs will be created in the community, this may be factored upward and a figure of 20 jobs long term jobs is more appropriate. This excluded the jobs such as household staff or general maintenance which are common to all developments.

The Job Creation Part Utility is therefore:

$$20 \times 0.0237 = \underline{0.474}$$

Personal Illness

It is unlikely in this scenario that the new housing development would reduce the illness significantly of the more affluent residents who already are able to afford healthcare and nutrition and who are not exposed to environmental hazards. The greatest effect is therefore with the poorer families.

Johnson (2007) notes that low income South African workers (earning less than R5000 per month) have an absenteeism rate of 2.3%. These are the workers most likely represented in the lowest income houses. This translates to 6 days lost per year due to ill health. Taking into account the reduction rates by Roper and Beard (2006:94), Linzmeyer (2008) and the City of Seattle (2008) it is possible to arrive at an improvement of 23% in the number of days lost. Thus the final number of sick days experienced per person per year for the development is 3.

The Personal Illness Part Utility is therefore:

$$3 \times (-0.4588) = \underline{-1.376}$$

Potable Water Use

The development claims to reduce potable water use by 60% in the market housing. This may be applied to the average use for middle income housing of 500 litres per day inferred from Thompson (1998:265). The household usage per day is therefore reduced to 200 litres.

The usage for the lower income housing is based on a lower percentage saved. Irrigation of gardens is less than in higher income homes and irrigation savings an important saving in higher income houses. Therefore the stated water reduction of 40% possible through the use of recycled water is likely to be the bulk of the water saved in poorer households. This is applied to the housed low-income daily rate of 98 litres per capita per day (Thompson, 1998:265). The household usage per day is therefore reduced to 180 litres.

63% of the households are market housing and 37% are low-income. The Potable Water Part Utility is therefore:

$$\left[(0.63 \times 200) + (0.37 \times 180)\right] \times (-0.0016) = (92.6) \times (-0.0016) = \underline{-0.308}$$

Environmental Health

The full site is 6 hectares. However, an area of the site has been allocated in order to preserve indigenous vegetation and provide social area for the residents. Assuming this area is 1 hectare, the Environmental Health Part Utility is therefore:

$$1 \times 0.2573 = \underline{0.257}$$

Annual Additional Maintenance

It is possible to calculate the average maintenance by looking at the additional equipment installed in the housing and described by Swilling and Annecke as well as

Forder (2009). In cases where the installed equipment is not fully described, assumptions have to be made based on the other relevant outcomes cited (water savings, electricity use changes, etc).

- Solar Water Heater:
  2% (Lenardic, 2009) of R10,000 capital cost (Eskom, 2009) = R200

- Septic Tank:
  2.8% (DWAF, 2002:4) of R7000 (DWAF, 2002:4) = R200

- Greywater Recycling:
  5% (GreenCon, 2008) of R3000 (GardenResQ, 2008) = R150

- On Site Composting/Recycling:
  15% (Wang et al, 2004) of R600 (Take2, 2009) = R90

The Annual Additional Maintenance Part Utility is therefore:

$$(200+200+150+90)\times(-0.0002) = 640\times(-0.0002) = \underline{-0.128}$$

Result

The final result for the development is the sum of the part utilities discussed above:

$$JC + PI + PW + EH + AAM = \text{Result}$$

$$0.474+(-1.376)+(-0.308)+0.257+(-0.128) = \underline{\underline{-1.081}}$$

5.6 Alternative Outcomes Classification

It is useful to attempt to find another result by varying the outcomes of the development. These variations are within the realm of possible outcomes for the development. The usefulness of this is that it serves as a sensitivity analysis to ensure that the coefficients give results which are sensible. In other words, if the outcomes

are improved, the utility result must improve accordingly. Table 15 shows the changes made to the outcomes and the effect of this on the result.

Table 17: Alternative outcomes analysis for Lynedoch

	JC	P	PW	EH	AAM	Result	% Change
Base Case	20	3	192.6	1	640	-1.081	0
Worsen P by 33%	20	4	192.6	1	640	-1.535	42%
Improve EH by 300%	20	3	192.6	4	640	-0.309	71%
Worsen JC by 50%	10	3	192.6	1	640	-1.318	22%

As personal illness (P) was the largest coefficient, it was varied in order to find out the effect of this on the result. The worsening of the number of sick days experienced per person per year by 33% (3 to 4) is a realistic yet large change. This resulted in the result worsening by 42% to -1.535. This is not an unduly large change and it is unlikely that the personal illness will in reality change by a larger amount than this due to any development.

The environmental health (EH) is the second largest. Therefore its effect was tested by improving the number of hectares of valuable natural environments and systems retained on site by a large percentage (300%). This improved the overall result by 71%. This is a large improvement in the result. It may overwhelm the result if there is an even greater change in the environmental health. However this may be justified due to the importance of preserving valuable land. Also, in the scale of developments commonly encountered, it is unlikely that a change much greater than this will be experienced.

Job creation was the attribute most highly correlated to choice in the stated preference survey. It has also been found to be difficult to estimate. It is therefore important to test its influence when varied. Reducing the number of long term jobs created by

50% is an attempt to note the change if job creation is overestimated. The change in the overall result by 22% is small. This is encouraging as even with the popularity of job creation as a measure of sustainability it does not overwhelm other measures found.

5.7 Discussion

While the result of the above calculations has a negative sign, it must not be taken to mean that the development is unsustainable. In fact, the method makes no reference to a single figure which represents sustainability. The value in the result is only when it is used as a comparison with another result from an alternative development option. When the outcomes of the development were varied the change in the result was of a reasonable magnitude. It was found that an intuitive improvement in the sustainability brought a resulting move in the result toward zero. Thus the closer the result to a positive number (or the more positive the number), the greater the sustainability of the development.

In the application of the coefficients, several important observations were made:

- The most important result is that it is possible to use the coefficients to determine a result in a real development.
- It is particularly difficult to estimate job creation figures for a development before it has been constructed. Job creation is subject to unpredictable schedules of maintenance, improvement and new building.
- It is difficult to use the coefficients unless details of the development are available. However this is not necessarily negative as when this technique is used in reality, these details will be available.
- All the coefficients are in a similar range when applied to the development. Therefore there is no case of one "overwhelming" another. This is a good result as if the contrary were true; it would not represent the limited substitutability concept.
- An important improvement in this assessment would be the alteration of effects to account for losses in efficiency as well as good/poor maintenance. These will change the resulting effects and a more reasonable estimate may be obtained. This would bring an important element of lifecycle analysis (LCA) to the assessment.

6 Discussion and Conclusions

Sustainability in practice is an aggregate concept. It is built up through the application of principles to important aspects. Weak sustainability has no need for aggregation as the decay in one aspect can be perfectly replaced by the improvement in another. Similarly strong sustainability has the need for the perfect preservation of all the aspects and the decay of one destroys the concept. Sensible sustainability is aptly named as it allows for the more useful processes of limited substitution and aggregation. Thus an important outcome of the literature review is that the objective of adherence to the concept of sensible sustainability is a valid one.

