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An Investigation into Sustainable Low Income Settlements in the Developing World: Lessons for South Africa

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A minor dissertation submitted in partial fulfilment of the requirements for the award of the degree of a Master of Philosophy in Development Studies

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COMPULSORY DECLARATION

This work has not been previously submitted in whole, or in part, for the award of any degree. It is my own work. Each significant contribution to, and quotation in, this dissertation from the work, or works, of other people has been attributed, and has been cited and referenced.

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 Date: 28/08/08

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Abstract

The aim of this study was to investigate cases of sustainable low income settlements from across the developing world in order to draw conclusions and recommendations for the South African context. Sustainable construction, which falls under the ambit of sustainable development, formed the theoretical basis of this study. In the developing world, where one of the most pressing issues is a dire housing shortage due to ever increasing urbanisation, and where the construction industry often impacts negatively on people and the natural environment, the need to make sustainable interventions in the built environment remains urgent for the survival of human beings. The developing world, despite its lack of resources, is in a prime position to base all its future development on the principles of sustainable construction. As South Africa deals with its own housing backlog and environmental degradation, this study drew from the lessons and experiences of existing sustainable low income housing projects in the developing world, as guidance for future housing projects in South Africa.

A case study approach was justified as an appropriate research strategy for this study. A number of cases were identified according to whether they fulfilled certain criteria. These were then screened down to nine cases as per a specific case study design. In line with previous research on sustainable case studies, the cases were analysed according to an evaluation framework of the seven principles of sustainable construction with 49 sustainability sub criteria. A separate framework was set out for each principle of sustainable construction and each case was tested against it.

The main conclusion to emerge out of this research was that there are indeed lessons to be learned from developing world housing projects for the South African Context. The evaluated cases indicated what is possible and the challenges that exist and provide valuable guidance for future South African housing projects. Many sustainability practices have successfully been implemented in the evaluated cases and include the reuse of old buildings, the creation of jobs, the use of solar power and the provision of settlements that are dense and well located. Certain barriers to the implementation of sustainable practices were also identified and include: low levels of user support and acceptability, high initial costs of certain sustainable measures, and the non provision of certain services so that communities are ill-equipped to live sustainably beyond the construction stage.

While the cases addressed varying areas of sustainability, their combined evaluation provided lessons for South Africa on how to address all components of sustainability. As an isolated example, however, the Lynedoch Eco Village (Case {3}) provides a particularly valuable example on how to achieve a sustainable settlement in that it fulfilled the most sustainability criteria (40/49) out of all the cases evaluated.

It is important to note that this dissertation reviewed the experiences of existing sustainable housing projects to draw guidance for future South African projects. Direct transfer of any concept can be dangerous and should be avoided unless based on careful study.

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List of Acronyms

ANC	African National Congress
BSRIA	Building Services Research and Information Association
CBD	Central Business District
DME	Department of Minerals and Energy
DOE	US Department of Energy
EA	Environmental Assessment
EIA	Environmental Impact Assessment
EMS	Environmental Management System
FENAVIP	Federacion Nacional de Vivienda Popular
GBC	Green Buildings Council
GBRC	Green Buildings Research Centre
GEAR	Growth, Employment and Redistribution
GNP	Gross National Product
GDP	Gross Domestic Product
JHC	Johannesburg Housing Company
KCIHT	Kutlwanong Civic Integrated Housing Trust
LDC	Lynedoch Development Company
RDP	Reconstruction and Development Programme
RSA	Republic of South Africa
TDP	Thlolego Development Programme
UNCHS	United Nations Centre for Human Settlements
USAID	United States Agency for International Development
WCED	World Commission on Environment and Development
WSSD	World Summit on Sustainable Development

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CHAPTER 1

Introduction

The purpose of this dissertation is to investigate good practice cases of sustainable construction in the quest to provide housing and shelter for low income communities in developing countries and formulate recommendations for sustainable low income housing projects in South Africa. This chapter introduces the main principles and concepts upon which this dissertation is based as well as the problem statement, hypothesis, research questions, objectives, methodology, limitations and the structure of the report.

1.1 The South African Housing Context

The *Bill of Rights* found in the South African Constitution (Act No. 108 of 1996) states that: “*Everyone has the right to have access to adequate housing.*” Yet South Africa has many years of housing delivery backlog inherited from the apartheid era. Estimates of almost 7 million historically disadvantaged South Africans still live in rural communities or informal settlements that lack basic shelter as well as other basic services (Lawson, 1991). Settlements are located far from job opportunities, shelter performance is substandard, layouts are monotonous and services are inadequate (Irurah, 2002). The Minister of Housing, Lindiwe Sisulu, said in a speech in 2006 that the Department of Housing needs to respond to the challenge of ever increasing urbanisation and homelessness (Sisulu, 2006). And that the Department’s marked increase in resources that are to be spent on housing for the next three financial years is indicative of the government’s commitment to dealing with the issue (Sisulu, 2007). According to the final draft of the *National Housing Code* (Department of Housing, 1999), the government’s goal is to increase housing delivery to a peak level of 350 000 units per annum until the housing backlog is overcome.

1.1.1 Background to Sustainable Development

By the middle of the twentieth century, people were beginning to question the capability of the earth to sustain the affluent lifestyle of the developed world (Hill *et al.*, 1997) and be concerned for the quality of development. Yet developing countries such as South Africa view large scale development as the key to addressing housing shortages and rapid urbanisation (du Plessis *et al.*, 2002). Development has thus come to be redefined as a process that must take place in a way that should not lead to the replication of the environmentally unsustainable economic systems that have evolved in the developed world (Swilling, 2005). The emergence of this notion of sustainability in the development sector can be traced back to the UN-sponsored 1972 Stockholm Conference, followed up with the Earth Summit in Rio in 1992, and the World Summit on Sustainable Development in Johannesburg in 2002. The central definition of sustainable development is ever evolving, but one which is widely used is from the Brundtland Report of 1987 and defines sustainable development as:

“Development that meets the needs of the present without compromising the ability of future generations to meet their own needs...As such it requires the promotion of values that encourage consumption standards that are within the bounds of the ecologically possible and to which all could reasonably aspire.” (WCED, 1987: 43)

It is generally agreed that sustainable development should address issues across all three of the so-called three "pillars" of sustainable development: people (social), prosperity (economic) and the planet (ecological protection). (du Plessis *et al.*, 2002)

In applying sustainable development to the South African context, (O' Riordan, 1997 cited in Hill *et al.*, 2002), proposes a "triple helix" of South African initiatives supporting sustainable development:

- ▶ *Economic growth and redistribution;*
- ▶ *Social reconstruction and political empowerment communities;*
- ▶ *Environmental policy and protection, including both ecological and cultural components.*

The South African government has committed itself to these principles of sustainability on a number of levels. The Constitution of the Republic of South Africa, 1996 (Act No. 108 of 1996), the Housing Act, (Act No. 107 of 1997), the Reconstruction and Development Programme (RDP (ANC, 1994)) and its successor Growth, Employment and Redistribution Strategy (GEAR (ANC, 1996)) all clearly state that the principles of sustainable development should be upheld.

South Africa must be one of the few countries in the world where every citizen has a constitutional right to sustainable development. The country's Bill of Rights in the Constitution (Act No. 108 of 1996) states in section 24: "*Everyone has the right... to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that prevent pollution and ecological degradation; promote conservation; and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development*".

The basic principles of sustainable development are indeed in place in the policies and regulations in South Africa and the country is shifting from the separate development of apartheid to a new order of sustainable development (Munslow *et al.*, 1995). The transition to sustainability in the built environment sector of the South African economy, however, has been slow (Anonymous, 2007). According to Hill *et al.* (2002) the built environment consists of the buildings in which human life plays out and the civil engineering infrastructure that links them. This includes housing for low income communities and the upgrading of informal settlements which is the focus of this dissertation. Hill *et al.* (2002) maintain that the reason for the slow transition can partly be attributed to the fact that it is not clear what is meant by sustainability in the upgrading of informal settlements, where financially vulnerable authorities often see sustainability as the ability of communities to pay for the services being delivered to them. The focus of the low income housing sector in South Africa has also been on the quantity of units produced at the expense of sustainable development (Hopkins, 1999 cited in Walker, 1999). The government, under pressure to deliver, is "*ensuring that affordable housing provision perpetuates unsustainable past patterns of low density peripheral sprawl and largely sterile monofunctional residential environments.*" (Hill *et al.* 2002:12)

If the South African government is truly committed to the principles of sustainability as per its policies and regulations, the construction of low income housing should firmly be rooted in all components of sustainable development.

1.1.2 Background to Sustainable Construction

“A ‘sustainable construction industry’ no longer means simply that the industry is able to continue its business and grow, but also that it supports the principles of sustainable development-which may mean that in some cases it needs to stop growing, or grow in different ways” (du Plessis et al., 2002: 4).

The environmental impact of the construction industry and its activities is enormous. It is responsible for a substantial amount of global resource use and waste emissions effecting both natural systems and quality of human life. In the developed world, the built environment generally constitutes over half of the national capital investment, accounts for up to half of all the raw materials taken out of the earth’s crust by weight, and consumes up to 50% of a country’s energy (du Plessis et al. , 2002). Irurah et al. (2003) indicate that the contribution of the low cost housing sector of the construction industry to these adverse impacts is a relatively minor but indeed still relevant.

The insufficient focus on sustainability in the built environment worldwide is being recognised by the construction industry and has lead to the rapid emergence of the concepts of sustainable construction and green building in recent years (Woolley et al., 1997). Both of these concepts fall under the ambit of sustainable development and for purposes of this dissertation are interchangeable. Hill et al. (1997) have presented four attributes of sustainability: social, economic, biophysical and technical, to advance the understanding of sustainable construction for providing and managing a sustainable built environment. These are the four “pillars” of sustainable construction, which use the three “pillars” of sustainable development, discussed above, as a foundation. By addressing the issues inherent in each of the “pillars”, it allows for the attainment of sustainable construction. In November 1994, the first International Conference on Sustainable Construction was held in Tampa, Florida, USA. The conference convener, Charles Kibert, proposed that sustainable construction is about: *“creating a healthy built environment using resource-efficient, ecologically based principles”* (Kibert, 1994b).

Building on the discussion document *Agenda 21* that was formulated at the Earth Summit in Rio de Janeiro as an international blueprint for sustainable development, *Agenda 21 on Sustainable Construction* was published in 1999 in recognition that the construction industry and its activities are responsible for a large amount of global resource use and waste emissions (du Plessis et al., 2002). The agenda sets out an international action plan for the implementation of sustainable construction and building on Kibert’s definition of sustainable construction, it proposes that:

“Sustainable construction is a holistic process aiming to restore and maintain harmony between the natural and built environments, while creating settlements that affirm human dignity and encourage economic equity” (du Plessis et al., 2002:8).

President Thabo Mbeki reaffirmed South Africa’s commitment to *Agenda 21* during the June 1997 special session of the United Nations General Assembly to review and appraise the implementation of Agenda 21 (Hill et al., 2002). In June 2007 the Green Buildings Council SA (GBC) was launched by the SA Property Owners’ Association as the first significant initiative by the building industry to commit to sustainable building practices (Anonymous, 2007a). Yet low income housing schemes have not taken up the opportunity to embrace sustainability. du Plessis et al. (2002:30) cite the South African

experience of low cost housing schemes as showing “*little improvement to the shack*” with “*poor thermal and structural performance, use of costly and highly processed materials and technologies, a short economic life span....inadequate community/owner participation*”. In June 1999, the then housing minister, Sankie Mthembu-Mahanyile, announced that 400 000 of the 600 000 low cost houses which had been built were substandard (Black, 1999).

The delivery of housing to the low income communities of South Africa should be based on all four of the “pillars” of sustainable construction. Any attempt to address South Africa’s housing backlog that disregards sustainability issues would be irresponsible development and counter to the country’s policies and legislation.

1.1.2.1 Sustainable Construction in Developing Countries

Developing countries’ problems of housing shortages, lack of infrastructure and rapid urbanisation are far more dire than that of the developed world, and their resources to deal with them are far fewer (du Plessis *et al.*, 2002). Their environmental concerns are both of affluence and over-consumption and of poverty and underdevelopment, and the capacity of local governments and the skill levels are often vastly different to those of the developed world (Hill *et al.*, 2002; du Plessis *et al.*, 2002). Creating a sustainable built environment in developing countries thus requires a different approach and a special *Agenda 21 for Sustainable Construction in Developing Countries* was therefore commissioned as part of the action plan for the implementation of *Agenda 21 on Sustainable Construction* and published as a contribution to the Johannesburg World Summit on Sustainable Development. The document provides an overview of sustainable construction, describes the developing world context within which the agenda is to be implemented, and provides a research and development agenda and strategy for action for sustainable construction in the developing world (du Plessis *et al.*, 2002).

The developing world, despite its diversity, shares similar developmental issues with the most critical of these being high rates of urbanisation and lack of adequate housing (du Plessis *et al.*, 2002). Lima, Peru for instance, experienced phenomenal growth in population: from 849 000 in 1940 to 6 459 000 in 1991, which has resulted in many slum settlements in and around the city (Dawson, 1992). *Agenda 21 on Sustainable Construction in Developing Countries* stresses the urgency of addressing these developmental issues by embracing the principles of sustainable construction to relieve the pressure on the resources in these countries thereby benefiting both humans and the natural environment (du Plessis *et al.*, 2002). According to du Plessis *et al.* (2002), however, sustainability in the construction industry in developing countries is still not commonplace with barriers such as a lack of capacity of the construction sector and a lack of interest in issues of sustainability hindering its implementation. But despite this, there are in fact examples of sustainability in the built environment in developing countries. In recognition of these cases, the Holcim Foundation offers annual awards to design projects that propose sustainable responses to the issues affecting building and construction; and the Habitat Awards is an initiative that identifies innovative and successful human settlement projects. Many past recipients of these awards have been from the developing world and it is such cases (i.e. good practice examples of sustainable construction in low income housing in the developing world) that are to be evaluated for the purposes of this dissertation. Their evaluation puts South Africa, along with the rest of

the developing world, in a unique position to avoid the unsustainable construction practices of the developed world by learning from the ways in which other developing countries are dealing with their similar issues. Benchmarking and assessing the various sustainable construction technologies and practices that are appropriate for developing country conditions, is vital for a better understanding of sustainable construction, the promotion of technology transfer between developing countries, the encouragement of these technologies into mainstream building practice, and to uphold the principles of sustainable development. This is especially relevant for the practices and technologies used in low income housing, as this sector of the built environment has been pursued as the most critical agenda for sustainable construction in the developing world (du Plessis *et al.*, 2002).

1.2 Problem Statement

The majority of low cost housing schemes promoted by the South African Government have to date not been designed according to principles of sustainability and this is likely to continue because there is a lack of research for generating a knowledge base about approaches and practices for more sustainable housing projects.

1.3 Research Questions

The research is to address the following questions:

- ▶ What is sustainable construction with particular reference to low income housing in the developing world?
- ▶ What are some good practice cases of sustainable construction in housing for low income communities in South Africa and other developing countries?
- ▶ How do these cases compare on issues of sustainability?
- ▶ What are the achievements, strengths and innovative aspects of the cases in terms of how they address the principles of sustainable construction?
- ▶ What lessons are to be learnt from these case studies in terms of the sustainable practices and technologies they used and their potential to deal with South Africa's housing backlog and environmental degradation?

1.4 Hypothesis

There are lessons to be learnt from developing world examples of sustainable low income housing schemes.

1.5 Aims and Objectives

The aim of this research study is to investigate developing world examples of sustainable housing to gain lessons for South African housing projects.

The objectives are to:

- ▶ Identify the basic principles of sustainable construction;
- ▶ Gain a better understanding of sustainable construction in South Africa and the developing world;
- ▶ Identify good practice cases of sustainable construction in the delivery and management of housing to low income communities in the developing world;
- ▶ Evaluate each case against a framework of specific criteria of sustainable construction;
- ▶ Assess the degree to which sustainable construction principles have been addressed by the cases; and
- ▶ Draw conclusions and recommendations from the evaluation of the case studies in terms of the practices and technologies used, and relating them to the South African context.

1.6 Methodology

The methodology to be adopted for this project will be divided into two areas of research:

- ▶ A literature review, and
- ▶ An assessment of case studies that represent good practice examples of sustainable construction in housing for low income communities in the developing world.

The *literature review* will entail a critical analysis of available national and international literature on sustainable construction for a deeper understanding of the term with specific relevance to South Africa. The review will also serve to identify sustainable housing examples from the developing world to be used as case studies and to formulate an evaluation framework to assess and compare each case study.

The assessment of the case studies will be carried out using an evaluation framework that will test whether principles of sustainability have been fulfilled. This assessment will then lead to recommendations being made on sustainable construction technologies and practices for low income housing in South Africa. The information needed for the evaluation will be acquired through informal interviews, site visits, construction drawings, project documentation and literature.