This review has helped to highlight the shortcomings of traditional sustainability assessment in practice. The initial review revealed a lack of widespread knowledge on the comparison of the basic elements of sustainability. This apparent lack of elemental understanding makes the urban developmental rating tools less trustworthy. This is as their credit systems are likely to be loosely based on a value judgement of the expected outcomes, rather than the diligent and repetitive application of standards.

However the review also makes it clear that there is potential for the use of effects as the repeatable standard with which to compare sustainable practices. A comparison based on these elements is more effective as it:

- allows techniques to be used which may not be present in the current rating system,
- allows techniques to be more easily re-weighted where their current weighting is inappropriate,
- allows the entire rating system to be altered and updated more easily,
- promotes sensible sustainability through the creation of limited substitution possibilities but does not set the limits of substitution,
- allows the systems to be easily used and understood,
- allows a top-down as well as a bottom-up approach to constructing indices

The literature review highlighted survey methodologies as important in the production of useful results. In particular, stated preference (choice) surveys were identified as the most useful due to their ability to represent multiple attributes while reducing bias. The multiple survey processes and the subsequent data analysis confirmed that survey

methods could be successfully used as intended. However the difficulties of the initial electronic survey highlight the difficulties in administering these. A high non-response rate is likely to be achieved even when the survey is distributed to individuals involved in the relevant field. This must therefore be taken into account in the planning stages. It must be noted that pre-survey testing proved to be very important in both the survey for selecting the attributes and the choice survey as the changes made to the survey after each round of pilot tests was significant. It is certain that attempting a full scale survey without extensive pre-survey testing is likely to produce inferior results.

It has also shown that the coefficients derived are of an appropriate scale. In the case study application no effect was seen to overshadow the others by its size. This confirms the complex nature of sustainability. It also substantiates the reasoning that no one effect/objective can be taken as overwhelmingly important, even if a hierarchy does exist. The use of the coefficients seems to be able to surmount some of the shortcomings of traditional urban development rating tools:

- Firstly they are relevant for lifecycle analysis provided detailed information is available. The availability of detailed information is likely to be a hindrance in the overall application of the coefficients. Detailed information is necessary to ensure the accuracy of the result.
- The coefficients take into account social and financial factors in a manner which is less esoteric than those in the rating systems. However, all the complexities of social function are still not fully represented.
- The coefficient system is more easily adaptable to varying conditions due to its simplicity and flexibility.

There is opportunity for the practice of effects based rating to be used in a wider setting. It need not only be applied to the often vague setting of residential development. There is significant potential for it to be used in more commercial construction applications where the clear-cut nature of the design and the predictability of the outcomes will lead to more accuracy.

With regard to residential development, it is important to note the importance of the human factor. Individual behaviour as well as collective preferences and expectations

have been shown to be a large determining factor in the achievement of sustainability. Each of the attributes found to be significant, are influenced largely by human behaviour post-design. Thus when using information to calculate the results with the coefficients, it is important to allow for the most likely behavioural aspects.

In view of the hypothesis of this work, it has been found that it is possible to create a transparent method of attaching importance to the effects of sustainability producing techniques. The successful achievement of this hypothesis and objective is even more important than the numerical outcomes found. The method itself is not flawless and criticism may always be made of the seemingly value laden nature of surveys. However the use of multiple surveys and a choice technique which largely removes bias is a major contribution in overcoming these criticisms. Upon reflection, it may be seen that the stated preference (choice) method used has been a large contributor to improving the reliability and validity of the results. It is certainly a technique which must be strongly considered for inclusion in any further research and development of this topic.

The usefulness of the outcome of this work is in the appraisal of techniques and even entire projects. It may be used to improve the accuracy of decision-making in urban planning. It may be used on its own or as a key performance indicator forming part of a larger set of assessment tools. The use of these results may certainly guide policy, financial and human development planning.

7 Recommendations

It is possible to make a number of recommendations for the further improvement of this work.

Due to the importance of the preliminary survey in determining the attributes, this process may be reviewed. Different methods for administering the preliminary survey may be tested. These may include new methods of attribute selection and ordering. Also, the sample size at this stage could be increased in order to allow for a variety of opinions. The result of these changes may be a preliminary survey process which is more representative of the population.

An increased study size may make use of a wider array of participants and a larger sample size in the final choice survey. It may also be valuable to include a wider range of professions (politicians, administrators, financiers) as well as people with little formal training but important local perspectives. A larger study makes it possible to use many more attributes while still keeping the burden on each respondent low. An increase in the number of attributes will theoretically improve the accuracy of the rating process. Another study will also allow the coefficients which result to be compared to those found here. Such comparisons over many studies will increase the validity of the results.

It is also possible to move from the predominantly top-down compilation method to a more balanced method including a bottom-up design process. This would recognise the important views and skills of those who experience the housing situation as stakeholders in various forms. They may not however have the formal training in the field and their expertise is often overlooked for this reason.

The case study testing is an important check on the results obtained. The use of further case studies is therefore recommended. These studies should include developments which have already been assessed through the use of other rating tools. This may however be difficult in the setting of South Africa as no relevant assessment tools are widely used in residential development. Also, another possible case study process may be the rating not of entire developments but of individual techniques.

This may lead to a wide set of techniques being assessed with this system. Such a set of assessed techniques could be used as a reference for urban practitioners in the preliminary design of developments.

Future studies must focus on the complex nature of social interaction and community function. These are often overlooked in such studies. A particular objection may be the limited social marking in this work. This may be the respondents' rejection of the social dimensions due to the limited understanding of this complex area. In future, an attempt must be made to reintroduce the social dimensions in an understandable manner.

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Appendix A: Review of Urban Sustainability Outcomes

Line	Objectives	Performance Measure	Technique	Effect/s	Reference
1	To recognise global effects at project level	The determination of the global significance of an unmitigated impact.	• Scoping • Using target indicators • no-net-loss-of-natural-capital rule		George, C. (1997). Assessing Global Impacts at Sector and Project Levels. *Environmental Impact Assessment Review*. 17, pp 227-247
2	To maintain the concentration of carbon in the atmosphere with no net increase.	No net increase in concentration in the atmosphere beyond the year 2000, together with a decline in fossil fuel use after 2010	Various techniques	Reduction in carbon concentration, globally balanced between developed and developing nations	Effectiveness Study (Sadler 1995) cited in George, C. (1997). Assessing Global Impacts at Sector and Project Levels. *Environmental Impact Assessment Review*. 17, pp 227-247.
3	To promote energy efficiency in low cost government housing			*A reduction in local air pollution with subsequent decreases in pulmonary pneumonia, carbon monoxide poisoning and other respiratory illnesses. A decrease in accidents and damage to property as a result of fire is also anticipated.*	Winkler, H and van Es, D. (2007). Energy efficiency and the CDM in South Africa: constraints and opportunities. *Journal of Energy in Southern Africa*. 18 (1), pp 29-38
4	Demand Side Management (DSM)	The reduction in electrical energy use.	Retrofitting of existing energy consuming technologies, particularly lighting and electric geysers.	• Reduction in electrical energy use. • Retrofitting costs. To be carried by developer or parastatal. • Increased social inclusion • Improved health • Lessened pollution	Winkler, H and van Es, D. (2007). Energy efficiency and the CDM in South Africa: constraints and opportunities. *Journal of Energy in Southern Africa*. 18 (1), pp 29-38

5	To create "a unified, more team-driven design and construction process"		Create a partnering approach using workshops to involve all relevant designers, managers, contractors and owners.	• *Cooperation in achieving high performance goals while breaking down traditional adversarial roles.* • *Acceleration of progress, eliminate redundant efforts, engender commitment to decisions, reduce errors, and identify synergistic opportunities.*	Tormenta, L.M. (1999). *High Performance Building Guidelines*. New York City Department of Design and Construction: New York City
6	To create spaces which potentially have many alternative uses.		• Design spaces in such a manner that they may be used for different activities over different periods.	• More efficient built area use. • Lessening built area and energy requirements.	Tormenta, L.M. (1999). *High Performance Building Guidelines*. New York City Department of Design and Construction: New York City
7	To develop on brownfield sites where possible.	To what extent the development takes place on a brownfield site and remediates the area.	Develop on sites which have previously been developed or negatively impacted.	• Reduction in urban sprawl. • Remediation of damaged sites. • Additional cost implications of developing on marginal land.	Tormenta, L.M. (1999). *High Performance Building Guidelines*. New York City Department of Design and Construction: New York City
8	To develop on sites served by existing infrastructure.	Sites that are serviced by adequate existing engineering services, telecommunications and water.	Select appropriate sites.	• Lessened cost of developing new connections. • Less environmental impact of construction.	Tormenta, L.M. (1999). *High Performance Building Guidelines*. New York City Department of Design and Construction: New York City

9	To catalogue and protect valuable site features.		• *Inventory and analyze the regional and local ecological context, topographical features, the urban historical context and the natural and cultural attributes of the site.*	• *This will allow the design team to better understand and respond to site conditions, opportunities and constraints.* • Additional cost implications associated with specialist studies.	Tormenta, L.M. (1999). *High Performance Building Guidelines*. New York City Department of Design and Construction: New York City
10	To achieve a reduction in outdoor lighting requirements.	The reduction in energy requirements for lighting.	• *Use light coloured or reflective edges along driveways or walks.* • *Use high-efficiency lights in exterior contexts.* • *Use solar power for exterior lights, telephones, and fountain pumps whenever site conditions allow.*	A reduction in energy requirements for lighting	Tormenta, L.M. (1999). *High Performance Building Guidelines*. New York City Department of Design and Construction: New York City

11	To reduce maintenance, water and energy requirements associated with landscaping.	A reduction in maintenance, water and energy requirements.	• Reduce reliance on plant species that require frequent irrigation and maintenance. • Consider water efficient irrigation systems. • Emphasize plant diversity, plants that are native, and those which naturally grow together and are self-sustaining (i.e. reseed and spread without much maintenance).	• Reduced water requirements. • Reduced maintenance requirements. • Maintenance of natural species. • Cost savings	Tormenta, L.M. (1999). *High Performance Building Guidelines*. New York City Department of Design and Construction: New York City
12	To encourage alternative transport.	A reduction in the use of traditional cars for travelling.	*Offer support facilities for bicycling, mass transit, electric vehicles, carpooling, and other less-polluting means of transportation.*	• Additional cost to construct certain facilities. • Lessened cost due to less traditional road construction.	Tormenta, L.M. (1999). *High Performance Building Guidelines*. New York City Department of Design and Construction: New York City
13	To reduce heating and cooling requirements.		• *Specify glazing with low emissivity (low-e) coatings and high R-values to reduce solar heat gain/loss.* • *Shading strategies* • *Moderation of interior temperature extremes through the use of thermal mass.* • *Enhanced insulation* • *Light-coloured, reflective roof surfaces*	• Temperature moderation • Costs to install thermal efficiency measures. • Reduced heating and cooling costs. • Reduced electrical energy requirements.	Tormenta, L.M. (1999). *High Performance Building Guidelines*. New York City Department of Design and Construction: New York City

14	To reduce energy requirements and save cost.	*High performance new buildings shall annually consume a minimum of 30% less energy on a Btu-per-gross-square-foot basis in comparison to what would be consumed if the building were designed for minimum compliance with the NYS Energy Code. Operational cost comparisons should be prepared to ensure that the high performance building will save at least the same percentage in energy costs as it achieves in combined actual energy use reductions.*			Tormenta, L.M. (1999). *High Performance Building Guidelines*. New York City Department of Design and Construction: New York City
15	To determine the financial viability of energy efficiency measures.	*While the resources available to cover the first cost of energy efficiency measures will vary by project, a 'simple payback' of first costs by projecting savings in operating costs over a period of seven (7) years may serve as a rule of thumb when evaluating whether a given combination of energy efficiency measures are economically viable.*			Tormenta, L.M. (1999). *High Performance Building Guidelines*. New York City Department of Design and Construction: New York City

16	To reduce the content of virgin materials in use.		• Incorporate salvaged or refurbished materials whenever possible. • Consider construction assemblies that allow for disassembly of materials at the end of their useful life. • Conform to existing product consensus standards for resource efficient materials.	• Reduction in use of new materials. • Cost savings. • Material and cost recovery at the end of the service life of the structure.	Tormenta, L.M. (1999). *High Performance Building Guidelines*. New York City Department of Design and Construction: New York City
17	To minimise the use of domestic potable water.	A reduction in potable water use.	• Use water saving toilet options such as multi-flush, composting toilets or waterless urinals. • Use aerating fittings for taps and showers. • Collect rainwater for use in irrigation, toilet flushing and other appropriate uses.	• Potable water savings. • Positive or negative short and long term cost implications of alternative methods.	Tormenta, L.M. (1999). *High Performance Building Guidelines*. New York City Department of Design and Construction: New York City
18	To protect the site from excess damage during construction.		Develop and implement a site protection plan detailing; protection of vegetation, waterways and topsoil as well as stipulating an area for storage of construction materials and equipment.	• Protection of sensitive habitats.	Tormenta, L.M. (1999). *High Performance Building Guidelines*. New York City Department of Design and Construction: New York City

19	To reduce the volumes of municipal solid waste (MSW) which enters a landfill.	The percentage reduction in MSW which enters landfills.	Recycling of certain wastes	• The need to train MSW management personnel. • Costs	Troschinetz, A.M., Mihelcic, J.R. (2008). Sustainable recycling of municipal solid waste in developing countries. *Waste Management.* doi:10.1016/j.wasman.2008.04.016
20	To ensure that, "each human being has the opportunity to develop itself in freedom, within a well-balanced society and in harmony with its surroundings."	A sustainable society	Fulfilment of the following categories: • Personal Development • Clean Environment • Well-balanced Society • Sustainable Use of Resources • Sustainable World		Van de Kerk, G. and Manuel, A.R. (2008). A comprehensive index for a sustainable society: The SSI - The Sustainable Society Index. *Ecological Economics.* 66, pp 228 – 242.
21	To ensure, "the provision of adequate and reliable energy services at affordable costs, in a secure and environmentally benign manner, and in conformity with social and economic development needs."			*Eradicating poverty. improving human welfare and raising living standards.*	Vera, I and Langlois, L. (2007). Energy indicators for sustainable development. *Energy*. 32, pp 875–882.
22	To create social equity				Vera, I and Langlois, L. (2007). Energy indicators for sustainable development. *Energy*. 32, pp 875–882.
23			Establishing a code of best practice to guide a development.	Creating "a more integrated and flexible approach" to achieving a sustainable outcome.	Bixio, D., Thoeye, C., Wintgens, T., Ravazzini, A., Miska, V., Muston, M., Chikurel, H., Aharoni, A., Joksimovic, D. and Melin, T. (2008) Water reclamation and reuse: implementation and management issues. *Desalination.* 218, pp 13–23
24	To encourage non motorised transport and discourage private vehicle use.	The reduction in motorised private vehicle use and the increase in non-motorised and public transit use.	Locate the development such that a large proportion of the site is within walking distance of public transit stops.	• Reduction in private motorised transport use. • Reduced urban sprawl. • Reduced construction cost (roadways for private vehicles)	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]