1.7 Limitations

The limitations of the research are as follows:

- ▶ Time and financial constraints may prevent site visits to some of the case studies, thus having an impact of the depth of understanding of the particular case study as well as the amount of literature consulted for the literature review.
- ▶ Due to the broad scope and ever evolving nature of sustainable development, an exploratory approach to the research will be adopted as opposed to a quantitative, rigorous form of research.
- ▶ The case studies in this dissertation will be chosen on the grounds of the information available and do not claim to represent the best examples of sustainable construction in the developing world. It will also be possible that information may be omitted due to the limitation of the available information.

1.8 Structure of the Dissertation

This dissertation will be structured as follows:

Chapter 1: Introduction, where the background to the research will be given by introducing the main principles and concepts upon which the dissertation is based as well as the problem statement, hypothesis, research questions, objectives, methodology and limitations.

Chapter 2: Sustainable construction, where the main principles of sustainable construction will be discussed for a deeper understanding of the concept with particular relevance to the South African context. This chapter will also discuss the impact of the construction industry on the environment in South Africa, as well as the state of affairs of sustainable construction in South Africa and the developing world.

Chapter 3: Methodology, where the method used to choose the case studies as well as the method used to evaluate them will be discussed.

Chapter 4: Results

Chapter 5: Discussion of the results

Chapter 6: Conclusions and recommendations

Appendices

NOTES:

- i. Developing countries are those countries outside of Europe with a per capita GNP of less than US \$7000 (World Bank, du Plessis *et al.* 2002)
- ii. For the purposes of this dissertation, the construction industry comprises the civil engineering and building construction industries.

CHAPTER 2

Sustainable Construction

The purpose of this chapter is to define and describe the theoretical framework upon which this dissertation is based, namely sustainable construction under the ambit of sustainable development. It will thus address the first research question posed in Chapter One:

- ▶ *What is sustainable construction with particular reference to low income housing in the developing world?*

2.1 Sustainable Development

Sustainable construction falls under the broader framework of sustainable development which is used as a basis for a better understanding of the concept of sustainable construction.

For the purposes of this dissertation, the most commonly used definition for sustainable development from the Brundtland Report as cited in Chapter One, will be used.

Most reviews of the field of sustainable development start with the UN-sponsored 1972 Stockholm Conference proceed through the Earth Summit in Rio de Janeiro in 1992, and end with the World Summit on Sustainable Development in Johannesburg in 2002 as is discussed below.

Irurah *et al.* (2003) view sustainable development as a convergence of two paradigms. The first being that of growth and development where until the late 1900s, there was a commitment to increase economic output as measured by Gross Domestic Product (GDP) for improved standard of living, while paying little attention to the environment. The second paradigm was that of the environmental movement which emerged in the 1950s out of concern for resource and environmental degradation arising from increases in population size, consumption and production. The Stockholm Conference in 1972 dealt with the challenge of reconciling the concerns of the two paradigms in the realisation that the two issues could no longer be addressed separately.

Hill *et al.* (1994) provide a thorough account of the evolution of the term sustainable development within the abovementioned environmental movement. The authors cite a document entitled "Limits to Growth" published by the Club of Rome in the same year as the Stockholm Conference as a strong substantiation of the argument that the earth's resources and environment could no longer sustain the world's population and economic growth (Meadows *et al.*, 1972). This new "limits-to-growth" perspective posed a challenge to the previous decade's "pro-growth" perspective and sparked intense global reaction (Hill *et al.*, 1994).

In 1987, the World Commission on Environment and Development (WCED) published "Our Common Future" (WCED, 1987) which is known as the "Brundtland Report" and has become a primary reference on sustainable development (Irurah *et al.*, 2003). The document stresses that for society to attain its

social and economic goals, it is vital to achieve environmental goals (Hill *et al.*, 1997). The definition of sustainable development used in the “Brundtland Report”, as quoted in Chapter One, is perhaps the most commonly used in the field. It is important to note that, in contrast to the “limits-to-growth” approach, the definition retains a developmental vision, on the condition that the environment and future generations are not compromised (Irurah *et al.*, 2003).

Much of this activity culminated in the United Nations Conference on Environment and Development (The Earth Summit) in Rio de Janeiro in 1992, where over a hundred and fifty national governments committed to specific targets and actions to protect the environment (Bhatti, 1994). *Agenda 21* was an important document to emerge from the Earth Summit which set out a framework to promote action by governments, non-governmental organisations and communities on key environmental and developmental issues (Bhatti, 1994). The preamble to Agenda 21 states that “*Human Beings are at the centre of concern for sustainable development*” (quoted in du Plessis *et al.*, 2002:5). du Plessis *et al.* (2002) therefore maintain that humans are the focus of sustainable development and sustainability is not a goal but a *process* of maintaining a “*dynamic balance between the demands of people for equity, prosperity and quality of life and what is ecologically possible*” (du Plessis *et al.*, 2002: 6).

The Johannesburg World Summit on Sustainable Development in 2002 was characterised by renewed intense debate and negotiation over sustainable development in developed nations versus sustainable development in developing countries (Irurah *et al.*, 2003). While for developed nations the challenge is to curb over-consumption and over-production, and to redistribute resources to the poorer sectors of their society; the challenge in developing countries is to avoid the unsustainable practices of the developed world and curb population growth while meeting the basic needs and improving the dire living conditions of the people (Irurah *et al.*, 2003).

The debate over the differentiated requirements of sustainable development and the fact that sustainable development is being adopted by more countries around the world, more disciplines and advocacy groups have contributed to the ever evolving nature of the interpretation of the term. According to Hardoy *et al.* (1992) there are at least 80 different definitions of sustainable development or part thereof. Hill *et al.* (1994a) state in addition that the concept of “sustainability” is so broad that it is impossible to capture all its nuances in a single definition. This is confirmed by Mawhinney (2002), who states that there is not sufficient clarity on the definition of the term to offer a simple starting point for theory and practice. Despite the contention over the interpretation of the term, however, there is a general consensus that unmanaged exploitation of natural resources is detrimental to humans in the long term (Hill *et al.*, 1994) and that human development, in order to make lasting progress, must take into account the reality of ecological constraints (Goldfinger *et al.*, 2008). In an increasingly resource constrained world, there has come a need to understand both human demand for ecological resources and the earth’s ability to meet this demand; where the “ecological footprint” is a resource accounting tool that makes this measurement possible (Goldfinger *et al.*, 2008). It is also generally agreed, as described by du Plessis *et al.* (2002), that there needs to be an equitable distribution of wealth in the form of resources and opportunities, as well as social and economic equity amongst individuals, communities and generations.

This line of reasoning has led to the so-called three “pillars” of sustainable development as cited in Chapter One (du Plessis *et al.*, 2002):

- ▶ Prosperity (economic development),
- ▶ People (social development), and
- ▶ The planet (environmental protection).

This concurs with O’Riordan’s “triple helix” of South African initiatives to embrace sustainability as described in Chapter One. These “pillars” of sustainability have indeed been entrenched in South Africa’s policies and legislation since the country’s emergence as a democratic state in 1994. South Africa has adopted many international protocols and frameworks on environmental conservation and sustainable development including Agenda 21 (Hill *et al.*, 1994a; Irurah *et al.*, 2003). Yet this has not been followed through in implementation in various sectors of the economy; and in the housing sector this is particularly significant as the delivery of low income housing has been one of the key programmes of the South African government since 1994 (Iruah *et al.*, 2003).

“We need to ensure that there is development to meet the basic needs of our people, but that development should be mindful of our fragile resources. So we must promote development that takes into account our reconstruction needs now as well as leaving our children and their children a share of our precious resources” (former South African President, Nelson Mandela, quoted in Whyte, 1995: ix).

2.2 Sustainable Construction

Having discussed the background to the term sustainable development, the purpose of this section is to discuss how sustainability relates to the built environment and thereby enhance the understanding of the term sustainable construction, also known as green construction/building.

When describing sustainable construction it is first necessary to distinguish literature on the topic from the broader ecological design literature. Van der Ryn *et al.* (1996) maintain that in many ways, environmental degradation has been a consequence of how products are designed; where they are often optimised with respect to cost or convenience while neglecting environmental considerations. Thinking ecologically about design and minimising environmentally destructive impacts by integrating with living processes is vital for the achievement of sustainable development and is known as *ecological design* (Cowan *et al.*, 1996). Luttrop *et al.* (2006) state that a major challenge for designers is to fulfil a need or to provide a benefit to the customer or user at the lowest environmental cost. The authors therefore provide “Ten Golden Rules” as generic advice for ecological design. Sustainable construction is a subset of ecological design and pertains specifically to the design of the built environment.

So in realising the extensive impacts of the design and construction of the built environment on the natural environment and at the same time being mindful of its important role in socio-economic development and quality of life, sustainable construction was proposed as a way of applying the principles of sustainable development to the construction industry (Hill *et al.*, 1997; du Plessis *et al.*,

2002). The First International Conference on Sustainable Construction was held in Tampa, Florida, United States of America in 1994. A major objective of the conference was to “*assess progress in the new discipline that might be called sustainable construction or green construction*” (Kibert, 1994a). In 1999, an internationally agreed upon *Agenda 21 on Sustainable Construction*, which builds on the international blueprint for sustainable development: Agenda 21, was published (du Plessis *et al.*, 2002). Its main objectives were to create a global framework that would contribute to other developmental agendas, and to provide a source document for research and developmental activities to do with sustainable construction. The document provided an overview of the concepts, issues and challenges of sustainable construction (du Plessis *et al.*, 2002). In recognising that the creation of a sustainable built environment would require a different approach to that of the developed world, a special *Agenda 21 for Sustainable Construction in Developing Countries* was commissioned as part of the action plan for the implementation of *Agenda 21 on Sustainable Construction* (du Plessis *et al.*, 2002). This document is discussed in greater detail in the final section of this chapter.

Sustainable construction is seen as a holistic process aimed at restoring the balance between the natural and built environments, and is applicable to the full range of construction activities from design, through construction, operation and maintenance and finally decommissioning or the deconstruction of buildings (Drager, 1996; du Plessis *et al.*, 2002).

According to the Building Services Research and Information Association (BSRIA) sustainable construction can be defined as:

“The creation and responsible management of a healthy built environment based on resource efficient and ecological principles” (Cited in Woolley *et al.*, 1997:5).

The BSRIA assert that these principles include (Woolley *et al.*, 1997):

- ▶ *Minimising non-renewable resource consumption,*
- ▶ *Enhancing the natural environment, and*
- ▶ *Eliminating or minimising the use of toxins.*

Kibert (1994b) embroiders on these three principles and offers the following principles of sustainable construction as being essential in order to protect the earth’s natural resources and create a harmonious natural and built environment:

Table 1: The Principles of Sustainable Construction (Kibert, 1994b)

i. Minimise resource consumption
ii. Maximise resource reuse
iii. Use renewable or recyclable resources
iv. Protect the natural environment
v. Create a healthy, non-toxic environment
vi. Pursue quality in creating the built environment

Hill *et al.* (1995) developed Kibert's six principles of sustainable construction further by adding a seventh principle: that of "promoting socio-economic sustainability". The authors argue that the principles of sustainable construction need to conform to the "pillars" of sustainable construction and therefore include the social and economic aspects as well. These six principles of sustainable construction as formalised by Kibert (1994) and the seventh as devised by Hill *et al.* (1995) are meant as a guideline to members of the construction industry in order to achieve more sustainable buildings and settlements (Drager, 1996). These seven principles are contextualised and discussed further in Appendix B.

The basic idea gleaned from the literature discussed above is that sustainable construction aims to achieve lasting environmental, social, and economic benefits through the construction of well designed buildings and settlements. Therefore sustainable construction is not simply about protecting the earth and its resources from over-exploitation or over-consumption; sustainable construction also considers the impact construction and its activities have on the occupants and users of the built environment. This ties in with the basic premise of sustainable development as mentioned above, that humans and their long term survival are at the centre.

As referred to in Chapter One, Hill *et al.*, (1997) propose four main criteria for the enhanced understanding of sustainable construction. These are based on the abovementioned three "pillars" of sustainable development (du Plessis *et al.*, 2002). Hill *et al.*, (1997) refer to these criteria as the four "pillars" of sustainable construction and they include social, economic, biophysical and technical sustainability; and a set of over-arching, process-oriented principles. Hill *et al.*, (1997) propose that the application of the four "pillars", using the process-oriented principles to decide on the emphasis to be given to each "pillar", would make the construction industry more sustainable.

Appendix A illustrates the four principles of sustainable construction as outlined by Hill *et al.*, (1997) while a summarised, adapted version is given in Table 2 below. The table is an amalgamation of literature from Hill *et al.*, (1997) and Sowman *et al.*, (1998) along with the author's own contribution. It outlines the principles most relevant to sustainable low income housing.

Table 2: The Principles of Sustainable Construction for Low Income Housing (after Hill *et al.*, 1997; Sowman *et al.*, 1998; author)

<p>Pillar 1: Social Sustainability</p> <p>Promote a sense of community and safety Promote and protect the physical and psychological well-being of inhabitants Promote skills training and capacity enhancement Promote self determination and cultural diversity Promote personal dignity</p>	<p>Pillar 2: Economic Sustainability</p> <p>Ensure affordability for beneficiaries (both capital and ongoing costs) Promote employment opportunities, asset and wealth creation Choose environmentally responsible suppliers and contractors Adopt policies and practices that advance sustainability</p>
<p>Pillar 3: Biophysical Sustainability</p> <p>Reduce the use of the generic construction resources (energy, water, land and materials) Minimise the use of non-renewable resources Maximise reuse and recycling Minimise all forms of pollution Create a healthy indoor and outdoor environment Minimise damage to sensitive landscape</p>	<p>Pillar 4: Technical Sustainability</p> <p>Construct durable, reliable and functional housing Pursue quality in the built environment Promote mix-use, pedestrian neighbourhoods Use appropriate technology for specific situations Continuous improvement and technological innovation</p>

du Plessis *et al.* (2002) asserts that for years, there has been a tendency in construction to give greater emphasis to technical sustainability, neglecting social and economic sustainability in particular. Dalglish *et al.* (1997), on the other hand, claim that in the low income housing sector in South Africa, social and economic sustainability have been given weight at the expense of technical and biophysical sustainability. A common thread, however, can be drawn from the literature: that for low income housing and, in fact any housing project to be sustainable, it must adhere to *all* of the above principles of sustainable construction. It is important nevertheless to be mindful that optimising each principle is not always feasible, and trade-offs and compromises may be necessary (Hill *et al.*, 1997).

South Africa needs to move away from its existing poor environmental and housing conditions in the informal settlements and address its housing backlog by considering all principles of sustainable construction. This will enhance the quality of people's lives by ensuring a healthy built environment in balance with the natural environment. The policies for this to occur are indeed in place: the 1997 Urban Development Framework of the Department of Housing for example, has sustainability as one of its goals and recognises the importance of considering environmental issues in planning (Department of Housing, 1997).

It is in implementation where the problem arises. Many past approaches to housing in South Africa have been concerned with political agendas such as the number of houses built and the improvement of economic indicators rather than quality and sustainability issues (Sowman *et al.*, 1998; du Plessis *et al.*, 2002). This is well illustrated by the following examples cited in Sowman *et al.* (1998):

- ▶ In Hornlee, Knysna in the Western Cape, many low cost houses were built on south-facing slopes. With less sunshine and more rainfall than north-facing slopes, houses are often damp and cold. There is a high incidence of tuberculosis in the area resulting in lost productivity and high health costs.
- ▶ In Delft in the Western Cape, concrete used in the construction of houses contained too much sand and was not mixed properly. Rain is able to enter the houses easily, resulting in damp walls and therefore disease, in addition to poor insulation.
- ▶ In Inanda in Kwazulu Natal pit toilets were built on the banks of a stream which get flooded and wastewater seeps into the stream. This has resulted in health risks and costly clean up.

Some of the major challenges to the implementation of sustainable construction in low income housing in South Africa are: a lack of capacity of the construction sector; a lack of consciousness and interest by the construction industry in the issue of sustainability; a lack of mechanisms and guidelines for translating policy principles into action; and a lack of data and information on achieving effective sustainable construction practices (Sowman *et al.*, 1998; du Plessis *et al.*, 2002).

Without underplaying these concerns, there are indeed examples of sustainable construction in the delivery of low income houses in South Africa and other developing countries. These are to be evaluated in this dissertation in an attempt to bridge the gap between South Africa's sustainability policies and their implementation and to challenge the perpetuation of unsustainable past approaches to the construction of low income houses.

In sum, the following definition for sustainable construction as cited in Chapter One is to be used for this dissertation:

“Sustainable construction is a holistic process aiming to restore and maintain harmony between the natural and built environments, and create settlements that affirm human dignity and encourage economic equity” (du Plessis et al., 2002: 8).

2.3 Sustainable Settlements

Having discussed the term sustainable construction in relation to sustainable development, the following section relates sustainable construction to a broader context of urban form and settlements as a whole.