25	To reduce material wastage due to construction of extensive bulk water and wastewater infrastructure.	A reduction in bulk water and wastewater infrastructure spending.	Locate the development such that there is no need to construct extensive water and wastewater infrastructure to service the site.	• Reduction in material use. • Reduction in construction costs. • Reduction in urban sprawl effects.	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
26	To reduce environmental degradation and sprawl.		• Develop on sites where the area has been previously damaged or the environment degraded. • Improve the environment on the redeveloped site through remediation measures.	• Reduced urban sprawl • Environmental improvement • Positive and negative cost implications.	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
27	To encourage non-motorised transport	Reduction in motorised transport use	• Provide a safe, adequate bicycling network. • Provide bicycle parking space.	Reduction in motorised transport use	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
28	To reduce routine distance travelled	Reduction in distance travelled	Create a diversity of uses, schools as well as job opportunities close to the development.	• Reduction in distance travelled, • Stimulation of local economies.	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
29	To create community interaction and connectedness		Ensure that no streets are gated.	A connected community and public space is created.	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
30	*Conserve land. Promote livability, transport efficiency, and walkability.*		Build residential and non-residential developments at a reasonably high density.	• Reduction in urban sprawl. • Reduction in engineering service costs. • Transport efficiency	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]

31	To promote residential diversity.	A diversity in the income and demographic profile of residents	Build a variety of housing types for various income levels as well as rental housing.	Increased community diversity and integration	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
32	To reduce built area and encourage non-motorised transport.	A reduction in parking area footprint	Reduce parking space allocation.	• Reduced built area. • Reduced construction cost. • Increase in non-motorised transport use	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
33	To encourage non-motorised transport	Reduction in motorised transport use	Provide a safe walking network.	Reduction in motorised transport use	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
34	To encourage multimodal transport.		• Create a street network with a high density and level of interconnectivity. • Provide pedestrian and walking lanes through cul-de-sacs.	• Increased use of non-motorised transport. • Reduction in urban sprawl	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
35	To encourage non-motorised transport	Reduction in motorised transport use	Provide adequate public transit facilities such as shelters, notice boards, security and secure parking.	• Increased use of non-motorised transport. • Additional cost	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
36	To encourage non-motorised transport	Reduction in motorised transport use	Create a transportation demand management program for the development with the aim of reducing motorised transport use and encouraging alternative transport modes.	• Increased use of non-motorised transport. • Additional cost of preparation and maintenance of the management plan	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]

37	To encourage community involvement.		Provide outdoor spaces in a variety of forms and accessible to a wide demographic near homes and places of work.	• Increased community involvement. • Increased physical activity	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
38	To encourage community involvement	Extent of community involvement in the design and planning of the development	Hold regular meetings (and implement design concerns) with the affected community and other interested and affected parties at the conceptual stage and throughout design and construction as well as post construction where necessary.	• Increased community involvement. • Increased community happiness.	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
39	To increase community and individual self reliance.	The extent to which food needs are met by on site crop production.	Designate space, provide training and support to community gardening initiatives.	• Increased self reliance. • Increased developer cost of training and ongoing support.	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
40	To prevent pollution	The extent to which construction pollution is lessened.	Create and implement a construction pollution management plan which identifies and monitors measures to reduce construction pollution.	• Reduced water use • Reduced dust pollution • Reduced soil degradation • Increased management cost	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
41	To reduce potable water use	A reduction in potable water use	Implement water saving techniques such as low flow fittings, multi-flush cisterns and water reuse systems.	• Potable water savings • Increased cost of fittings	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]

42	To reduce the energy requirement due to heating and cooling.	The reduction in energy use for heating and cooling	Orient buildings such that the long axis is along the east-west axis in order to maximise heat gain from the sun.	Reduced energy requirements	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
43	To reduce the energy used from non-renewable sources	The reduction in energy used from traditional supply lines.	Provide infrastructure on site to reduce the amount of energy required as well as to generate energy from renewable sources such as solar and wind.	• Reduced pollution • Increased capital and maintenance cost. • Increased energy security and reliability.	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
44	To reduce energy demand	The reduction in energy requirements of municipal infrastructure.	Use streetlights, water and wastewater infrastructure as well as other municipal infrastructure which reduces energy required in comparison to traditional methods.	• Reduced pollution • Increased capital cost	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
45	To reduce pollution and potable water use.	The reduction in wastewater flows.	Design processes such that wastewater is either reused where possible or treated with beneficial on-site treatment processes.	• Reduced wastewater to municipal sewers. • Reduced potable water use. • Increased cost	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
46	To reduce pollution and material wastage.	The reduction in material used for construction	Design infrastructure such that recycled material may be used in construction in place of virgin material.	• Reduced material use. • Reduced cost	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
47	To reduce pollution and material wastage.	The reduction in recyclable material wastage from construction.	Design construction processes such that recyclable and reusable material may be reused either on site or on other sites where appropriate.	• Reduced material use. • Reduced cost from transport of waste.	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]

48	To reduce waste from households.	The percentage of recyclable waste which is collected for recycling.	Implement systems such as household collection or convenient drop-off zones for recycling in order to allow residents to easily recycle or compost suitable materials.	• Reduced recyclable household waste. • Reduced municipal cost of waste transport.	U.S. Green Building Council. (2007). *LEED for Neighborhood Development Rating System.* United States of America: U.S. Green Building Council [Online]. Available: http://www.usgbc.org/ [2007, June 18]
49	To create community buy-in and increase end user satisfaction.		Create programmes to involve the affected communities and incorporate this input into design.	• Increased community satisfaction. • Increased cost	Building Research Establishment. (2006). BREEAM: Multi-residential Pre-Assessment Estimator. United Kingdom: Building Research Establishment [Online]. Available: http://www.breeam.org [2007, June 19]
50	To ensure the efficient long term operation of systems, structures and processes.		Create a guide which informs future users of the development as to the correct operation of the systems installed.	• Improved efficiency of systems. • Lower long term cost	Building Research Establishment. (2006). BREEAM: Multi-residential Pre-Assessment Estimator. United Kingdom: Building Research Establishment [Online]. Available: http://www.breeam.org [2007, June 19]
51	To reduce energy requirements for lighting.	The reduction in energy consumption for lighting purposes.	Design spaces such that natural light is allowed to enter.	Reduction in lighting energy requirements	Building Research Establishment. (2006). BREEAM: Multi-residential Pre-Assessment Estimator. United Kingdom: Building Research Establishment [Online]. Available: http://www.breeam.org [2007, June 19]
52	To reduce energy requirements for cooling.	The reduction in energy consumption for cooling purposes.	Design structures such that external windows are openable.	• Reduction in cooling energy requirements. • Improvement in internal air quality.	Building Research Establishment. (2006). BREEAM: Multi-residential Pre-Assessment Estimator. United Kingdom: Building Research Establishment [Online]. Available: http://www.breeam.org [2007, June 19]
53		The extent of provision of private outdoor space.	Design housing such that private or semi-private outdoor space is provided.	• Increased safety. • Increased outdoor activity.	Building Research Establishment. (2006). BREEAM: Multi-residential Pre-Assessment Estimator. United Kingdom: Building Research Establishment [Online]. Available: http://www.breeam.org [2007, June 19]

54	To reduce the use of personal motorised transport.	The extent of the reduction in personal motorised transport use.	Reduce the number of parking bays in the development.	• Reduced personal motorised transport use. • Decreased construction cost. • Increased development density. • Reduced impermeable surfaces.	Building Research Establishment. (2006). BREEAM: Multi-residential Pre-Assessment Estimator. United Kingdom: Building Research Establishment [Online]. Available: http://www.breeam.org [2007, June 19]
55	To encourage the use of non-motorised transport.		• Provide safe cycle lanes and bicycle storage areas. • Provide safe paths for walking. • Design lanes and paths such that important areas of the site are accessible.	• Increased commuter safety. • Increased non-motorised transport use. • Increased development space use.	Building Research Establishment. (2006). BREEAM: Multi-residential Pre-Assessment Estimator. United Kingdom: Building Research Establishment [Online]. Available: http://www.breeam.org [2007, June 19]
56	To reduce potable water use.	The reduction in potable water use.	• Design landscaping such that low flow irrigation systems are used. • Channel flows such that they enter green areas to allow irrigation by rainwater.	• Decreased potable water use. • Decreased irrigation costs.	Building Research Establishment. (2006). BREEAM: Multi-residential Pre-Assessment Estimator. United Kingdom: Building Research Establishment [Online]. Available: http://www.breeam.org [2007, June 19]
57	To reduce waste sent to municipal disposal sites.	The reduction in waste sent to municipal disposal sites.	• Design space where all households may collect recyclable waste, either individually or communally. • Create systems such that this waste may be collected for recycling.	• A reduction in waste sent to municipal disposal sites. • Increased cost of creating infrastructure. • Decreased development density.	Building Research Establishment. (2006). BREEAM: Multi-residential Pre-Assessment Estimator. United Kingdom: Building Research Establishment [Online]. Available: http://www.breeam.org [2007, June 19]

58	To preserve built cultural heritage.	The identification and protection of cultural heritage areas.	• Recognise cultural heritage sites through both academic analysis and survey of the local and new population of the proposed development area. • Incorporate the views on built cultural heritage into the design of the development.	• Increased social equity • Retention of cultural identity.	Tweed, C and Sutherland, M. (2007). Built cultural heritage and sustainable urban development. *Landscape and Urban Planning*. 83, pp 62–69
59	To encourage the transition to post-materialistic values.		• Create community • Increase social inclusion	• Increased overall sustainability • Increased happiness	Zidansek, A. (2007). Sustainable development and happiness in nations *Energy*. 32, pp 891–897
60	To create equity in access to resources.			• Equity in access to resources	Valentin, A and Spangenberg, J.H. (2000). *Environmental Impact Assessment Review*. 20, pp 381-392
61	To create societal tolerance and cohesion	• Number of participant meetings held	Create participatory democracy.	• An increase in societal tolerance and cohesion. • An increase in capacity and education among participants.	Valentin, A and Spangenberg, J.H. (2000). *Environmental Impact Assessment Review*. 20, pp 381-392
62				• Decreased spending on transport by low income residents.	Goebel, A. (2007). Sustainable urban development? Low-cost housing challenges in South Africa. *Habitat International*. 31, pp 291–302
63	To create security of tenure for poor residents.		Provide subsidised rental housing for poor residents who earn beyond the maximum amount for government sponsored low-cost housing.	• Increased security of tenure. • Decreased reliance on exploitative, informal rental arrangements	Goebel, A. (2007). Sustainable urban development? Low-cost housing challenges in South Africa. *Habitat International*. 31, pp 291–302

64	To allow for flexibility and greater user specification in housing		Design housing and plot arrangements to allow residents to create alterations as circumstances change.	• Increased livability of housing. • Increased housing retention time of the original owner.	Goebel, A. (2007). Sustainable urban development? Low-cost housing challenges in South Africa. *Habitat International*. 31, pp 291–302
65			Provide improved sanitation to the poor.	• Increased health of residents	Goebel, A. (2007). Sustainable urban development? Low-cost housing challenges in South Africa. *Habitat International*. 31, pp 291–302
66	To ensure sustainability of financing across successive projects.	The percentage cost recovery in low income housing.	Sensitively institute measures of cost recovery in low income housing projects.	• Maintenance of the cycle of spending and recovery in order to be able to create more housing in the future. • Improved developer/investor confidence.	Kamete, A.Y. (2000). The practice of cost recovery in urban low-income housing: a discourse with experiences from Zimbabwe. *Habitat International*. 24, pp 241-260
67			Evaluate both the ability and willingness to pay of beneficiaries in low income housing projects.	• Increased ease of cost recovery.	Kamete, A.Y. (2000). The practice of cost recovery in urban low-income housing: a discourse with experiences from Zimbabwe. *Habitat International*. 24, pp 241-260
68			Evaluate the fit between the repayment and cost recovery schedule and the socio-economic standing of the beneficiary and tailor the repayment schemes as such.	• Decreased defaulting on repayments. • Increased cost recovery.	Kamete, A.Y. (2000). The practice of cost recovery in urban low-income housing: a discourse with experiences from Zimbabwe. *Habitat International*. 24, pp 241-260

69	To allow local communities to provide their own services where possible and acceptable.		• Correspond with the local or intended population to determine whether they have the desire and capacity to assist in the delivery of certain services. • If possible, involve the community in design and construction of the infrastructure.	• Local job creation • Greater community satisfaction and buy-in with regards to services. • Reduced initial costs.	Choguill, C. L. (1996). Ten Steps to Sustainable Infrastructure. *Habitat International*. 20 (3), pp 389-404
70	To encourage residents to invest personally in their properties.		Secure formal tenure for informal, poor residents in particular so that they may invest in their properties without fear that they may be lost through evictions and relocations.	• Greater resident maintenance of property. • Greater community pride. • Greater social cohesion. • Reduced local authority maintenance costs.	Choguill, C. L. (1996). Ten Steps to Sustainable Infrastructure. *Habitat International*. 20 (3), pp 389-404
71	To reduce project capital costs.		Design infrastructure in collaboration with the community such an acceptable basic level may be provided and that it may be upgraded over time.	• Reduced initial costs. • Increased community buy-in. • Possibility of limited acceptance for lower infrastructural standards by the community.	Choguill, C. L. (1996). Ten Steps to Sustainable Infrastructure. *Habitat International*. 20 (3), pp 389-404