Sustainable human settlements are those cities, villages and their communities that: *“enable us to live in a manner that supports the...principles of sustainable development and have the institutional, social and economic systems that will ensure their continued existence.” (du Plessis et al., 2002: 7)*

The phenomenon of ever increasing urbanisation, particularly in the developing world as discussed further in Chapter 2.5, has seen the emergence of literature on 'sustainable cities'. The literature stresses the scale of global urbanisation and its resultant problems, emphasising the urgency of ensuring that cities contribute to sustainable development. Lyman (2000) and Findlay (1996) provide ideas and discussion on the topic, while du Plessis (2001), Pieterse (2008) and Keiner *et al.* (2004) provide insight into sustainable cities in the developing world in particular. The latter authors point out that the developmental problems and worldviews of the developing world are distinctive and require a different approach to the west. du Plessis (2001), for instance, argues that the context of poverty and rapid urbanisation suggests that sustainable cities should be the focus of sustainable construction in Africa, but should be undertaken in a way that is relevant to the culture in Africa. Pieterse (2008) argues that current developing world policies do not deal with the causes of urban problems; and the author proposes an alternative political agenda to make cities more effective and sustainable. Keiner (2004) focuses on the sustainable urban development of medium-sized cities and through three developing world case studies proposes ways to create urban areas that contribute to sustainable development.

According to du Plessis *et al.* (2002), the interaction of the following four patterns determines whether a settlement is sustainable or not:

- ▶ *The physical structure*-how a settlement relates to the natural environment, and different parts of the city,
- ▶ *The utilisation patterns*-the way the settlement uses its resources,
- ▶ *The social patterns*-how people live, work and relate to their settlement and the opportunities the settlement provides to meet social needs, and
- ▶ *The operational patterns*-how the settlement functions and is managed.

Hill *et al.* (2002) cite South African settlements and cities in particular, as adhering to very few of the above patterns. The authors describe them as inefficient and spatially distorted; with low density urban sprawl, mono-functional areas and trapping the poor and newly-urban in large dysfunctional townships

on the outskirts of the city; therefore rendering them unsustainable. This sprawling, fragmented and separated land pattern results in inefficient, energy consuming and costly transport measures; expensive city administration; the exclusion of people from easy access to economic opportunities and facilities, and the destruction of valuable ecological and agricultural land. This pattern of South African cities is a legacy of the residential segregation of apartheid and other factors such as the adoption of inappropriate planning and urban design models, squatting, and incorrect assumptions about urbanisation trends. This is then perpetuated by political pressure for short-term delivery of housing and services and a crisis-driven search for land by local authorities to accommodate urban expansion (Dewar, 1991; Hill *et al.*, 2002).

Crane *et al.* (2008) present a case study of Cape Town as a South African city that concurs with the account of South African settlements given by Hill *et al.* (2002) above. Crane *et al.* (2008) draw on the most current data on energy, water, waste, transport, land, biodiversity and climate change to demonstrate the unsustainable use of resources in the city and that if ignored could undermine any further investments in growth and poverty eradication. The authors, however, present the case study in such a way as to demonstrate opportunities for innovation and suggest some system changes and initiatives to position Cape Town as a sustainable city.

In line with such literature on sustainable cities and in light of the global push for sustainability, it is a matter of urgency to make existing South African settlements more sustainable. By increasing the density of development, employing multi-functional and mixed-use environments, giving priority to public transport and non-motorised transport modes and including issues such as urban design and the provision of social infrastructure, as well as protecting and enhancing the natural environment, it would help to ensure more efficient and sustainable South African settlements. Crane *et al.* (2008:285) state that if South African cities seized the opportunity, they could access the large amount of funds available nationally and globally for this purpose and could become “*vibrant and thriving multicultural*” sustainable settlements where “*poverty could well be a thing of the past.*”

2.4 The Impact of the Construction Industry

“In the developed world, the built environment generally constitutes more than half of the total national capital investment, accounts for up to half of all the raw materials taken out of the earth’s crust by weight, and consumes between 40% and 50% of a country’s energy. The built environment consumes substantial financial and natural resources, and generates considerable waste streams.” (Hodgson, 2002: i)

According to Goldfinger *et al.* (2008:4), the Ecological Footprint “*measures people’s demand on the biosphere in terms of the area of biologically productive land and sea required to provide the resources people use and to absorb the waste they generate.*” Humanity’s Ecological Footprint first exceeded global biocapacity in the 1980s and this overshoot has been increasing ever since (Goldfinger *et al.*, 2008). This Ecological Footprint includes the biologically productive areas required to produce the resources needed for the construction industry. Within this context and in order to understand the thinking behind the principles of sustainable construction better, it is necessary to take cognisance of the contribution of the construction industry on humanity’s Ecological Footprint; in other words its impact

on people and the environment. In the discussion that follows, these impacts have been divided into environmental and socio-economic impacts. However, it is important to note that this distinction does not occur in reality. According to du Plessis *et al.* (2002), the industry's environmental impact is the most measurable, but its socio-economic impacts should not be negated. The discussion includes impacts of the construction industry over the entire construction process from construction to deconstruction, as well as the impacts of the manufacturing and extraction of the materials used in the industry.

a) *The environmental impacts of the construction industry*

The physical environment and the construction sector are linked by the demand construction places on natural resources; this is especially significant in the case of housing which is very resource-intensive (du Plessis *et al.*, 2002). The simplest point at which to begin evaluating the impact of the construction industry is to look at the inefficient use of the four of the generic resources used in construction: materials, energy, land, and water (Hill *et al.*, 1997) as well as the industry's contribution to pollution.

Materials most commonly used in construction are outlined in the table below. They are divided into renewable and non-renewable resources:

Table 3: Important Materials in the Building Industry (van den Akker *et al.*, 1979)

Non-renewable resources		Renewable Resources
Limited resources	Ample resources	
Steel Aluminium Copper Lead Zinc Fossil fuels: coal, oil, natural gas	Stone Sand Gravel, Chippings Lime, Gypsum Cement Bricks(clay) Sandstone Concrete Glass	Timber Flax Cotton Cane and Rushes Cork Rubber

Building materials vary in their impact on the environment but, of the materials listed, the biggest culprits and those that form the basis of modern construction, are concrete and steel (du Plessis *et al.*, 2002). Cement production has been identified as the biggest anthropogenic contributor to greenhouse gas emissions after the burning of fossil fuels (du Plessis *et al.*, 2002). Concrete lacks tensile strength, so where such forces are liable to occur, reinforcement is required. Steel, a non-renewable resource, is most often used for the purpose of reinforcement. Steel is also used for central heating installations and window and door frames and according to van den Akker *et al.* (1979) is the most widely used of all the metals in housing. Steel is one of the most energy-intensive materials and the production of iron and steel together account for 4.1% of global energy use (du Plessis *et al.*, 2002). As can be seen in Table 3, most building materials are derived from non-renewable resources. They are being used at an unsustainable rate and du Plessis *et al.* (2002) maintain that this unsustainable consumption rate is perpetuated by high wastage of materials both as waste and as a material unnecessarily incorporated into a building. This pattern of over-consumption of resources is thought to be the main cause of much environmental degradation (Kibert, 1994).

Energy is an essential element of all development projects from the manufacture of materials through to the project's operation. In South Africa, the fossil fuel coal is the predominant energy source in the manufacturing of construction materials as it is abundant and cheap to extract through open cast mining (van den Akker *et al.*, 1979). But as alluded to above, the production of construction materials depletes non-renewable energy sources at an unsustainable rate and emits greenhouse gases causing massive environmental pollution. According to Lewis (1991) the excessive carbon dioxide output from the burning of coal is widely believed to be contributing to the global subtle warming of the earth's climate. Since air pollution levels in South Africa are amongst the worst in the world, there is a great need to move towards non-polluting and sustainable energy sources (Sowman *et al.*, 1998). Much of South Africa's electricity is also generated by coal-burning power stations, and while access to electricity is seen as far more desirable than the use of other household energy sources such as paraffin, wood and candles which pose fire and health hazards, coal burning power stations remain a point of contention in terms of their sustainability and their impact on the environment (Sowman *et al.*, 1998) The electrification of homes of the urban poor, which is a key objective of the Reconstruction and Development Program (RDP) (ANC, 1994), places more demand on South Africa's electricity supplier, Eskom, which is currently experiencing a shortage of electricity capacity mainly due to incorrect forecasting on demand trends (Anonymous, 2008). This electricity shortage in South Africa renders an even more urgent need for alternative energy sources and energy conservation as South Africa "*faces serious economic problems unless there is an urgent and enormous push for renewable energy*" (Johns, 2008:4). Authorities and service providers need to take heed of the electricity shortage in the servicing and provision of low income housing where the use of off-grid electricity supplies, energy-efficient fixtures and appliances as well as design measures ensuring good insulation and ventilation, should be employed.

Land is another inefficiently used resource in the construction industry. The building materials industry is responsible for the filling up of landfill sites which not only consumes land that could otherwise be used for agriculture, housing or for its natural beauty or value (Hill *et al.*, 1995), but contributes to the degradation of ecosystems (du Plessis *et al.*, 2002). The extraction of materials needed for the construction industry through mining is also a major cause of pollution, land degradation and the disruption of natural terrain. Furthermore, deforestation can be attributed to the construction industry where buildings alone account for one quarter of the earth's wood harvest (Birkeland, 2002). The construction industry also has a huge impact on agricultural land through soil erosion and other forms of land degradation. Indeed, the annual loss of soil in South Africa is acknowledged to be extremely high: "*This may well be the greatest environmental problem facing South Africa*" (Verster, 1992; cited in Whyte, 1995: 43). South African cities are "*exploding outwards in a sprawling, amorphous, low density form*" (Dewar, 1991; 93) resulting in the loss of priceless agricultural land and natural resources (Dewar, 1991). Censuses between 1960 and 1981 revealed that within the Cape Town Metropole alone, 67 square kilometres of prime farmland were lost to urban development (Gasson, undated, cited in Dewar, 1991) which also caused damage to the invaluable Cape Flats aquifer and the destruction of coastline and mountain slopes (Dewar, 1991). Land is a costly commodity and forms the basis of many economic activities. It is important to use it efficiently.

Water is a natural resource used in the construction process during the manufacturing of materials, in construction, as well as during the operation of the building. Water is scarce in South Africa, with annual rainfall below the world average and overall demand predicted to exceed supply by 2020 (Whyte, 1995; Dewar, 1991). Yet despite the potential seriousness of the problem of water quantity, the resource is not efficiently used within the construction industry. According to Hill *et al.* (1997), standard household fixtures such as taps and shower heads allow for unnecessarily high volumes of water to flow through; where more efficient water saving fixtures such as low flow shower heads would ensure large water savings. The construction industry also impacts on water quality and according to Dewar, (1991) this is as a result of three construction processes in particular. The first is the manufacture of construction materials, where waste products are often dumped illegally into water courses. The second source is poor urban land management, and the third is the fact that little attention is paid to the reuse of water as a result of poor management of "grey water" effluent from households, storm water runoff and sewage disposal (Dewar, 1991).

Like any other industrial process the recovery and production of construction materials causes pollution by emitting pollutants into the air and watercourses. The production of iron, steel and non ferrous metals and the production of construction materials such as glass and bricks, for example, contribute 20% to annual dioxin and furan emissions (du Plessis *et al.*, 2002). While housing itself causes little pollution in comparison to the more sophisticated industrial processes, buildings do indeed emit pollutants via the materials and appliances used within them. According to Pearson (1998:63), toxins may be emitted from "*wood treatments, insulation, formaldehyde impregnated materials, paints and vinyl floor coverings*" used in households. Gas appliances used for cooking and heating produce, amongst others, large amounts of carbon monoxide and dioxide, while air conditioning and cooling systems contribute to the depletion of the ozone layer through the emission of chlorofluorocarbons (Pearson, 1998; Edwards, 1996). Insufficient ventilation, which has been cited by Sowman *et al.* (1998) as a common scenario in South African low income housing, only aggravates the health burden that these household pollutants pose. Noise, dust and odour pollution during the actual construction process, further contribute to the negative impact of construction on the environment (Hill *et al.*, 1997).

b) *The social and economic impacts of the construction industry*

Apart from the more mainstream school of thought of the impact of man's activities on the environment as discussed above, there are the lesser known impacts of man's activities on people themselves and the economy. The following section will discuss the socio-economic impacts of the construction industry.

The construction process itself, especially due to its labour-intensive nature, provides employment opportunities which have a profound influence over the quality of people's lives. du Plessis *et al.* (2002) maintain that the "employment intensity" of construction activities is much higher in developing countries in comparison to developed countries; which indicates that the construction industry can play a major role in improving the lives of the poor.

Buildings themselves directly affect people's safety and well-being. The structural integrity of buildings, appropriate design for the environment, and design in direct accordance with the types of activities occurring within them, determine whether a building will be safe for human occupation particularly in adverse conditions. du Plessis *et al.* (2002), for instance, cite the example that sub standard construction products were partially to blame for the high death toll in the earthquakes that occurred in recent years in Turkey and India.

The risk to personal health from buildings is a relatively recent concern. Baggs *et al.*, (1996) maintain that the building industry has caused many problems in the past which are only now emerging in some of today's health problems. These health problems are a result of what Pearson (1998) and Day (1990) refer to as "sick buildings" whereby synthetic materials, poor design, lack of ventilation, poor choice of site, fixtures and appliances in buildings affect the well-being of the occupants.

Synthetic building materials for instance are often fire hazards and give off pollutant vapours which are harmful to health. In many modern buildings these vapours are unable to escape due to the impermeable nature of the building materials; many modern tightly sealed, insulated buildings have radiation levels up to 25 times that of the external environment (Day, 1990). Pearson (1998) cites cases where people have complained of recurrent symptoms including headaches, fatigue, and nausea, all as a result of "sick building syndrome" where indoor air was found to contain a complex mix of pollutants including: radon, carbon monoxide, sulphur dioxide and particulates. Symptoms were also thought to derive from fluorescent lighting, a build up of positive ions and stale air (Pearson, 1998; Day, 1990). To avoid "sick building syndrome", buildings should be seen as a "third skin" that breathes, absorbs, evaporates, and regulates and at the same time offers protection, comfort and shelter (Pearson, 1998; Day, 1990). According to Baggs *et al.* (1996), this "third skin" should ideally be comprised of non-polluting, non-toxic, renewable and permeable natural materials.

The site and the position on the site, the natural systems and patterns also need to be considered in order to create a built environment that does not adversely affect humans. The site of a building may be affected by positive or negative ground energies and building over areas affected by negative energies such as geological faults, can affect health. (Pearson, 1998; Baggs *et al.*, 1996). These adverse health effects associated with living in such areas include disturbed sleep, cardiovascular disease and changes to the central nervous system, and is known as "geopathic stress" (Baggs *et al.*, 1996). The sound, smell and look of a site also have a profound impact on human health. Noise from passing traffic or trains, for instance, has considerable effects on our feelings, thoughts and well-being (Baggs *et al.*, 1996). The position on the site also affects human health and comfort: positioning a building in a valley, for instance, exposes occupants to trapped air pollution and colder night and early morning temperatures (Sowman *et al.*, 1998). In the Southern Hemisphere, areas that are north-facing are also warmer and more hospitable than those facing south (Sowman *et al.*, 1998).

The modern day convenience of electricity tends to overshadow the relatively new consideration of its potentially harmful effects on human health and well-being (Pearson, 1998). Electric devices used in buildings emit electromagnetic radiation distorting the natural magnetic field of the earth which in turn

upsets the electromagnetic balances of the body causing symptoms such as headaches, disturbed sleep and nausea (Hawkins, 1989 cited in Day, 1990). More serious effects typically take years to show and include metabolic malfunctions and allergies; moreover the link between close proximity to overhead electric cables and the incidence of leukaemia and cancer is gaining official recognition (Pearson, 1998; Day, 1990). Static electricity which is also caused by electric appliances in addition to synthetic materials not only increases stress levels and irritability but contributes to a range of under-oxygenated blood ailments such as depression and lethargy (Day, 1990).

As has been alluded to, buildings also affect the metaphysical or psychological health of humans, so *"apart from the obvious need to live in homes that are healthy for the body, there is the much older desire to dwell in a place that is healthy for the mind and spirit"* (Pearson, 1998; 45). Day (1990) speaks of how without consciously looking at them, we absorb our surroundings with all our senses; and as a result harsh, uncaring, insensitive and depersonalised buildings such as modern council flats only leave the emotional part of the human being feeling empty. Day (1990) proceeds with the fact that this emptiness often manifests itself in undesirable activities such as crime. Such unwelcoming structures are also not valued by their occupants and often fall into disrepair and are prone to vandalism (Kibert, 1994b; Hill *et al.*, 1995; Heron, 2003).

Sowman *et al.* (1998) observe that many South African examples of low income housing are merely sterile rows of freestanding "boxes" that do not create vibrant living environments or a "sense of place" as is illustrated in Figure 2 below. South African housing projects should instead strive to promote a sense of place, peacefulness and well-being.