72	To create community ownership of infrastructural assets.	Community ownership of assets.	Allow communities who finance, construct and incrementally upgrade infrastructure to own the infrastructure with the possibility of sale to the local authority when appropriate quality standards have been met.	• Increased community wealth. • Increased community pride. • Increased community maintenance and upkeep of infrastructure. • Reduced local authority cost and responsibility.	Choguill, C. L. (1996). Ten Steps to Sustainable Infrastructure. *Habitat International*. 20 (3), pp 389-404
73	To reduce the energy requirement for heating and cooling.	The reduction in energy requirement for heating and cooling.	Upgrade insulation by *techniques of roof insulation, cavity fill, double-glazing, internal wall lining and exterior wall cladding.*	• Reduced heating and cooling energy requirements	Omer, A. M. (2007). Green energy saving mechanisms. *Renewable and Sustainable Energy Reviews.* doi:10.1016/j.rser.2007.01.003
74	To reduce the energy requirement for heating and cooling.	The reduction in energy requirement for heating and cooling.	• Design in such a way that natural ventilation may take place. • The ventilation must be controllable by the occupants.	• Reduced heating and cooling energy requirements. • Improved indoor air quality.	Omer, A. M. (2007). Green energy saving mechanisms. *Renewable and Sustainable Energy Reviews.* doi:10.1016/j.rser.2007.01.003
75	To replicate natural watercourses.	A reduction in negative impacts of urban water.	Implement Sustainable Urban Drainage Systems (SUDS).	• Reducing overall load on the conventional drains, holding back peak flows to prevent overloading, and removing diffuse source pollution to clean up discharges. • Creation of more natural environments in cities.	Jones, P. and Macdonald, N. (2007). Making space for unruly water: Sustainable drainage systems and the disciplining of surface runoff. *Geoforum.* 38, pp 534–544

76	To ensure that implemented systems continue to operate as designed.	The continued operation of systems as intended.	Implement maintenance programs to sustainable systems.	• Continued functioning of systems. • Reduced long-run cost. • Avoidance of problems associated with system malfunction.	Jones, P. and Macdonald, N. (2007). Making space for unruly water: Sustainable drainage systems and the disciplining of surface runoff. *Geoforum.* 38, pp 534–544
77	To create a labour market able to provide long term jobs.	A decrease in unemployment.	• Create jobs in construction and maintenance for local unemployed workers. • Implement skills training initiatives.	• A decrease in unemployment amongst unskilled and semi-skilled workers. • Reduced negative social effects of unemployment. • Increased economic stimulation of the region.	Klang, A., Vikman, P. and Brattebø, H. (2003). Sustainable management of demolition waste - an integrated model for the evaluation of environmental, economic and social aspects. *Resources, Conservation and Recycling.* 38, pp 317-334
78	To lessen per capita energy use.	To decrease in per capita energy use.	Increase housing density.	• A reduction in per capita energy use.	Shore, W.B. (2006). Land-use, transportation and sustainability. *Technology in Society*. 28, pp 27-43

Appendix B: Objectives from Literature Review

The revised list of objectives is presented below:

1. To recognise global effects at project level
2. To maintain the concentration of carbon in the atmosphere with no net increase.
3. To create "a unified, more team-driven design and construction process"
4. To create spaces which potentially have many alternative uses.
5. To develop on brownfield sites where possible.
6. To develop on sites served by existing infrastructure.
7. To protect valuable site features.
8. To reduce negative impacts associated with landscaping.
9. To encourage alternative transport.
10. To reduce household energy requirements.
11. To determine the financial viability of energy efficiency measures.
12. To reduce the content of virgin materials in use.
13. To minimise the use of domestic potable water.
14. To protect the site from excess damage during construction.
15. To reduce the volumes of municipal solid waste (MSW) which enters a landfill.
16. To ensure equal opportunities for development of all residents.
17. To ensure the provision of adequate and reliable energy services at affordable costs.
18. To create social equity
19. To encourage non motorised transport
20. To reduce material wastage due to construction of extensive bulk water and wastewater infrastructure.
21. To reduce environmental degradation.
22. To reduce urban sprawl.
23. To encourage non-motorised transport
24. To reduce routine distance travelled
25. To create community cohesion.
26. To conserve land.
27. To promote residential diversity.
28. To reduce built area.
29. To encourage multimodal transport.
30. To encourage community involvement.

31. To increase community and individual self reliance.
32. To prevent pollution
33. To reduce household potable water use
34. To reduce the energy used from non-renewable sources
35. To reduce energy demand
36. To reduce noise pollution.
37. To reduce water pollution.
38. To reduce air pollution.
39. To reduce soil pollution.
40. To reduce waste from households.
41. To create community buy-in.
42. To increase end user satisfaction.
43. To ensure the efficient long term operation of systems, structures and processes.
44. To reduce the use of personal motorised transport.
45. To encourage the use of non-motorised transport.
46. To reduce waste sent to municipal disposal sites.
47. To preserve built cultural heritage.
48. To encourage the transition to post-materialistic values.
49. To create equity in access to resources.
50. To create societal tolerance.
51. To create security of tenure for poor residents.
52. To allow for flexibility and greater user specification in housing
53. To ensure sustainability of financing across successive projects.
54. To allow local communities to provide their own services where possible and acceptable.
55. To encourage residents to invest personally in their properties.
56. To reduce project capital costs
57. To create community ownership of infrastructural assets.
58. To replicate natural watercourses.
59. To ensure that implemented systems continue to operate as designed.
60. To create a labour market able to provide long term jobs.

Appendix C: Preliminary Questionnaire

Dear Sir/Madam

I am a MSc. student in Civil Engineering at the University of Cape Town. My dissertation research concerns sustainable development in residential housing and mixed use housing developments. In particular I would like to develop a method of objectively determining the effectiveness of techniques aimed at creating a sustainable development. The setting is Cape Town, South Africa.

My reason for attempting this research is based on the limited usefulness of traditional points-based rating systems for sustainable development. These systems are not able to compare techniques based on the extent of change they create in the development. Thus my work will focus on making the extent of these effects central to the rating and comparison of techniques. The end application of this may be simply to compare techniques and decide which is more applicable, or to assist in the creation of more useful future rating systems.

I aim to complete my research using both literature review and survey processes and the procedure is therefore divided into several phases:

- An initial literature review of techniques related to sustainable development. A particular emphasis was placed on the objectives and effects of these techniques. From this review, a summary of the important objectives, and the effects which contribute to the objectives, was made.
- The second phase of research is divided into two stages. This survey forms the first of these and a stated preference questionnaire the second. The purpose of the stated preference questionnaire is to discover a consensus view on the relative importance of certain attributes used to indicate sustainability, and this first survey is the process by which these attributes are selected.
- The final stage in the process is a compilation of the survey results and the presentation of coefficients of significance for each of the attributes selected. These will then be tested in application case studies.