"Every client, occupant, user, even those not yet born, is an individual, a human person, not a feelingless statistic to be packaged. They need their own places as houses for the soul, not as boxes for the body" (Day, 1990: 127).



Figure 1: Low income housing, Soweto, South Africa

Source: <http://www.livingneighborhoods.org/ht-0/santarosa.htm>

According to du Plessis *et al.* (2002), the construction industry also has the capacity to affect economic sustainability as the built environment constitutes more than half of the total national capital investment; in most countries across the world. The industry plays a vital role in the creation of small, medium and micro enterprises with a large portion of construction workers being employed by them, and the construction industry also supports small and informal contractors such as paint and tile manufacturers (du Plessis *et al.*, 2002; Hill *et al.*, 1997).

The negative environmental, social and economic impacts of the construction industry can all be mitigated through changes in the practices in the construction industry. Developing countries such as South Africa have the opportunity to base all future development including the provision of housing to low income communities on principles of sustainable development. The sustainable construction of low income homes will not only benefit the environment, but will have a positive effect on people's physical and mental and economic well-being too.

The following section considers the developing world context with regard to sustainable construction.

2.5 The Developing World Context

Developing countries, despite their diverse cultures, histories, economic conditions and climates, have certain developmental issues and conditions in common, du Plessis *et al.* (2002) cite that urbanisation and housing are two such issues which are particularly pertinent in developing countries. These issues have put the construction industry under the microscope as it is a key industry in the quest to deal with them.

Urbanisation is taking place in developing countries at an unprecedented rate; the urbanisation rate in the less developed Asian and African countries for example, is approximately 3.6% per annum, which amounts to 170 000 more people per day living in urban areas (Swilling, 2005). The majority of the world's megacities are in developing countries where there is not enough investment in infrastructure and planning to keep up with the high urbanisation rate (Giradet, 1996).

According to du Plessis *et al.* (2002), one of the most pressing infrastructure deficiencies in developing countries is housing. This has resulted in rapid growth of slums and unauthorised settlements, overcrowding, strained infrastructure and services as well as a neglect of the environment. This is echoed in the South African experience where there is a large housing backlog with a large sector of the population living in informal settlements, as well as the Brazilian experience as cited below:

The Brazilian experience

"The current state of Brazilian cities is due to the absence of public or private housing programmes capable of financing or promoting the production of housing and urban infrastructure on a large scale. Thus the housing deficit today is characterised as one of the biggest problems faced by the population and a major challenge to the construction industry. Poor distribution of income is the main cause of the housing deficit...Self-construction in peripheral areas or high-risk areas such as steep slopes or flood plains has seen the creation of the 'illegal' city. These clandestine shanty towns are still the main source of housing production in Brazil." (du Plessis *et al.*, 2002: 29)

In response to the developing world's unique and extreme problems and the realisation that their resources to deal with them are far fewer than developed countries, the discussion document *Agenda 21 for Sustainable Construction in Developing Countries* was published as a contribution to the Johannesburg World Summit on Sustainable Development in 2002 (du Plessis *et al.*, 2002). It represents both a sector response and a developing country response to the challenge of sustainable

development in the built environment and sets out a research and development agenda and a strategy for action for sustainable construction in the developing world. The document recognises that developing countries are largely still under construction rendering the urgent need to ensure that this construction takes place sustainably (du Plessis *et al.*, 2002).

Sustainability, however, is not yet receiving sufficient attention in the construction industry in the developing world. du Plessis *et al.* (2002) cite the reasons as being that governments and societies adopt a "crisis-driven" approach to dealing with the dire problems, with little regard for the long term impact of their actions on people and the environment; as well as a lack of capacity of the construction sector, low urban investment and a general lack of interest in the issue of sustainability. Although not commonplace, there are indeed examples of sustainable construction in the delivery and management of low income houses across the developing world. Irurah *et al.* (2002), for example, provide a comprehensive account of sustainable settlement initiatives in South Africa. The Habitat Awards is an initiative that identifies innovative and successful human settlement projects around the world. The recipients of the awards very often uphold the principles of sustainable construction (Habitat, 2008). The Holcim Foundation, as mentioned in Chapter One, offers awards to sustainable architecture, engineering, urban design, and settlement upgrading design projects; with many recipients of the award being developing world projects (Holcim, 2008). These housing projects provide an important foundation for others to follow and are therefore to be investigated in Chapter Four of this dissertation. Case studies will be selected from across continents ensuring a broad spectrum of sustainable construction practices and technologies from which to draw conclusions and recommendations for the South African housing situation.

2.6 Conclusion

Chapter Two has outlined the theoretical basis of this study namely sustainable construction, as an aspect of ecological design, under the ambit of sustainable development. It has included a review of literature on sustainable settlements and sustainable cities in particular taking into account that sustainable construction relates to a broader context of urban form and settlements as a whole. The chapter has also discussed the extensive impacts of the construction industry on people and the natural environment and therefore on humanity's ecological footprint providing a better understanding of the need for sustainable practices in the built environment. The chapter concludes by giving an overview of the developing world where one of the most pressing issues is a dire housing shortage due to ever increasing urbanisation. It is not commonplace to address this housing shortage using sustainable construction practices; and yet the need to make sustainable interventions in the built environment remains urgent for the survival of human beings. The developing world, despite its lack of resources, is in a prime position to base all its future development on the principles of sustainable development. So by drawing from existing developing world low income housing projects with a sustainability agenda, this dissertation will offer the lessons and experiences learnt from these as a foundation for future housing projects in South Africa, as the country deals with its own housing backlog and environmental degradation.

CHAPTER 3

Research Method

This chapter describes and justifies the research method employed in this dissertation for the investigation of developing world examples of low income housing.

The chapter is structured by first justifying a case study approach and then developing a case study design. The chapter proceeds by giving a review of previous research on sustainable case studies in order to demonstrate a method for the analysis of the case studies chosen for this dissertation and finally developing an evaluation framework design.

3.1 Justification of a Case Study Approach

According to Yin (1994) there are several ways of doing social science research. These include experiments, surveys, histories and case studies and each has advantages and disadvantages over others depending on three conditions:

- a) The type of research question,
- b) The control an investigator has over actual behavioural events, and
- c) The focus on contemporary as opposed to historical phenomena.

It is therefore necessary to discuss each condition as it relates to this research project as a means of justifying the particular research strategy to be employed. This dissertation is to investigate developing world examples of low income housing and has the following research questions as posed in Chapter One:

- ▶ *What are some good practice cases of sustainable construction in housing for low income communities in South Africa and other developing countries?*
- ▶ *How do these cases compare on issues of sustainability?*
- ▶ *What are the achievements, strengths and innovative aspects of the cases in terms of how they address the principles of sustainable construction?*
- ▶ *What lessons are to be learnt from these case studies in terms of the sustainable practices and technologies they used and their potential to deal with South Africa's housing backlog and environmental degradation?*

Three of the four research questions are "what" questions and are exploratory in nature which, according to Yin (1994), would warrant the use of most research strategies including exploratory surveys or exploratory case studies. The "how" question, however, is more explanatory in nature and, according to Yin (1994), likely to lead to the use of case studies, histories and experiments as preferred research strategies.

Considering the "how" question is an important aspect of this study; histories, case studies and experiments are three potential research strategies. In order to make a further distinction among the three, the conditions of the extent of the investigator's control over events and the degree of focus on contemporary, as opposed to historical events, need to be determined (Yin, 1994). In this research project in an investigation into sustainable low income housing, the investigator does not require control of behavioural events and is to play a passive role without imposing any influence on the case. The research project is also to examine contemporary events over historical events. According to Yin (1994), the preferred research strategy is therefore case studies. Yin (1994:72) defines case studies as "*studies of events within their real life context*" and, though it relies on many of the same techniques as a history, a case study has two additional important sources of evidence: direct observations and interviews. Kumar (1999) states that case studies provide the researcher with an opportunity for thorough analysis of specific details which other methods often overlook. A case study approach is therefore suitable for this dissertation as a thorough analysis is needed to identify specific sustainable achievements by developing world projects as recommendations for the South African context.

Having justified a case study approach as an appropriate research strategy for this dissertation, the following section develops a case study design.

3.2 A Case Study Design

Case studies for this research project will be identified through contacting relevant people and organisations in the sustainable construction field as well as consulting relevant sustainable construction literature. This method does not attempt to select a truly representative sample of case studies but is to provide an unrestricted approach to finding out what is out there as well as access to further references. This method of identification also offers a degree of "accidental" randomness, particularly as the initial contacts will not be chosen according to a rigorous process (Edwards, 2001).

Cases will be selected if they fulfil the following criteria:

- ▶ They encompass the provision of low income housing (Housing built for low income communities; those people that qualify for government subsidies. In South Africa, housing subsidies are granted to households with a joint income of less than R3500 per month (Dalglish *et al.*, 1997).)
- ▶ They are located in the developing world (GNP of less than US\$7000; du Plessis *et al.*, 2002); and
- ▶ They have an explicit sustainability agenda

Cases will be further screened according to the availability of information and the accessibility to architects, planners and other relevant professionals. Geographical location will also be considered in the screening process so as to ensure a broad spectrum of case studies from both rural and urban areas across the developing world.

The following section justifies and develops a method for the analysis of the case studies.

3.3 Case Study Analysis

As a means of formulating and justifying a method for the analysis of the chosen case studies, a critical review of previous research (1994 -2007) on sustainable case studies was undertaken.

Hill *et al.* (1994b) undertook a study on the practice of sustainable construction in South Africa which included an analysis of the environmental management applied during the construction phase of three case studies. The three case studies were analysed in terms of a framework for the attainment of sustainable construction (Hill *et al.*, 1994a). The framework consists of two parts: the application of Environmental Assessment (EA) during planning and design stages, and the implementation of Environmental Management Systems (EMS) during construction (Hill *et al.*, 1994b). The second part was the focus of the study where Hill *et al.* (1994a) developed four key requirements to be met in developing an EMS in the construction phase of a project. It was these requirements that were used as a checklist for each case study to determine the degree to which the projects satisfied the requirements of an EMS. This technique provided a systematic and logical means of evaluating the three case studies. The findings were, however, displayed in a paragraph format which did not allow for easy comparison of the case studies or for the easy identification of the requirements that each case study fulfilled.

Drager (1996) investigated the extent to which principles of sustainability had been fulfilled across the life-cycle of six selected buildings across South Africa, using an evaluation framework method. The framework was intended as a checklist of the theoretical principles of sustainable construction against which to test the practical achievements of the case studies; and therefore evaluate the state of sustainable construction in South Africa. The framework consisted of a matrix of rows and columns, where the rows indicated the case studies and the columns indicated the criteria for fulfilling each principle of sustainability. The reason for doing this was to emphasise that the *principles* were the main focus of evaluation and not the case studies. A separate framework was set out for each principle of sustainable construction and each case was tested against it. The information required for the framework was acquired through literature, drawings and informal interviews with relevant people for each case study. This method provided a thorough and rigorous evaluation of the case studies and allowed for easy identification of each case study's practical achievements. The matrices also allowed for easy comparison of the case studies.

Barret (2002) assessed the extent to which construction companies applied the principles of sustainable construction in building developments. The author chose two medium-sized construction companies as case studies and obtained the relevant information through a number of semi structured interviews with construction professionals in each company. The questions were formulated according to the research questions previously posed, and the interviewees' responses were then grouped and discussed under five headings: social, economic, technical and environmental sustainability, and barriers to the application of sustainable construction. Although the data was validated by conducting many interviews per case study, other sources of evidence would have increased the validity further. There did not seem to be a clear and logical link between the questions asked in the interviews and the discussion

under the five headings mentioned. This gave the impression that the questions were formulated randomly and without rigour and were not a true representation of the extent to which the principles of sustainable construction had been applied in the two companies. This highlights the fact that a thorough and logical evaluation method will not only ensure that nothing "falls between the cracks" but will provide a logical flow from the findings to later discussions and therefore ensure better readership.

Irurah *et al.* (2002) presented a selection of sustainable settlement case studies for the Department of Housing. The research was intended to illustrate outstanding initiatives in the field of sustainable housing and not necessarily to test the extent to which sustainability had been fulfilled or to compare the case studies on issues of sustainability. It was, therefore, not necessary to use a rigorous checklist as an evaluation framework; the case studies were instead evaluated using a broad framework of the four "pillars": economic, social, institutional and environmental sustainability. Positive aspects of each case study were identified by using the aforementioned four aspects of sustainability as a guide. While this method allowed for a descriptive depiction of South African sustainable housing initiatives, it did not allow for an in-depth investigation of the case studies or for their comparison.

Afodote *et al.* (2005) evaluated the best practices of green buildings in Cape Town in order to establish whether they met the requirements of green building design. Three case studies of buildings reputed to be best practices in green design were chosen. The research used both unstructured interviews and open questionnaires to gather data, and the questions were formulated and structured according to previously identified indicators in green buildings. The questions provided a systematic checklist of which requirements had been met by each case study, and these were then summarised into tabular form which allowed for easy identification of each green building's shortcomings as well as their comparison. The validity of the information gathered, however, is compromised by the fact that it was only obtained from one person per case study through a questionnaire and interview. Making use of other sources of evidence such as literature and other interviewees would have substantiated the data.

Canning (2005) investigated the extent to which sustainable construction had been implemented in the building construction industry in the Western Cape. The author selected and evaluated three case studies as part of the investigation. The case studies were evaluated using a framework of sustainability principles (resource minimisation, resource reuse maximisation, use of renewable resources, protection of the natural environment, creation of a non-toxic environment, quality in the built environment and socio-economic upliftment) and the findings were represented in eight tables: one table for each principle. The tables were then condensed into a one page summary of whether or not each case study met the sustainability criteria. Using sustainable construction principles as an evaluation framework provided a systematic and thorough means of testing the extent to which each case study had fulfilled the principles of sustainability. The way in which the author set out the tables, however, did not provide a clear distinction between the case studies, as each case study was not given a separate row but was evaluated erratically under one principle. As a result there was no logical flow to the summary table as this provided a clearer layout and allowed for the comparison of the case studies.

Lombard (2006) undertook an empirical study of green architecture in the Western Cape. Part of the research evaluated four houses all designed by a "green" architectural firm in the Western Cape. The evaluation was to establish whether or not the firm was meeting the criteria required for their buildings to be "green". The four case studies were evaluated according to five previously established sustainability criteria: socio-economic upliftment, resource consumption, resource maximisation, building quality and a healthy, holistic environment. Information was gathered through relevant documents and telephonic conversations and informal interviews with the owners and architects. The use of many sources of evidence helped to improve the validity of the data. The findings were represented in a similar fashion to Drager (1996) and were tabulated with a separate table per sustainable criterion; and criteria that had not been fulfilled were shaded. The five sustainability criteria provided a thorough and logical framework with which to evaluate the case studies and the tables provided a clear representation of the criteria fulfilled by each case study, which in turn assisted later discussion.

Chakwizira *et al.* (2007) examined sustainability and construction materials in affordable housing and infrastructure. Their research drew from two case studies and the study methodology included the examination of each case study against a set of key sustainability parameters through physical observations and field measurements. The two case studies and the parameters were set up in a matrix. The matrix allowed for easy comparison of the two case studies and one could easily identify the case study's achievements against each parameter. The fact that there were only two case studies, however, did compromise the research in terms of its uniqueness and validity.

3.3.1 Lessons Learned

All of the above reviewed researchers used an evaluation framework for the analysis of case studies. Each used a certain set of parameters as a checklist for each case study: to test each case study's performance against the checklist in order to highlight the case study's strengths and weaknesses and/or to compare the case studies or to give a descriptive depiction of the case study. Depending on the aim of the research, the evaluation frameworks were used to varying degrees of rigour; and depending on whether a broad description or specific details and comparisons were needed, the frameworks were displayed in paragraph or matrix format. The data for all of the reviewed research was collected through interviews, questionnaires, literature and drawings and the number of case studies evaluated varied from 2 to 4, except for Irurah *et al.* (2002) who evaluated 47 case studies. Many important learning points can be gleaned from the above reviewed research on sustainable case studies:

- ▶ The layout of the findings is important as this provides the foundation on which later discussions and conclusions are based; the flow between the findings and the discussion needs to be logical and clear. A table/matrix (provided each case study is evaluated separately i.e. given a separate row/column) allows for easy comparison of the case studies and allows for easy identification of the criteria it fulfilled. Shading of criteria fulfilled or not fulfilled provides a suitable method for ease of identification. A paragraph format is more suitable for more

descriptive depictions of case studies as opposed to their comparison or the highlighting of specific points.

- ▶ The more rigorous and thorough an evaluation framework, the more in-depth the analysis of the case studies with less information "falling through the cracks".
- ▶ Too few case studies compromise the research in terms of its uniqueness and validity.
- ▶ Too few sources of evidence compromise the validity of the data collected.

This dissertation is to compare case studies on issues of sustainability and to draw from the sustainable practices of the case studies as possible lessons for South African sustainable low income housing. It is therefore important to be able to compare the case studies easily on issues of sustainability. It is also important to identify the sustainable principles that each has fulfilled and what practices have been utilised for the fulfilment of the principle so as to draw recommendations for the South African context. So from the lessons learned from the review of previous research on sustainable case studies, a rigorous evaluation framework is deemed appropriate for the analysis of the case studies and the findings will be set up in a matrix where criteria fulfilled will be shaded. Sources of evidence for the evaluation of the case studies will include documentation such as construction drawings, archival records, web-based information, informal interviews and direct observation where possible. More than two case studies will be analysed for the sake of generalisability, validity and comparison, and to draw from as broad a range of sustainable practices and technologies from the developing world as possible; but will be limited to less than 10 due to time constraints.

3.4 Evaluation Framework Design

The seven principles of sustainable construction, as introduced in Chapter Two and discussed in greater detail in Appendix B, will be used as a framework for the evaluation method and will provide a structured set of parameters to test whether the criteria of sustainable construction have been achieved by each case study and therefore allow for their comparison on issues of sustainability. It is important to note that this method will not test the degree to which each criterion has been achieved, but rather whether it has been addressed at all. This is in line with the research conducted by Drager (1996), Afodole *et al.* (2005), Canning (2006) and Lombard (2006) reviewed above where the details of how well the criteria had been fulfilled, was not of primary concern, rather whether or not the criteria had been fulfilled. In the majority of the previous research reviewed, explicit attempts were made to avoid bias and subjectivity in the evaluation of the case studies. This will be the case in this study where the evaluation framework will be formulated so as to offer as objective an evaluation as possible. Certain parameters, however, such as whether a building is aesthetically pleasing cannot be excluded and will depend on the investigator's subjective opinion.

As mentioned, a rigorous evaluation framework will be used. A thorough framework will allow for an in-depth analysis of the case studies and will therefore assist in identifying specific sustainable practices and technologies that could perhaps be applied in the South African context, whereas a broader framework would instead give a more superficial overview of each case study.

For ease of analysis, the framework will consist of a matrix of rows and columns where the rows will indicate the case studies and the columns will indicate the criteria for each principle of sustainable construction. Following Drager (1996), a separate framework will be set up for each principle so as to allow for easy comparison of each case study according to a specific principle of sustainable construction. Any additional information that may be in excess of what is required in the matrix or of particular interest and in need of elaboration will be included subsequently. The following table is an example of a framework matrix; it illustrates the evaluation of two case studies against the criteria of Principle 2 of sustainable construction:

Table 4: Example of framework matrix

Principle 2	Maximise resource reuse					
CASE STUDIES	CRITERIA					TOTAL (5)
	Reuse materials			Reuse water	Reuse land	
	Design for disassembly	Reuse waste materials	Reuse of old building	Grey water systems	Use of "grey" land	
Inolego Development Project		New materials used	New houses built	Grey water used for agriculture	Land previously degraded and eroded	2
Johannesburg Housing Company		Reuse of materials	Reuse of derelict buildings	No	No	2

Each criterion achieved by a specific case study will be shaded and each case study's performance for a specific principle of sustainable construction will be given in terms of the number of criteria it fulfilled. Both these approaches will allow for the comparison of the case studies and to highlight its strengths. For example, both case studies in Table 4 fulfilled 2 criteria out of a possible 5 for Principle 2; but each addressed unique ways of maximising resource reuse. The full evaluation frameworks are found in Appendix D of this dissertation.

3.5 Conclusion

This chapter has provided a justification for the case study approach as an appropriate research strategy for this dissertation, as well as outlining a case study design. In line with previous research on sustainable case studies, the case studies in this dissertation will be analysed according to an evaluation framework of the seven principles of sustainable construction. This research strategy will be taken forward into the following chapters with the introduction of case studies and their subsequent analysis.

CHAPTER 4

Results

The purpose of this chapter is to introduce and provide an overview of the cases evaluated and present the results of their assessment against the framework of seven principles of sustainable construction. The following research questions as posed in Chapter One are addressed:

- ▶ *How do the case studies compare on issues of sustainability?*
- ▶ *What are the achievements, strengths and innovative aspects of the cases in terms of how they address the principles of sustainable construction?*

The cases were chosen according to the case study design outlined in Chapter Three. The task of finding relevant cases did not prove to be simple, as "sustainable housing" is a relatively new field in developing countries. Access to sufficient information, particularly for projects outside of South Africa, proved to be a further barrier; hence the larger number of South African cases. A full list of the initial cases, before the screening process, and further comments, are given in Appendix C.

The results of the evaluation are displayed in a matrix format in Appendix D with a separate matrix for each of the seven principles of sustainable construction, tested against all nine of the cases. These matrices are elaborated upon in this chapter to expand upon the short notes confined within them as well as to provide any additional comments that are not accommodated in the matrices. A summary of each case's performance is given in terms of the number of criteria it addresses per principle and out of a possible total of 49, as well as the number of principles it fulfils out of a possible 7. A principle is deemed fulfilled if more than half the respective criteria are addressed. Innovative aspects gleaned from the evaluations are also listed in the summaries.

The chapter concludes by providing an overall graphical summary of the cases for their easy comparison.

The geographical location of the cases is depicted in figure 3 and an introduction to the cases and their performance in the evaluation is given below:



Figure 3: Location of the Case Studies

4.1 Douglas Rooms (Johannesburg Housing Company)

4.1.1 Overview of Douglas Rooms

Address: Johannesburg inner city, Gauteng, South Africa.

Location: Urban.

Time period: Starting its activities in 1996 with one building, the Johannesburg Housing Company (JHC) now owns and manages 24 buildings and 3000 housing units. Douglas Rooms was bought in 1997 and the restoration process took two years. The conversion allowed the JHC to offer 65 single and double rooms for rental.

Description: The past two decades have seen many businesses move from the Johannesburg inner city to the northern suburbs, leaving many buildings unoccupied or squatted and falling into disrepair and used as centres for criminal activity. Douglas Rooms, in particular, was at the core of many social problems: squalid, overcrowded and a haven for drug lords. The Johannesburg Housing Company (JHC) was initiated as a response to this situation and has worked to preserve such well located and valuable buildings through their renovation and adaptive reuse. The JHC continuously forms partnerships and alliances with a variety of housing organisations, banks and overseas funding organisations and various spheres of government including the City of Johannesburg and the Johannesburg Development Agency. Funding has been made available by the European Union, the Flemish Regional government, the Provincial Housing Department and commercial bank loans. The Douglas Rooms project has delivered mixed-tenure, affordable rental housing and has sparked urban regeneration of the Johannesburg city centre. A focus has been on the sustainable construction principle of socio-economic development whereby employment opportunities are promoted, affordable houses provided, and community programmes and tenant committees are formed to promote social interaction and integration as well as to encourage tenants to participate in managing their houses and maintaining the standards in their buildings. The JHC was awarded a Habitat award in 2006. Although Douglas Rooms has mixed-income occupants, 50 percent are low income; and this case study is therefore still deemed to fall within the criteria of the case study design.

Source of information: Irurah *et al.* (2002), Habitat (2008), JHC (2008)



Figure 4: Douglas Rooms, Johannesburg, South Africa
Source: www.jhc.co.za

4.1.2 Results of the Evaluation of Douglas Rooms

Table 5: Performance of Douglas Rooms in evaluation procedure

PRINCIPLE	Total criteria	No. of criteria addressed	Principle fulfilled
1 (Conserve)	9	4	X
2 (Reuse)	5	1	X
3 (Renew)	5	0	X
4 (Protect)	8	2	X
5 (Healthy)	6	4	√
6 (Quality)	6	6	√
7 (Soc-ec)	8	7	√
Total	49	24	3

Case study's strengths:

- ▶ Principle 5: Create a healthy, non-toxic environment
- ▶ Principle 6: Quality in the built environment
- ▶ Principle 7: Social and economic upliftment

Innovative aspects:

- ▶ Good location (Principle 6). Douglas Rooms is located in the Johannesburg CBD, close to economic opportunities.
- ▶ Reuse of old building stock (Principle 2) Douglas Rooms demonstrates the extension of the economic lifespan of a building through the refurbishment and maintenance of a derelict and abandoned inner city building. This ensures that the manufacture and transportation of new construction materials is avoided. The improved building has led to the rejuvenation of the surrounding area.
- ▶ Tenant participation and capacity building (Principle 7) The JHC spent six months working with previous and new tenants to address issues such as new rental levels, limitations on the number of people per unit, and the banning of illegal activities. An ongoing culture of involvement in decision making in respect of management of housing and in community development activities is promoted and encouraged. Inter-building sporting activities involve many young people and many tenants are given the opportunity to go on training courses in childcare, HIV/AIDS, financial planning and home maintenance.
- ▶ A culture of prompt payment, cleanliness and order (Principle 7) This culture is insisted upon to ensure the continued quality of the building.

4.2 Cato Manor

4.2.1 Overview of Cato Manor

Address: Durban, Kwazulu Natal, South Africa.

Location: Urban (5km from the Durban CBD).

Time period: The development of Cato Manor was initiated in the early 1990s. There are currently approximately 25 000 households accommodating 150 000 people.

Description: The area lay empty for 20 years after the forced removal of people under the Group Areas Act of the 1950s and 1960s. The led up to South Africa's transition to democracy in the late 1980s and the early 1990s saw rapid informal settlement and the resultant environmental degradation and social problems. This prompted various Community Based Organisations, Non-governmental Organisations, the Local Authority and donor agencies to embark on an initiative called the Cato Manor Urban Renewal Project. The aim was to upgrade the area in recognition of its close proximity to the Durban Central Business District (CBD), and the need to afford poor people the opportunity to live closer to socio-economic opportunities to facilitate job creation and entrepreneurship. One of the top priorities became the pursuance of quality in the built environment. (Principle 6 of sustainable construction) and the provision of sustainable housing in a fully integrated neighbourhood offering other infrastructure and facilities such as roads, community transport, health centres, schools, shops, business centres and open spaces. Innovative spatial planning was employed making site layouts as efficient as possible and reducing site size to ensure higher density. The project received large amounts of funds from public, private and international funders including the Reconstruction and Development Programme (RDP) fund, the KwaZulu Natal Housing Development Board, Durban Metro Council, European Union, Development Bank of South Africa, and the United States Agency for International Development.

Source of information: Irurah *et al.* (2002), Cato Manor (2008), Pato (2008), Sustainable (2008)



Figure 5: Aerial view of Cato Manor: "A city within a city", Durban, South Africa
Source: www.crida.org.za

4.2.2 Results of the Evaluation of Cato Manor

Table 6: Performance of Cato Manor in evaluation procedure

PRINCIPLE	Total criteria	No. of criteria addressed	Principle fulfilled
1 (Conserve)	9	5	√
2 (Reuse)	5	0	X
3 (Renew)	5	0	X
4 (Protect)	8	4	√
5 (Healthy)	8	4	√
6 (Quality)	6	4	√
7 (Soc-ec)	8	6	√
Total	49	23	5

Case study's strengths:

- ▶ Principle 1: Minimise resource consumption
- ▶ Principle 4: Protect the natural environment
- ▶ Principle 5: Create a healthy, non-toxic environment
- ▶ Principle 6: Quality in the built environment
- ▶ Principle 7: Socio-economic upliftment

Innovative aspects:

- ▶ Good location (Principles 6/7): Cato Manor is located 4 km from the Durban CBD and 10km from several major employment centres and is easily accessible from both the N2 and N3 highways. Belair road which weaves through the area was recognised for its economic potential and was planned as an activity corridor and designed as a four-lane route to accommodate both flowing and "stop-start" traffic that will benefit the shops built along the route.
- ▶ High density (Principle 6) Cato Manor's dense layout attempts to compact the city and enables the opportunities available within and adjacent to the community to be shared by more people. The project has reached net residential densities of between 40 and 55 units per hectare (Irrah *et al.*, 2002). High densities are ensured by using a variety of housing typologies according to the different slopes of the site; these include detached incremental housing, semi-detached, attached, double storey maisonettes and three-to-four storey walk-up housing.



Figure 6: Double-storey housing type with buildings in close proximity to each other to achieve high density, Cato Manor

Source: www.sustainableneighbourhoods.com

- ▶ Integrated development and mixed usage (Principle 6) The project integrates a wide range of social facilities, economic opportunities and effective transportation systems over and above housing. Shops, schools, libraries, workshops, parks, sports facilities and clinics create a sense of community and make the environment workable. These are also provided in a cost-effective way by developing facilities in clusters or "multipurpose" centres that share facilities and are open to the surrounding communities. This approach conserves land, saves on building costs, maximises the use of facilities and provides the potential for more efficient long-term maintenance arrangements. A high intensity activity corridor also exists along Bellair and Booth roads in Cato Manor where there is a mixture of economic opportunities on the ground level and residential space above. Other economic opportunities include light industrial parks, informal trading areas, and an Arts and Crafts Centre.



Figure 7: Park and children's play area integrated into residential area, Cato Manor
Source: www.sustainableneighbourhoods.co.za

- ▶ Capacity building and job creation (Principle 7) There is an overall facilitation programme to promote Local Economic Development (LED), whereby the Cato Manor Development Association (CMDA) plays an active role in creating an enabling environment for economic projects and initiatives in order to create a sustainable entrepreneurial framework. One such initiative is the Entrepreneurial Support Centre and incubator programme that assists entrepreneurs with resources and advice. Skills training help people to become employable and start new businesses. Investment is attracted into the area and jobs created through the existence of business and light industrial parks, informal markets, and craft projects.

Key challenges and barriers:

- ▶ Cato Manor, despite being well funded, did not consider solar water heaters or dual flush toilets due to their high initial costs. The layout and design of the structures were also not conducive to the instalment of solar water heaters. This illustrates the importance of considering such aspects upfront. In general, energy, water and materials efficiency were not well addressed.

4.3 Lynedoch Eco Village

4.3.1 Overview of Lynedoch Eco Village

Address: Stellenbosch, Western Cape, South Africa.

Location: Peri-urban.

Time period: The village was founded in 1999. In 2005/2006 12 houses were built.

Description: Lynedoch is largely a farming area where a large number of impoverished people have no access to adequate housing and services such as education, affordable energy and employment. The Lynedoch Eco Village arose to address this need as well as to challenge South Africa's legacy of economic apartheid whereby the rich and poor have remained segregated, and this attempted to bring together farmers, farm workers, their families, professionals and people with an interest in living more sustainably. The village has become the first intentionally ecologically designed and socially mixed* community in South Africa. It is managed by the non-profit Lynedoch Development Company (LDC) where the board consists of local community leaders and professionals. The Sustainability Institute (a non-profit Trust based at the Lynedoch Eco Village), in collaboration with the University of Stellenbosch, identified and mobilised funding from the Development Bank of Southern Africa, local bankers, local authorities and the buyers of the properties. The village consists of a primary school, a pre-school, a multipurpose hall, commercial space, village green, organic agriculture and landscaped areas, and 42 residences of which the 15 earmarked for low income people will be the focus in this dissertation. The houses demonstrate issues inherent in the principles of minimising resource consumption, protecting the environment, and using renewable resources. These include: energy efficiency and renewable energy as well as water saving measures, innovative sanitation, and materials efficiency.

Source of information: Swilling (2006), Thomson-Smeddle (2008)



Figure 8: Low income residences, Lynedoch Eco Village, South Africa

Source: Author

*While the Lynedoch Eco Village is a socially mixed community which consists of both commercial and subsidised houses, the focus in this dissertation will be the low income/subsidised houses.

4.3.2 Results of the Evaluation of Lynedoch Eco Village

Table 7: Performance of Lynedoch Eco Village in evaluation procedure

PRINCIPLE	Total criteria	No. of criteria addressed	Principle fulfilled
1 (Conserve)	9	9	√
2 (Reuse)	5	1	X
3 (Renew)	5	4	√
4 (Protect)	8	6	√
5 (Healthy)	6	6	√
6 (Quality)	6	6	√
7 (Soc-ec)	8	8	√
Total	49	40	6

Case study's strengths:

- ▶ Principle 1: Minimise resource consumption
- ▶ Principle 3: Use renewable, recyclable and recycled resources
- ▶ Principle 4: Protect the natural environment
- ▶ Principle 5: Create a healthy, non-toxic environment
- ▶ Principle 6: Quality in the built environment
- ▶ Principle 7: Socio-economic upliftment

Innovative aspects:

- ▶ Water conservation (Principle 1) Lynedoch conserves water through a number of methods. There is a dual water supply where potable water is supplied from the municipal water line to each unit and recycled water is supplied to each household for toilet flushing and irrigation. All plumbing fittings are water saving and rainwater harvesting is optional for each household. Storm water runoff is minimised through the restriction of hard surfacing, thereby increasing percolation into the ground. Soil stabilisers are used so as to prevent erosion.
- ▶ Water and sanitation system (Principles 1/2/4) All grey and black water is treated on site. The effluent from households passes through septic tanks where the main solids are deposited and then goes on to a *vertically integrated constructed wetland* where the effluent is treated aerobically on top of the wetland and then anaerobically at the bottom as the effluent sinks through a filter. The treated effluent goes into a dam from where it gets pumped into storage tanks for transmission into the housing units for toilet flushing and irrigation. The effluent from other buildings in the village is channelled into a biolytic filter which effectively deals with solids aerobically so that the treated water retains primary nutrients for reuse as fertiliser. Both systems are appropriate to the environment, are odour-free and do not require the use of chemicals. By treating all the black and grey water on site, the Lynedoch Eco Village avoids the burden of capital costs for bulk sanitation and the operating costs for such a service.