This survey

The nine most important objectives were determined through an examination of the literature review process. These objectives are assigned effects (also from literature) which may either positively or negatively affect them. Certain effects may apply to more than one objective. The performance measures of these effects were selected so that at least two options were available per objective.

The aim of this preliminary survey is to ascertain the best proxy (performance measure) for each of the nine most important objectives. I would therefore ask that you complete this survey by considering the performance measures and deciding what you consider being the best and second best performance measures for each objective.

The table containing the objective, effects and performance measures has been placed in the email body.

I hope that you may complete and reply to this email at your earliest convenience. I appreciate your assistance in my research and please do not hesitate to contact me should you require anything further.

Regards,

Courtney Dick

082 390 9589

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Objectives		Including effects……	Performance measures	Performance measures chosen	
				Best	**Second Best**
1	Time	• Time change in comparison to traditional techniques	1. Percentage change in time in comparison to the use of traditional non-sustainability oriented techniques. 2. Time required by residents using new techniques. 3. Maintenance and repair time required.		
2	Water	• Potable water savings. • Wastewater to municipal sewers.	1. Percentage change in potable water consumption in comparison to the use of traditional non-sustainability oriented techniques. 2. Wastewater volume in sewers 3. Water runoff 4. Percentage of development area comprising impermeable surfaces.		
3	Energy	• Electrical energy use. • Energy security and reliability. • Motorised transport use • Distance travelled. • Transport efficiency • Non-motorised transport use • Efficiency in built area use. • Urban sprawl. • Built area. • Development density.	1. Average change in electricity use per household. 2. Percentage of houses consistently using electricity. 3. Distance travelled using private motorised vehicles. 4. Distance travelled using public transport vehicles. 5. Distance travelled using private non-motorised vehicles. 6. Housing density of built area		

4	Social Integrity	• Unemployment amongst unskilled and semi-skilled workers. • Increased community wealth. • Community buy-in. • Social equity • Cultural identity. • Social inclusion • Community diversity and integration • Community involvement. • Community happiness. • Safety. • Societal tolerance and cohesion. • Reliance on exploitative, informal rental arrangements • Local job creation • Capacity and education among participants. • Security of tenure. • Livability of housing. • Connectedness of community and public space. • Poverty. • Human welfare and living standards. • Access to resources • Self reliance. • Outdoor activity.	1. Job-days created 2. Crimes committed 3. Length of home ownership 4. Availability of quality public space as a percentage of the developed area 5. Unemployment		

5	Financing	• Economic stimulation of the region. • Local authority cost and responsibility. • Defaulting on repayments. • Cost recovery. • Stimulation of local economies. • Cost implications. • Engineering service costs. • Spending on transport by low income residents.	1. Capital costs of development 2. Resident payment defaults. 3. Extent of governmental cost recovery. 4. Extent of local economic development. 5. Long run development cost. 6. Average income of residents 7. Percentage of income spent on transport by residents.		
6	Materials and Waste	• Waste sent to municipal disposal sites. • Recyclable household waste. • Use of new materials. • Material recovery at the end of the service life of the structure.	1. Amount of recyclable waste recovered before being landfilled. 2. Recycled material use in the development. 3. Alternative uses created for waste types. 4. Extent of material recovery at end of structural design period. 5. Extent of local material utilisation.		
7	Environmental Health	• Natural environments in cities. • Natural species. • Environmental impact of construction. • Impact on pollution • Soil degradation • Environmental change • Remediation of damaged sites. • Temperature moderation • Protection of sensitive habitats.	1. Retention of valuable natural environments and systems 2. Endemic species retention 3. Construction induced damage to environment 4. Conservation methods introduced 5. Environmental amenity provided to residents		
8	Human Health	• Health of residents	1. Work days lost due to illness. 2. Resident spending on healthcare.		

9	System Function	• Problems associated with system malfunction. • Community maintenance and upkeep of infrastructure. • Resident maintenance of property. • Maintenance requirements. • Cooperation in achieving high performance goals while breaking down traditional adversarial roles. • Housing retention time of the original owner. • Accidents and damage to property as a result of fire.	1. Longevity of social structures for neighbourhood management. 2. Maintenance of relationship between community and local authority. 3. Cost of maintenance required 4. Development of increasingly effective management processes 5. Local political stability		

Appendix D: Stated Preference (Choice) Questionnaire

Information for Respondents

- The total development area is 40 hectares
- An average household produces 30kg of solid waste per week
- An average household uses 775kWh of electricity per month
- The average working resident experiences 4 lost work days per year as a result of illness
- An average household uses 500 litres of potable water per day
- An average household spends 80 hours per week on household upkeep and maintenance
- The site consists of 10 hectares of environmentally important, conservation-worthy land

The context for this questionnaire is the comparison of alternative development proposals for a piece of land. This comparison is in terms of the sustainability of each alternative, described through the cumulative effect of its techniques and represented by eight measures. The developments consist mainly of homes of mixed type as well as incomes ranging from low-income government sponsored homes to upper-middle income homes. There is also the possibility of other structures such as light commercial or retail buildings. Heavy industrial applications are excluded from the development. For the purposes of this comparison it is not necessary to describe the exact deviations from standard development design used but rather the effects that these have collectively produced. It is sufficient to state that certain techniques are used in order to attempt to provide some measure of sustainability to the design. The effects of these techniques are represented in the outcomes of each alternative. Each alternative therefore has certain assigned effects and it is necessary to decide which alternative is preferable based on the accumulation of these.

The outcome of two alternative development designs incorporating sustainability techniques are described below.

Please indicate which alternative you prefer.

	Alternative 1	Alternative 2
Job Creation	35 long term jobs created	100 long term jobs created
Solid Waste Recycling	24kg per household per week sent to landfill	10kg per household per week sent to landfill
Electrical Energy Use	545kWh per household per month used	815kWh per household per month used
Personal Illness	2 sick days experienced per person per year	2 sick days experienced per person per year
Potable Water Use	250 litres per household per day used	250 litres per household per day used
Domestic Upkeep	84 hours per household per week upkeep required	95 hours per household per week upkeep required
Environmental Health	Zero hectares of valuable natural environments and systems retained on site	Zero hectares of valuable natural environments and systems retained on site
Annual Additional Maintenance	R 260	R 70

Pair	Choice
1	

The outcome of two alternative development designs incorporating sustainability techniques are described below.

Please indicate which alternative you prefer.

	Alternative 1
Job Creation	100 long term jobs created
Solid Waste Recycling	24kg per household per week sent to landfill
Electrical Energy Use	815kWh per household per month used
Personal Illness	2 sick days experienced per person per year
Potable Water Use	550 litres per household per day used
Domestic Upkeep	84 hours per household per week upkeep required
Environmental Health	7 hectares of valuable natural environments and systems retained on site
Annual Additional Maintenance	R 10

Pair	Choice
2	

	Alternative 2
Job Creation	100 long term jobs created
Solid Waste Recycling	10kg per household per week sent to landfill
Electrical Energy Use	815kWh per household per month used
Personal Illness	4 sick days experienced per person per year
Potable Water Use	550 litres per household per day used
Domestic Upkeep	95 hours per household per week upkeep required
Environmental Health	7 hectares of valuable natural environments and systems retained on site
Annual Additional Maintenance	R 180

The outcome of two alternative development designs incorporating sustainability techniques are described below.