Figure 9: Biolytic Tanks and the surface area of the *vertically constructed wetland*-Lynedoch Eco Village

Source: Dowling (2007)

It is worth noting that three buyers collaborated during the construction phase of the project to replace their septic tanks with a biogas digester. The digester, which is made of brick in a dome structure, collects grey and black water as well as organic kitchen waste. It captures methane gas at the top of the dome which is released back into houses as cooking gas.

LYNEDOCH VILLAGE BIOGAS DIGESTER

This biogas digester is capable of producing and storing 3.8m³ per day of methane rich biogas from the sewage and food waste from three households.

The biogas produced by this digester can be used as follows:

Application	3.8m ³ per day biogas equivalent
Lighting	Equal to 60 watt bulb for 22.8 hours
Cooking	5 meals a day for 20 people
Fuel (motor pump)	2.50kg of petrol
Start power	Able to run a 1kW power motor for 4.71 hours
Electricity	Able to generate 4.75 kilowatt hours of electricity

The digester also produces a nutrient rich odourless liquid with 85% of the pathogen removed. This effluent then undergoes further processing in a aerobic phase represented by a wetland and ponding pool to ensure 100% pathogen removal.

WHAT IS BIOGAS?
Biogas is a mixture of methane and carbon dioxide. It is produced by the action of bacteria on vegetable organic material in anaerobic conditions which is why the process is also known as "anaerobic digestion". The bacteria slowly digest the material (usually animal dung, kitchen wastes and crop residues) and produce methane and carbon dioxide.

Composition of biogas	
Component	Percentage
Methane	65%
Carbon dioxide	35%

...and lighting. It makes a meaningful contribution to the local ecological...

Figure 10: Biogas digester, information board, Lynedoch Eco Village

Source: Author

- ▶ Duplication of infrastructure (Principle 1) The grey water system and fire fighting water supply systems are combined.
- ▶ Mixed income settlement (Principle 7) The village accommodates people from a range of income, class and race brackets. This social mix is achieved through the provision of both commercially priced and subsidised plots, to ensure a socially mixed community and to guarantee that the low income bracket access adequate and affordable homes, the existing housing subsidy was used and enhanced. This made certain that sustainable measures such as insulation and solar water heaters that are not covered by the subsidy, could be provided. This "green financing" was obtained through public/private sector partnerships. These included a partnership with Nedbank, the Southern Africa Development Bank, private funders and

landowners. Private sector finance was also sought extensively, particularly through establishments that fund green developments.

- ▶ Pedestrian friendly environment (Principles 4/6/7) Traffic calming measures are in place, such as gravel wearing coarse surface internal roads and the restriction of cars to designated parking areas are in place.
- ▶ Recycling of refuse (Principles 3/4) The municipal refuse is managed by the Lynedoch Home Owners Association (LHOA) and all residents are required to separate their refuse into containers which is then further separated at a depot. The LHOA is responsible for collection of the waste and for selling it to recyclers. There is also a composting depot where organic waste is collected for use in community gardens.



Figure 11: Lynedoch Eco Village: low income residence with solar water heater



Figure 12: Sustainable, natural materials; Lynedoch Eco Village

Source: Author

4.4 Kutlwanong Eco Houses

4.4.1 Overview of Kutlwanong Eco Houses

Address: Kimberley, Northern Cape, South Africa.

Location: Peri-urban.

Time period: Established in 1994 to accommodate the overflow from other nearby settlements. By 2000 over 200 energy-efficient housing units had been developed.

Description: Kutlwanong, located fifteen minutes' drive from the Kimberley city centre, was previously an informal settlement characterised by shacks, pollution, unemployment, and a lack of social amenities. In 1995, a co-operation agreement was established between the governments of South Africa and the United States of America. The Kutlwanong Eco Housing Project was one of the beneficiaries of this agreement in order to address the social and environmental problems of the area. The project involved various stakeholders: PEER Africa (a civil engineering firm with an interest in energy-efficient housing), the United States Agency for International Development (USAID), the US Department of Energy (DOE), the Kutlwanong community, the South African Department of Minerals and Energy (DME), and the Northern Cape provincial government's Department of Housing. The project aimed to provide both housing and training of the community to equip them with the skills to manage the project in the long term. An emphasis of the project was also on energy efficiency in the houses, cost optimisation to ensure affordability, job creation, alternative finance and entrepreneurship support.

Source of information: Eland *et al.* (2000), Iruran *et al.* (2002), Sustainable (2008)



Figure 13: Kutlwanong Eco Houses, Kimberley, South Africa

Source: Eland *et al.* (2000)

4.4.2 Results of the Evaluation of Kutlwanong Eco Houses

Table 8: Performance of Kutlwanong in Evaluation Procedure

PRINCIPLE	Total criteria	No. of criteria addressed	Principle fulfilled
1 (Conserve)	9	4	X
2 (Reuse)	5	0	X
3 (Renew)	5	1	X
4 (Protect)	8	0	X
5 (Healthy)	6	4	√
6 (Quality)	6	3	√
7 (Soc-ec)	8	6	√
Total	49	18	3

Case study's strengths:

- ▶ Principle 5: Create a healthy, non-toxic built environment
- ▶ Principle 6: Pursue quality in the built environment
- ▶ Principle 7: Social and economic upliftment;

Innovative aspects:

- ▶ Energy-saving measures (Principle 1) Kimberley regularly experiences very low night time temperatures in winter. Passive thermal regulatory measures to retain warmth in winter were implemented in two housing types through insulation and thermal storage:
 - The first type has an insulated ceiling and a cavity wall with insulation between two brick skins. This, along with a concrete floor, store heat during the day for release during the night.
 - The second type has an insulated ceiling and a steel frame with wall insulation between an internal gypsum board and an external brick layer. Both housing types display north-orientation and roof overhangs as passive thermal design measures. Insulated ceilings also ensure that no energy is lost through the roofs.



Figure 14: Large windows and overhang on the north elevation, Kutlwanong Eco Houses
Source: www.sustainableneighbourhoods.co.za

- ▶ Renewable energy (Principle 3) *Solar cookers* are promoted and available for sale. According to Sowman *et al.* (1998), *solar cookers* concentrate the sun's energy to cook food and work on "greenhouse effect" principles: it can keep food warm for a long period of time and it has no fuel costs and there is no risk of fires or burns.

- ▶ Monitoring (Principle 5) There is a post-occupation monitoring and evaluation programme to monitor thermal comfort, indoor air quality and electricity consumption. Socio-economic aspects are also monitored and these include the use of combustible fuels, levels of acceptance, skills development and job creation and external impacts of the Kutlwanong project.
- ▶ Capacity building and job creation (Principle 7) Kutlwanong Civic Integrated Housing Trust (KCIHT), the housing support centre in Kutlwanong, has been developed to help other South African communities to employ the techniques used in Kutlwanong. The project also creates jobs and enhances skills in the community. A skilled builder is identified from within the community at the start of the construction process and is then responsible for the training of a team of ten apprentices of which two are required to be female. The teams are taught general construction skills and passive thermal design measures. After every ten houses, the leader passes on the reigns and moves on to train a new team.
- ▶ Innovative finance (Principle 7): The KCIHT drew on a partnership with a United States-based environmental agency PEER Africa; together with provincial government, Kimberley Municipality, USAID and other beneficiaries. This partnership allowed for the project to harness a “green-finance” programme for energy efficiency in housing. Such programmes supply the funding to cover any of the additional capital costs needed to save energy. PEER Africa assisted KCIHT to access funding from USAID as well as green finance from global climate change funds of the International Finance Corporation.

Key challenges and barriers:

- ▶ The project has successfully addressed a number of challenges that faced the community and the environment. No social amenities, however, such as schools and clinics were provided. Due to a lack of planning, no money was set aside for such amenities which means the community goes without access to such services. This highlights the notion that forward planning ought to involve the provision of facilities and services over and above houses. This would ensure vibrant and convenient human settlements.
- ▶ Opportunities for water management and sanitation were not fully explored in the projects. This was not a deliberate omission but rather due to financial constraints. Solar water heaters were also not considered for their high capital costs.
- ▶ The project also lacks a strategy to optimise the density of the settlement and the land use despite its good location.

4.5 Thlolego Development Project (TDP)

4.5.1 Overview of the Thlolego Development Project

Address: The Thlolego Eco Village is situated on 150ha of land, 16km west of Rustenburg in North West Province, South Africa.

Location: Rural.

Time period: The TDP was established in 1991 as an attempt to save a farm school from closure. The founders bought the 150 hectare farm, kept the school open and in 1994, the founder residents began their practical training in sustainable building technologies and built a series of experimental buildings over the next two years. During 1996, two prototype houses were constructed and in 1998, prototype three was built.

Description: The TDP was established to address the challenge of rural poverty in South Africa's North West Province in a sustainable manner. The Tswana word "thlolego" means "creation from natural origins" and sums up the holistic approach of this development project (Irurah *et al.*, 2002). The houses are owner-built and low-cost and to date three prototype houses have been built. They address the principle of resource minimisation through the use of low embodied energy, locally sourced mudbricks, as well as the employment of passive thermal design and rainwater collection. Grey water systems and solar water heaters are also utilised. The settlement includes permaculture food security gardens which establish a valuable source of healthy food and increase the size of the homestead's living areas, and on-site waste management through the use of a composting toilet is also employed. The sustainable principle of socio-economic development is a large priority for the TDP where the local community is trained in sustainable building techniques and the Eco Village is promoted as an ecotourism destination. The TDP director was awarded an Ashoka International Fellowship in recognition of the innovative nature of the TDP and its potential to become a model of sustainable development. The project therefore enjoys financial support from the Fellowship. Thlolego has received wide media coverage and is endorsed by the government, private sector and community organisations for its pioneering work in housing rural low income communities.

Source of information: TDP (2008)



Figure 15: Thlolego Development Project: Prototype 1 house

Source: <http://www.sustainable-futures.com/images/housing/F&KNew.jpg>

4.5.2 Results of the Evaluation of the Thlolego Development Project

Table 9: Performance of Thlolego Development Project in evaluation procedure

PRINCIPLE	Total criteria	No. of criteria addressed	Principle fulfilled
1 (Conserve)	9	6	√
2 (Reuse)	5	2	X
3 (Renew)	5	3	√
4 (Protect)	8	5	√
5 (Healthy)	6	5	√
6 (Quality)	6	5	√
7 (Soc-ec)	8	5	√
Total	49	32	6

Case study's strengths:

- ▶ Principle 1: Minimise resource consumption
- ▶ Principle 3: Use renewable, recyclable and recycled resources
- ▶ Principle 4: Protect the natural environment
- ▶ Principle 5: Create a healthy, non-toxic environment
- ▶ Principle 6: Pursue quality in the built environment
- ▶ Principle 7: Social and economic upliftment

Innovative aspects:

- ▶ Sustainable building materials (Principles 1/3/4/5) The houses are built with sundried Adobe bricks (earth bricks). These are both inexpensive and offer insulation properties. Residents save 50-60% on cooling and heating costs due to the earth bricks (Iruan *et al.*, 2002). The earth bricks are made out of mud and straw and left to soak in a pit overnight. The mud straw is then pushed into moulds to form bricks, and is dried for approximately four days. Once the bricks are built into the walls, no mortar is needed. The bricks are coated with linseed oil and turpentine to make them water resistant.



Figure 16: Earth brick making, Thlolego Development Project
Source: www.sustainable-futures.com

- ▶ Water efficiency (Principles 1/2) Storm water is retained in tanks and allowed to seep into the soil and is used for permaculture. Greywater from bathrooms and kitchens is also reused for permaculture. The composting toilet, discussed below, uses no water and provides composted manure for the garden.
- ▶ Integrated planning in a rural settlement (Principles 5/6/7) Over and above the housing, there is a school, and food is grown for resale to sustain the community. The food is grown according to a system of "permaculture" which integrates farming more closely with local eco-systems, has high yields from small areas of ground and is not labour or energy intensive (Irurah *et al.*, 2002). Staples such as corn, wheat, squash and pumpkin are grown at TDP. Mulching improves the quality of the soil and all the toilets are composting.
- ▶ Innovative sanitation system (Principle 4) A composting toilet is used at the TDP which is low-cost, easy to construct, environmentally friendly and virtually odour-free (Sowman *et al.*, 1998). Composting toilets are based on a natural process, whereby liquid and solid waste are separated and converted into compost using surrounding heat and adequate ventilation in a sealed container (Sowman *et al.*, 1998).



Figure 17: Composting toilet, Thlolego Development Project

Source: www.susa@sustainable-futures.com

Key challenges and barriers:

- ▶ A key challenge faced at TDP was the low acceptance of the sustainable livelihood technologies, especially the earth brick houses and the composting toilets. Such technologies are perceived as "backward" and more modern/western designs are desired.
- ▶ A further barrier has been limited financial resources to follow up on other initiatives after the revamp of the school.

4.6 Improved Traditional Housing Systems*

4.6.1 Overview of Improved Traditional Housing Systems

Address: Papua New Guinea.

Location: Rural and urban.

Time period: The improved traditional housing project consists of 312 individual projects that have been developed over the last 25 years. Eighty two of these are housing projects with the remainder being health or community buildings.

Description: This case study, a Habitat Award finalist in 2003, addresses a tendency in Papua New Guinea to replace its traditional building heritage with modern architecture that is foreign to the traditional way of life, expensive and prone to deterioration due to poor design and inappropriate materials. The Improved Traditional Housing Systems project is dedicated to drawing upon local knowledge and traditions to understand and maintain the value of traditional design and construction systems, and only adapt it where necessary to meet modern housing needs. Residents are involved in the development process and there is a large emphasis on affordability, the use of local, durable materials, income generation and having designs that are appropriate to the climate, ecology and culture. A range of income sources are used to fund the projects and include private sector funding as well as international and national subsidy.

Source of information: Habitat (2008)



Figure 18: Improved traditional housing systems, Papua New Guinea

Source: www.worldhabitatawards.org

* This case study involves a building scheme (promoted and implemented across Papua New Guinea), as opposed to an individual "sustainable settlement". This will count against it in the evaluation procedure used in the next chapter. It is, however, still deemed an appropriate case study for the purposes of this dissertation because of the noteworthy sustainability practices it demonstrates.

4.6.2 Results of the Evaluation of Improved Traditional Housing Systems

Table 10: Performance of Improved Traditional Housing Systems in evaluation procedure

PRINCIPLE	Total criteria	No. of criteria addressed	Principle fulfilled
1 (Conserve)	9	5	√
2 (Reuse)	5	0	X
3 (Renew)	5	3	√
4 (Protect)	8	2	X
5 (Healthy)	6	4	√
6 (Quality)	6	4	√
7 (Soc-ec)	8	6	√
Total	49	24	5

Case study's strengths:

- ▶ Principle 1: Minimise resource consumption
- ▶ Principle 3: Use renewable, recycled or recyclable resources
- ▶ Principle 5: Create a healthy, non-toxic environment
- ▶ Principle 6: Pursue quality in the built environment
- ▶ Principle 7: Social and economic upliftment

Innovative aspects:

- ▶ Use of traditional architecture (Principles 6/7) Papua New Guinea's traditional buildings which make use of local materials, and are suited to the economy, the climate and way of life, are increasingly being replaced by imported designs that are expensive and make use of inappropriate materials. The Improved Traditional Housing Project draws upon traditional Papua New Guinea architecture to harness its value; adjusting it only where it is necessary to cater for modern demands such as electricity, water, sanitation, space for cars and privacy.
- ▶ Use of local, sustainable resources (Principles 1/4/6/7) All houses are constructed using locally sourced, sustainable materials that are small requiring fewer resources. Timber is obtained from sustainable forests in Papua New Guinea and typical products used are adzed hardwood posts, and gravel from local riverbeds, treated roofing shale and saplings, bamboo and cane. Rattan is used for finishings. These natural materials ensure naturally cool houses so that air conditioning is not needed.
- ▶ User consultation (Principle 7) Each housing project is designed and constructed with extensive user consultation through a workshop process. Workshops are first held to decide what, in general, a house in the area should be like and, secondly, to decide upon the more detailed design process. Traditional building skills are retained and enhanced through the building process by employing local people and through capacity building.

4.7 Yaodong Cave Dwellings

4.7.1 Overview of Yaodong Cave Dwellings

Address: Loess Plateau, North Central China.

Location: Rural.

Time period: Started with a pilot project in the Zaoyun Village between 1996 and 2001. The project has now seen the development of over 1000 dwellings.

Description: Living conditions in the Loess Plateau in China are amongst the worst in the country. Ninety percent of the area's population live in "yaodong" or cave dwellings. With the rapid growth in China's economy, however, most rural people tend to want to live in modern housing and become dissatisfied with the yaodong dwellings. This project was started to preserve these traditional homes for cultural continuity, while making them sufficiently modern to be attractive to the local people and to meet modern housing needs. The houses are built through self help construction, and address issues inherent in the sustainable construction principle of minimising resource use as the utilisation of innovative solar energy systems, thermal mass protection, roof planting and natural ventilation methods reduces the consumption of energy. The dwellings are two storeys high to increase the amount of functional space available, and are designed to be conducive to interacting with neighbours. There is no government support, and the housing costs and the houses are funded by the families living in the houses. Technical support provided by the Green Building Research Centre (GBRC) is free because this is subsidised by the national government. This case study was a Habitat award finalist in 2006.

Source of information: Habitat (2008)



Figure 19: Yaodong Cave Dwellings, China
Available at: www.worldhabitatawards.org

4.7.2 Results of the Evaluation of Yaodong Cave Dwellings

Table 11: Performance of Yaodong Cave Dwellings in evaluation procedure

PRINCIPLE	Total criteria	No. of criteria addressed	Principle fulfilled
1 (Conserve)	9	5	√
2 (Reuse)	5	1	X
3 (Renew)	5	2	X
4 (Protect)	8	4	√
5 (Healthy)	6	5	√
6 (Quality)	6	5	√
7 (Soc-ec)	8	6	√
Total	49	28	5

Case study's strengths:

- ▶ Principle 1: Minimise resource consumption
- ▶ Principle 4: Protect the natural environment
- ▶ Principle 5: Create a healthy, non-toxic environment
- ▶ Principle 6: Pursue quality in the built environment
- ▶ Principle 7: Social and economic upliftment

Innovative aspects:

- ▶ Passive thermal design measures (Principle 1) The housing design is based on traditional design, enhancing and retaining passive thermal design measures. The houses include a sunspace at the front which reduces the need for internal heating. The earth-sheltered roofs ensure that the internal temperature is maintained at a comfortable level and the sharing of common walls ensure that they are less exposed to adverse climatic conditions and so need less energy for heating.
- ▶ Cultural continuity through the use of traditional designs (Principle 6/7) Traditional "yaodong" cave designs are preserved while making them sufficiently modern to be attractive to young people.
- ▶ Sense of community and community participation (Principle 7) Residents and other local people are involved in the design process and high importance is attached to the residents' comments. People work together with friends and neighbours to build their home which creates a sense of community and pride. The cluster configuration of the dwellings also encourages community.
- ▶ Roof planting (Principle 4/5) The cave dwellings have green roofs/root planting whereby vegetation is grown on the roof. According to Snell *et al.* (2005), although green roofs are difficult to construct and require a strong supporting structure, the benefits include: the reduction of runoff into sewers, the provision of green space and a natural habitat which is particularly important in urban areas, energy efficiency in terms of its thermal mass, durability, non-toxicity and aesthetic qualities which contributes to human well-being.



Figure 20: Example of a "Green Roof"

Source: www.bbg.org/.../handbooks/cact/greenroof.htm

Key challenges and barriers:

- ▶ A key challenge in this project is the low acceptance of traditional designs especially by younger people. Modern, western city-type dwellings are preferred and perceived to increase status.

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4.8 Eco Barrio Suerte 90, Columbia

4.8.1 Overview of Eco Barrio Suerte 90

Address: Cali, Columbia.

Location: Urban.

Time period: The project was initiated in 2000.

Description: This "eco village" was a Habitat award finalist in 2005 and includes over 200 homes, along with recreational facilities and community gardens. Cali is considered one of the most dangerous cities in the world with high levels of crime and a breakdown of social networks, a high housing deficit, lack of infrastructure and services, and a lack of green space and social facilities. The Eco Barrio Suerte 90 project was designed to address this range of social and environmental issues experienced by the city's poor. The "eco village", the first in South America, consists of 13 residential blocks, housing over 270 low income families in Cali. Working with the Federacion Nacional de Vivienda Popular (FENAVIP) and the Social Housing Department of the city of Cali, the local community actively participate in planning and decision-making and are responsible for the ongoing management of the project. The homes are incremental and were constructed by residents themselves; and environmentally friendly, earthquake resistant building materials were used, including recycled debris and sugar cane ash. In addition, the village includes individual and collective vegetable gardens, a community centre, pharmacy, restaurant, and a recreational park. Serviced land and funding were provided by the Social Housing Department Housing Fund and additional housing subsidies were provided by various private sector stakeholders. The combination of housing subsidies and a low interest savings and credit scheme by FENAVIP has made housing affordable and accessible to the poorer sectors of the population; addressing the sustainable construction principle of socio-economic development.

Source of information: Habitat (2008)



Figure 21: Eco Barrio Suerte 90, Cali, Columbia

Source: www.worldhabitatawards.org

4.8.2 Results of the Evaluation of Ecobarrio Suerte 90

Table 12: Performance of Ecobarrio Suerte 90 in evaluation procedure

PRINCIPLE	Total criteria	No. of criteria addressed	Principle fulfilled
1 (Conserve)	9	5	√
2 (Reuse)	5	1	X
3 (Renew)	5	4	√
4 (Protect)	8	7	√
5 (Healthy)	6	5	√
6 (Quality)	6	6	√
7 (Soc-ec)	8	7	√
Total	49	35	6

Case study's strengths:

- ▶ Principle 1: Minimise resource consumption
- ▶ Principle 3: Use renewable, recyclable or recycled resources
- ▶ Principle 4: Protect the natural environment
- ▶ Principle 5: Create a healthy, non toxic environment
- ▶ Principle 6: Pursue quality in the built environment
- ▶ Principle 7: Social and economic upliftment:

Innovative aspects:

- ▶ Environmentally friendly materials (Principles 1/4) The project uses environmentally friendly materials including recycled debris and sugar cane ashes to make cement, bricks and blocks. These materials are suitable to withstand the area's seismic activity and can be produced in half the time and at 20 % reduction in cost compared to conventional bricks (Habitat, 2008). Other materials include micro-concrete and cement made from pieces of rubble.
- ▶ Mixed usage (Principles 4/6) The Eco village displays integrated planning and includes facilities, services and programmes over and above housing. These facilities include pharmacies, restaurants, a community centre and shops and vegetable gardens. Two areas have been set aside for sports facilities and a leisure park. Ecobarrio Suerte 90 also includes a "Native Germoplasm Bank" for the cultivation of endangered plant species. An agricultural production cooperative, as part of a food security project, was created, and this project also works to raise awareness and provide training to residents in the treatment and management of organic residues (used as fertiliser) and the disposal of domestic waste. The project established a cultural programme for young people and worked with the community to grow medicinal and aromatic plants and organic vegetables. The project encourages residents to work together in planning and management of the project.
- ▶ Initiatives to make housing affordable (Principle 7) Housing units are made affordable by using low cost materials and by the fact that they are incremental with a basic single-storey unit covered by a concrete slab which allows for future upward expansion. Dwellings are also built

by residents as another cost saving measure. A funding mechanism for low income families, who do not have access to formal credit, was also established.

- ▶ Self management (Principle 7) The residents work together in the planning and overall management of the project including housing construction, agricultural work cooperatives, community activities and decision-making. This has created a space for participation, tolerance and dialogue amongst the community and therefore a step towards resolving the tensions and internal conflict in Colombia.

Key challenges and barriers:

- ▶ Barriers to the project included: a lack of available funding for community facilities and a delay in obtaining government approval for the family housing allowances.

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4.9 Janapur Slum Resettlement Scheme

4.9.1 Overview of Janapur Slum Resettlement Scheme

Address: Delhi, India.

Location: Urban.

Time period: Fifty two dwelling units were built in 1997 for the re-housing of 3 600 former slum households.

Description: The Janapur Slum Resettlement project is listed as "Good Practices" under Best Practices of United Nations Centre for Human Settlements (UNCHS) and was a Habitat award finalist in 2003. Delhi is one of the fastest growing cities in India and, as a result, experiences a severe lack of infrastructure and land to accommodate the ever growing population. The Janapur slum resettlement scheme addresses the appalling living conditions of many of Delhi's slum dwellers and the pilot project involves a cluster design of dwellings on degraded highland near the city. The project shows that land that is previously labelled "unfit for development" can be used and it demonstrates innovative design and construction systems along with sanitation systems that are to be maintained by the community. The layout of the settlement ensures social sustainability in that clusters of nine dwellings are grouped together in a "through cluster" rather than an enclosed court. Funds for construction are mainly dependent on municipal funding.

Source of information: Anangpur (2008), Habitat (2008)

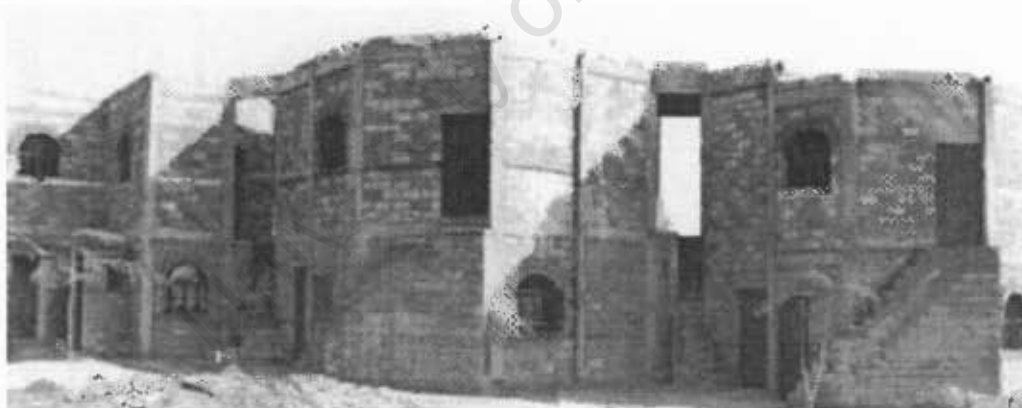


Figure 22: Janapur Slum Resettlement Scheme, India

Source: www.worldhabitatawards.org

4.9.2 Results of Evaluation of Janapur Slum Resettlement Scheme

Table 13: Performance of Janapur Slum Resettlement Scheme in evaluation procedure

PRINCIPLE	Total criteria	No. of criteria addressed	Principle fulfilled
1 (Conserve)	9	6	√
2 (Reuse)	5	3	√
3 (Renew)	5	0	X
4 (Protect)	8	6	√
5 (Healthy)	6	5	√
6 (Quality)	6	6	√
7 (Soc-ec)	8	6	√
Total	49	32	6

Case study's strengths:

- ▶ Principle 1: Minimise resource consumption
- ▶ Principle 2: Maximise resource reuse
- ▶ Principle 4: Protect the natural environment
- ▶ Principle 5: Create a healthy, non-toxic environment
- ▶ Principle 6: Quality in the built environment
- ▶ Principle 7: Social and economic upliftment

Innovative aspects:

- ▶ Reuse of degraded land (Principles 1/4) The dwellings were built on the Southern Ridge area of Delhi. The project was a pilot project to examine this unconventional approach of the use of degraded land. The land was classified as degraded/waste land owing to the conception that the land, due to its undulating and quarried nature, is too expensive to develop and unsuitable for human settlement. The Janapur Slum Resettlement Scheme has shown, however, that the land is highly suited to human habitation owing to large catchment areas which refill the aquifers and can accommodate on-site sewage disposal. The coarse, sandy soil is ideal for absorption, filtration and ground water recharge.
- ▶ Innovative construction systems, techniques and materials (Principles 1/2/4) A range of construction materials and techniques were used. Funicular shell roofing was employed. This type of roofing minimises the need for reinforcement, and thus uses less material than conventional roofing systems. Roofs were also built with waste stone quarried locally on the site. The use of steel and concrete was kept to a minimum and hollow concrete blocks were used for walling, and training was provided for residents on how to make these. The hollow blocks used for the project have an impermeable, non-erodable diaphragm. The internal roads were paved with concrete panels faced with waste stone such as granite and marble which are easy to maintain and aesthetically pleasing. The joints between the panels also allow for percolation of storm water into the ground.



Figure 23: Funicular shell roofing with waste stone infill, Janapur Slum Resettlement Scheme

Source: www.anangpur.org



Figure 24: Stone faced concrete paving panels, Janapur Slum Resettlement Scheme

Source: www.anangpur.org

- Careful planning and layout to ensure social sustainability (Principle 7) The dwellings are designed in clusters of 9 and laid out in a "through cluster" rather than an enclosed court. The grouping and layout creates identity and prevents encroachment and allows for cross ventilation. Plots are placed diagonally to create interest in layout as a break from conventional, monotonous grid layouts. Each cluster comprises four dwelling units in one row and five in another row and each cluster is provided with 2 toilets, a bath, a washing area and a court.

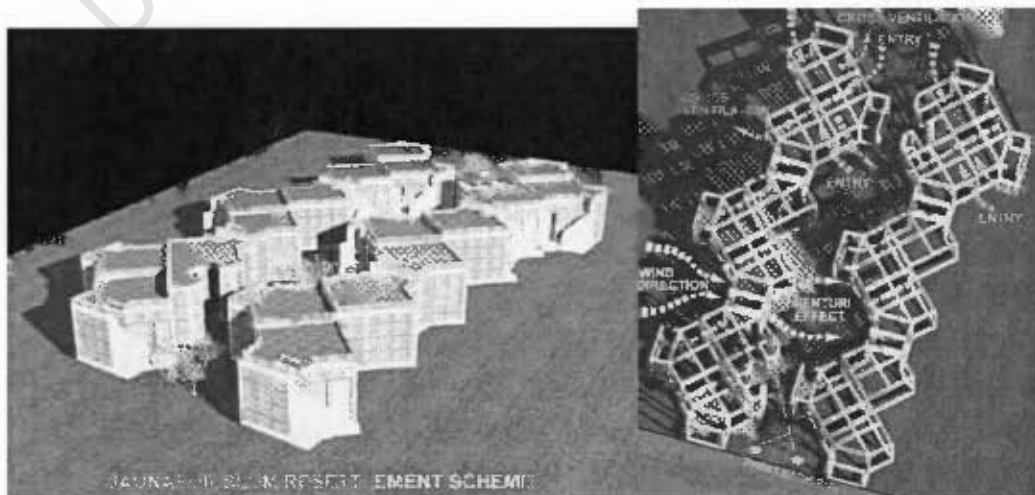


Figure 25: Janapur Slum Resettlement Scheme: "through cluster" design

Source: www.anangpur.org

4.10 Conclusion

This chapter has given an overview of the nine case studies chosen according to the case study design outlined in the previous chapter. All of the cases have a sustainable agenda and were initiated to accommodate low income communities.

This chapter has also illustrated how the nine selected case studies have measured up to a range of sustainability criteria. The achievements, strengths, innovative aspects and key challenges and barriers of the case studies were listed, and the number of criteria each case study addressed and the number of sustainable construction principles it fulfilled were also displayed.

In sum, the following graph is an overall summary of the evaluation of the case studies. The graph displays the number of criteria each case study addressed out of a possible 49, and the number of sustainable construction principles each fulfilled out of a possible 7.

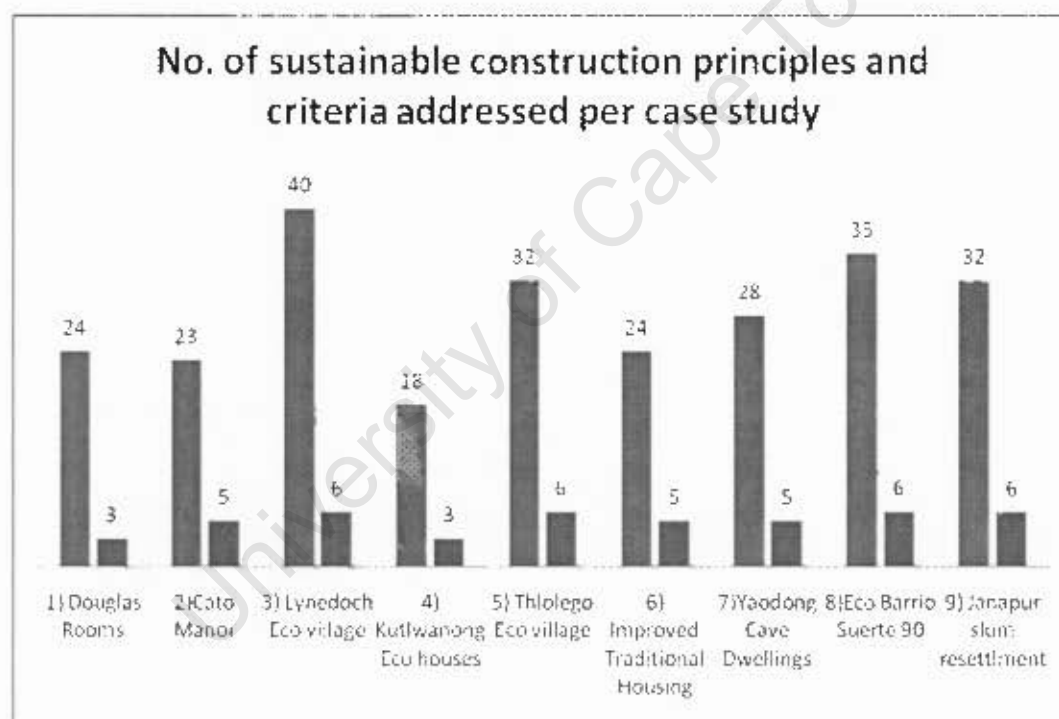


Figure 26: Overall summary of the evaluation procedure illustrating the number of sustainable construction principles and criteria addressed per case study

Out of the nine case studies evaluated, Lynedoch Eco Village (3); Thlolego Eco Village (5); Eco Barrio Suerte 90 (8) and the Janapur Slum Resettlement Scheme (9) fulfilled the greatest number of sustainable construction principles (6/7). Lynedoch Eco Village (3), however, as it fulfils the most criteria (40/49), is deemed the "most sustainable" case study. The "least sustainable" case study, according to the evaluation, is the Kutlwanong Eco Houses (4) as it only addresses 18 criteria and 3 sustainable construction principles. While the Lynedoch Eco Village (3) is a particularly valuable example on how to attain a sustainable settlement, all of the cases address various areas of sustainability, displaying particular achievements and challenges; thus all providing valuable lessons for future low income housing projects in South Africa.