Please indicate which alternative you prefer.

	Alternative 1		Alternative 2
Job Creation	35 long term jobs created		100 long term jobs created
Solid Waste Recycling	24kg per household per week sent to landfill		24kg per household per week sent to landfill
Electrical Energy Use	545kWh per household per month used		545kWh per household per month used
Personal Illness	4 sick days experienced per person per year		2 sick days experienced per person per year
Potable Water Use	550 litres per household per day used		250 litres per household per day used
Domestic Upkeep	84 hours per household per week upkeep required		95 hours per household per week upkeep required
Environmental Health	7 hectares of valuable natural environments and systems retained on site		7 hectares of valuable natural environments and systems retained on site
Annual Additional Maintenance	R 3,040		R 4,080

Pair	Choice
3	

The outcome of two alternative development designs incorporating sustainability techniques are described below.

Please indicate which alternative you prefer.

	Alternative 1	Alternative 2
Job Creation	35 long term jobs created	35 long term jobs created
Solid Waste Recycling	10kg per household per week sent to landfill	10kg per household per week sent to landfill
Electrical Energy Use	815kWh per household per month used	545kWh per household per month used
Personal Illness	2 sick days experienced per person per year	2 sick days experienced per person per year
Potable Water Use	250 litres per household per day used	550 litres per household per day used
Domestic Upkeep	84 hours per household per week upkeep required	95 hours per household per week upkeep required
Environmental Health	7 hectares of valuable natural environments and systems retained on site	7 hectares of valuable natural environments and systems retained on site
Annual Additional Maintenance	R 940	R 200

Pair	Choice
4	

The outcome of two alternative development designs incorporating sustainability techniques are described below.

Please indicate which alternative you prefer.

	Alternative 1	Alternative 2
Job Creation	35 long term jobs created	100 long term jobs created
Solid Waste Recycling	10kg per household per week sent to landfill	24kg per household per week sent to landfill
Electrical Energy Use	815kWh per household per month used	545kWh per household per month used
Personal Illness	4 sick days experienced per person per year	4 sick days experienced per person per year
Potable Water Use	550 litres per household per day used	550 litres per household per day used
Domestic Upkeep	84 hours per household per week upkeep required	95 hours per household per week upkeep required
Environmental Health	Zero hectares of valuable natural environments and systems retained on site	Zero hectares of valuable natural environments and systems retained on site
Annual Additional Maintenance	R 0	R 210

Pair	Choice
5	

The outcome of two alternative development designs incorporating sustainability techniques are described below.

Please indicate which alternative you prefer.

	Alternative 1	Alternative 2
Job Creation	100 long term jobs created	35 long term jobs created
Solid Waste Recycling	24kg per household per week sent to landfill	24kg per household per week sent to landfill
Electrical Energy Use	815kWh per household per month used	815kWh per household per month used
Personal Illness	4 sick days experienced per person per year	4 sick days experienced per person per year
Potable Water Use	250 litres per household per day used	250 litres per household per day used
Domestic Upkeep	84 hours per household per week upkeep required	95 hours per household per week upkeep required
Environmental Health	Zero hectares of valuable natural environments and systems retained on site	7 hectares of valuable natural environments and systems retained on site
Annual Additional Maintenance	R 1,080	R 60

Pair	Choice
6	

The outcome of two alternative development designs incorporating sustainability techniques are described below.

Please indicate which alternative you prefer.

	Alternative 1	Alternative 2
Job Creation	100 long term jobs created	35 long term jobs created
Solid Waste Recycling	10kg per household per week sent to landfill	24kg per household per week sent to landfill
Electrical Energy Use	545kWh per household per month used	815kWh per household per month used
Personal Illness	2 sick days experienced per person per year	2 sick days experienced per person per year
Potable Water Use	550 litres per household per day used	550 litres per household per day used
Domestic Upkeep	84 hours per household per week upkeep required	95 hours per household per week upkeep required
Environmental Health	Zero hectares of valuable natural environments and systems retained on site	Zero hectares of valuable natural environments and systems retained on site
Annual Additional Maintenance	R 3,180	R 40

Pair	Choice
7	

The outcome of two alternative development designs incorporating sustainability techniques are described below.

Please indicate which alternative you prefer.

	Alternative 1	Alternative 2
Job Creation	100 long term jobs created	35 long term jobs created
Solid Waste Recycling	10kg per household per week sent to landfill	10kg per household per week sent to landfill
Electrical Energy Use	545kWh per household per month used	545kWh per household per month used
Personal Illness	4 sick days experienced per person per year	4 sick days experienced per person per year
Potable Water Use	250 litres per household per day used	250 litres per household per day used
Domestic Upkeep	84 hours per household per week upkeep required	95 hours per household per week upkeep required
Environmental Health	7 hectares of valuable natural environments and systems retained on site	Zero hectares of valuable natural environments and systems retained on site
Annual Additional Maintenance	R 270	R 3,940

Pair	Choice
8	

Appendix E: Responses to the Choice Survey

The forty responses to the choice survey are represented below. The descriptors (Male/Female; Below 45/Above 45; Engineer, Non-Engineer) have been removed in order to protect the anonymity of the respondents.

Question Pack	Pair							
	1	2	3	4	5	6	7	8
1	1	1	2	1	1	2	1	1
2	2	2	2	2	2	1	2	1
3	2	1	2	2	1	2	2	1
4	2	2	2	1	2	2	1	1
5	2	1	1	2	2	2	2	1
6	2	1	2	1	2	1	1	1
7	2	1	2	1	2	1	1	1
8	1	1	2	2	2	1	2	1
9	2	1	2	2	2	2	2	1
10	2	1	2	2	2	2	1	1
11	2	1	1	2	2	2	1	1
12	1	2	2	2	2	2	1	1
13	1	2	2	2	2	2	1	1
14	1	1	2	2	1	1	1	1
15	2	1	2	2	2	1	1	1
16	2	1	1	1	1	1	2	1
17	2	1	1	1	2	1	1	1
18	2	2	2	2	1	2	2	1
19	2	2	2	1	1	2	1	1
20	2	1	2	2	2	1	1	1
21	2	2	2	2	2	2	1	1
22	1	2	2	1	2	2	1	1
23	2	1	2	2	1	2	1	1
24	2	1	2	2	2	1	1	1
25	2	1	2	1	2	2	2	1
26	2	2	2	1	2	2	1	1
27	2	1	2	2	2	1	1	1
28	2	2	2	1	2	2	1	1
29	2	1	2	1	2	2	1	1
30	2	1	2	1	1	1	1	1
31	2	1	2	2	2	1	1	1
32	2	1	2	2	2	1	1	1
33	2	1	1	1	1	1	2	1
34	2	1	2	2	2	1	1	1
35	2	1	1	2	2	2	2	1
36	1	1	2	2	2	2	2	1
37	2	1	2	2	2	2	1	1
38	2	2	2	2	2	2	1	1
39	2	1	2	2	2	2	1	1
40	2	1	2	2	2	2	1	1