CHAPTER 5

Discussion of the Results

This chapter discusses the findings from the evaluation of the nine cases in the previous chapter and addresses the research question posed in Chapter One, namely:

- ▶ *What lessons are to be learnt from these case studies in terms of the sustainable practices and technologies they used and their potential to deal with South Africa's housing backlog and environmental degradation?*

The findings are discussed under the seven principles of sustainable construction and the case studies are referred to by number as follows:

1. Douglas Room, Johannesburg, South Africa
2. Cato Manor, Durban, South Africa
3. Lynedoch Ecovillage, Stellenbosch, South Africa
4. Kutlwanong, Kimberley, South Africa
5. Thlolego, Rustenburg, South Africa
6. Improved Traditional Housing, Papua New Guinea
7. Yaodong Cave Dwellings, China
8. Ecobarrio Suerte 90, Cali, Colombia
9. Janapur Slum Resettlement Scheme, Delhi, India

Whenever a particular criterion falls under more than one principle, it is discussed in the first principle under which it falls.

The sustainable practices and technologies used in developing world housing projects as identified in the previous chapter are discussed to recommend ways of fulfilling the seven principles of sustainable construction in the provision of low income housing in South Africa. It is important to be mindful of the fact that this discussion reviews the experiences of existing sustainable housing projects as an exchange of lessons and to provide guidance for future South African projects; direct transfer of sustainable practices and technologies, however, should be avoided without careful study.

5.1 Discussion of Findings

The following is a discussion on how to address the seven principles of sustainable construction in low income housing in South Africa in light of the experiences in existing developing world projects:

5.1.1 Principle 1: Minimise Resource Consumption

This principle which addresses the underlying cause of much environmental degradation: the over-consumption of the four generic resources (energy, water, land and materials), was generally well addressed by all of the cases. Case {3}, in particular, addressed all of the criteria, providing valuable lessons for sustainable low income housing in South Africa.

In light of the current electricity crisis in South Africa, energy-saving is of high importance. Many energy-saving practices were displayed by the cases. Passive thermal design as displayed by cases {2}, {3}, {4}, {5}, {6} and {7} is perhaps a viable sustainability practice for low income housing projects in South Africa. South Africa's temperate climate offers the ideal conditions to be able to increase comfort levels in housing quite cost effectively using passive thermal design; instead of resorting to expensive, energy inefficient, quick fix solutions driven by the purchase of appliances. The National Energy Council (1992) has shown that passive thermal design can be employed in low income housing at little extra capital cost. Once operational, these features lower energy costs, maintenance costs in addition to pollution levels (Sowman *et al.*, 1998).

A further means of conserving energy would be to replace energy consumptive materials like cement blocks and corrugated iron or tile roofs often used in South African low income housing (Development Action Group, 1992) with less consumptive materials. Case {6} exemplifies the use of materials with low embodied energy, notably natural materials such as timber and bamboo in unique and attractive designs. In the South African context, a good principle to apply would be to utilise local building materials that can be harvested sustainably. These include straw, thatch, earth and clay. Sundried earth bricks as used in {3} and {5}, for instance, offer a low embodied energy alternative to conventional bricks and cement blocks. A study carried out by the Development Action Group into alternative building systems and materials for low cost housing showed that there are few materials that perform better or are cheaper than the clay brick (Development Action Group, 1992). Case {5} highlights a barrier to the implementation of alternative materials, however, where there are instances of low acceptance by the residents, and the sustainable technology is perceived as "backward" in comparison to more western designs and materials. Thus the adoption of alternative materials in low income housing will possibly require raising of environmental awareness, and educating residents in sustainable practices.

Compact fluorescent light bulbs as used in {1}, {2}, {3} and {4} offer an energy efficient system, especially pertinent where electricity is obtained from non-renewable sources. Despite the initial capital cost, electricity bill savings and lowered maintenance costs due to their higher durability, have been displayed by the cases. Other systems that could be considered for South African low income housing include: insulating boilers {1}, lowering of thermostats {1}, day-night sensors {1}, and the use of gas-hobs as an alternative to energy consumptive stoves {3}.

South Africa is a semi-arid country, rendering the water saving initiatives displayed by cases {3}, {5}, {6}, {8} and {9} necessary options to consider for future low income housing projects. Household fittings such as low-flow shower heads {3}, dual flush toilets {3} and flow restrictors {3} can help to save water. It is interesting to note that case {2} did not install these fixtures due to their high initial cost which highlights a likely barrier for their widespread implementation. Flow restrictors, however, should at least be considered as these are fairly cheap water saving devices that can be fitted onto almost any tap (Sowman *et al.*, 1998). Long term savings should also be considered: in case {3} it has been calculated that low income households will save 90% of their normal water bills with the installation of water saving fixtures and other water recycling measures (Swilling *et al.*, 2006). Preserving and restoring indigenous vegetation, as in {3}, {5} and {8}, is also a very efficient means of saving water and one which also contributes to principles 4 and 5 of sustainable construction as well. Case {3} minimises storm water runoff through the restriction of hard landscaping, thereby increasing percolation into the ground and uses stabilisers to hold the soil in place; demonstrating a cost effective way of conserving water. Water harvesting used in cases {3}, {5} and {6} is another plausible way of saving water. Water harvesting is of particular value to low income communities as piped water is costly and it means that gardens can be maintained even when there are municipal water restrictions. Water harvesting, however, will require upfront planning as certain roof types as highlighted by case {6}, are not suitable for collecting water runoff when the water is to be used for drinking purposes. According to Swilling *et al.* (2006), the cost of off-site sanitation services will rise faster than the average rate of inflation over the next twenty years, which urges the consideration of on-site sanitation as displayed by {3} and {9}, particularly in low income communities. Case {3} has a particularly innovative and effective environmentally friendly water and sanitation system holding valuable guidance for future projects in South Africa. Feasibility studies in terms of cost and land suitability, however, will be warranted for on-site sanitation systems.

Insofar as minimising materials is concerned, all of the case studies complied with this criterion as low income houses are, by definition, small and use few resources. All of them used durable materials if not necessarily materials with low embodied energy, pointing to the fact that durability and low energy consumption of materials need to be optimised. Particularly innovative means of conserving materials included the sharing of walls which was displayed by {1}, {2}, {7}, {8} and {9} (which incidentally also conserves energy and is conducive to creating a sense of community), the dual use of infrastructure and structures displayed by {3} and {5}, the use of topography to form part of the structure and the sharing of facilities in a cluster of dwellings as displayed by {9}. These are all effective material saving practices which serve as guidance for future South African low income housing.

Cases {1}, {2}, {3}, {7}, {8} and {9} demonstrate feasible layouts of settlements as high density alternatives to South Africa's current trend of a plot per housing unit, where large tracts of productive land are being lost. Linked, two/three storey alternatives all minimise land use. Interestingly, none of the buildings evaluated, exceeded three storeys, which keep the scale human and comfortable. A barrier, however, is public resistance to densification and low-rise cluster alternatives (Dalglish *et al.*, 1997) and is one which needs to be considered and overcome in the South African context.

5.1.2 Principle 2: Maximise Resource Reuse

This principle was generally not well addressed by the cases, with the exception of {9}. The fact that this principle was generally not well approached by the case studies is not clear as it is a relatively inexpensive and simple principle to adhere to.

Cases {8} and {9} show that materials can be reused successfully. Waste stone and rubble can be used for the actual structure and for the roofing, and as people upgrade from their informal houses to formal housing, they can reuse materials such as doors and window frames from their previous homes as shown by case {9}. This is an inexpensive and environmentally friendly possibility for South African housing, and could also offer business opportunities for dealers in reusable materials (Dalglish *et al.*, 1997).

Case {1} demonstrates that previously derelict and squalid inner city buildings can be refurbished and reused; which presents a possibility for the reuse of many well located but run-down buildings in South Africa's urban centres. Cases {5}, {7} and {9} demonstrate that "grey" land can be successfully developed and is a viable solution when there is a shortage of "suitable" land for development and to preserve valuable fertile or aesthetically significant land. Case {9}, in particular, demonstrates an unconventional and cost-effective approach to land selection, and shows that land classified as "unfit for development" can be successfully utilised for sustainable human settlements.

Cases {3}, {5} and {9} have grey water systems where water is recycled for irrigation and/or toilet-flushing purposes. These case studies report substantial long term savings on water costs; despite the cost of many commercial systems being relatively high. According to Sowman *et al.* (1998), it is easy to build simple and efficient grey water filters from cheap and readily available materials. Grey water systems should therefore be considered for South African low income communities particularly when large quantities of water are needed for purposes such as irrigation, bearing in mind that water is a costly and scarce commodity. Case {3} demonstrates another valuable cost saving means for the installment of grey water systems useful for low income housing whereby the grey water and fire fighting water systems are combined.

It is interesting to note that none of the cases was "designed for disassembly". There seems to be no significant reason for this as there seems to be no noteworthy barrier (cost or other) that would hinder its implementation. Cognisance should be taken of this criterion in the design and construction of low income housing.

5.1.3 Principle 3: Use Renewable, Recyclable or Recycled Resources

This principle was generally not well addressed by the low income housing projects evaluated; except for cases {3} and {8} that each addressed four of the five criteria.

Cases {3}, {4}, {5} and {6} demonstrate the use of renewable energy in the form of solar power. It is noteworthy that none of the evaluated case studies make use of solar energy to generate electricity. This can perhaps be attributed to the fact that solar panels are expensive and are only suitable for providing electricity for non-heating appliances such as lights, radios and televisions (Sowman *et al.*, 1998). The case studies do, however, display low cost ways of harnessing the sun's energy in the form of solar water heaters in cases {3}, {5}, {6} and {7} and solar cookers in case {5}. South Africa has an ideal climate for the utilisation of the sun's energy, and in light of the country's heavy dependence on fossil fuels, increasing costs of grid electricity, and shortage of electricity supply, and while some form of subsidy may be warranted for electricity generating solar panels, solar water heaters and solar cookers should be considered as feasible and necessary features in low income housing projects. Case {2} highlights the importance of considering such aspects upfront as the layout and design of the structures were not conducive to the installation of solar water heaters at a later stage.

Renewable and recyclable materials, including earth, timber and bamboo, were only used in four of the nine cases, namely {3}, {5}, {6} and {8}; and recycled materials were used in {7} and {8}. Case {8}, in particular, innovatively made cement and blocks out of recycled debris and sugar cane ash. Renewable/recyclable/recycled materials are relatively easily available, since so few case studies made use of such materials is perhaps indicative that certain less obvious barriers exist for their widespread utilisation. High initial capital costs as well as the perception that they are inferior to conventional materials, need to be considered for the South African context as this may warrant the need for subsidies and education. These case studies have, however, shown that renewable/recyclable/recycled materials can be used effectively. Case {3} is particularly noteworthy in the use of such materials in that it uses hardwoods from sustainable Mozambican forests as opposed to the more common woods imported from unsustainable forests (Swilling *et al.*, 2002).

Few of the cases recycled the construction waste produced which can perhaps be attributed to a lack of awareness and a lack of facilities for recycling to occur. This is discussed further under the next principle.

5.1.4 Principle 4: Protect the Natural Environment

This principle which refers to the minimisation of the construction industry's negative impacts on the environment along with the rectification and restoration of degraded environments, was particularly well addressed by cases {3} {8} and {9}.

None of the housing projects completed an Environmental Impact Assessment. This is perhaps because none felt there was a specific policy urging them to incorporate sustainability features in their projects; which highlights the need for enforced building codes that promote sustainability.

Cases {3}, {5}, {6}, {8} and {9} demonstrate the successful use of safe and environmentally suitable sanitation systems as an alternative to water-consuming, costly, water-borne sewerage. These include the septic tank and composting toilet. On site sanitation systems are also used in cases {3} and {9}. Whereas water-borne sewerage is the most commonly used sanitation system in South African low income housing, and is perceived by most people to be the most convenient, safest and healthiest sanitation option; the case studies have shown that alternative systems can be successfully utilised. The kind of sanitation system that is most suitable for a particular project, however, will depend on the soil conditions, drainage and the height of the water table (Sowman *et al.*, 1998).

Cases {2}, {3}, {5}, {7} and {8} display ways of designing with nature and preserving the natural vegetation. These provide innovative and valuable lessons for South Africa where many low income projects show little regard for the environment (Dalglish *et al.*, 1997). Case {3}, for instance, has demonstrated ways to connect with nature by planting kikuyu grass in the open storm water channels and minimising hard landscaping thereby minimising storm water runoff. Case {8} displays housing that is built into the landscape and includes green roofs. Green roofs may be of particular value in built up, urban areas where there is insufficient space for the preservation of green and open areas. Case {5} uses permaculture which integrates farming closely with natural ecosystems, as a means of designing with nature and creating food security. By designing with nature these case studies have also contributed to the restoration of degraded land.

Few cases separate household waste for recycling. This can perhaps be attributed to the fact that this criterion requires that residents are educated in recycling and that convenient recycling services are available. This drives home the point that communities need to be equipped with the necessary knowledge, commercial incentives and services to manage and protect the environment beyond the construction stage. Case {3} is a valuable example on the recycling of household refuse.

5.1.5 Principle 5: Create a Healthy, Non-toxic Environment

This principle was well addressed by all of the case studies with each demonstrating valuable lessons for the creation of healthy, non-toxic environments in South African low income housing.

Insofar as protecting the physical health of residents in low income housing is concerned, all the case studies demonstrate ways of achieving this as all of them addressed the majority of the criteria involved. These include choosing an appropriate site and position as well as having a well ventilated structure and using natural, permeable materials. Cases {3} and {4} demonstrate the use of non-toxic appliances and products with case {3} explicitly making use of non toxic paints and wood treatments. Case {4} has a unique and successful monitoring programme to maintain healthy air quality. This is a particularly noteworthy initiative as valuable example of how to maintain a healthy environment beyond the construction stage.

Ways of contributing to the psychological health of low income communities include: the provision of green areas in the form of recreational parks as in case {8}, village greens as in case {3}, community

gardens in cases {3}, {5} and {8} and roof planting used in case {7}. Such initiatives have improved the living and environmental conditions of the case studies involved. The provision of flexible, contrasting and interesting designs by providing a range of housing types as displayed by cases {1}, {2}, {3}, {5} and {6}, varying and interesting colours used in cases {1} and {7}, and allowing for the ongoing involvement of users so that they may shape housing designs as shown by case {6} also contribute to psychological well-being. All but case {2} demonstrate naturally lit, well ventilated structures that maintain links with nature and the site's existing character. These all represent viable ways of protecting the psychological well-being of South Africa's low income communities.

5.1.6 Principle 6: Pursue Quality in the Built Environment

This principle was generally well addressed by the evaluated cases, with cases {1} {3} {8} and {9} addressing all of the criteria.

In pursuing quality low income settlements in South Africa, multi-functional and mixed-use environments should be employed whereby infrastructure such as schools, community centres, health centres, shops, and recreational parks are provided over and above the housing. This was displayed by cases {1}, {2}, {3}, {5}, {8} and {9}. The settlement should also be well located with regards to economic opportunities and be compact and efficient with less automobile-dependence. Case {2} is particularly exemplary in demonstrating a well located settlement with integrated and efficient planning. A valuable lesson can be learnt from {4} where a lack of planning for social amenities meant that there was no money set aside to provide these amenities along with the houses. As a result, the community goes without easy access to such services. This highlights the need to focus on mixed-use environments that create vibrant settlements instead of the notion that only houses need to be delivered.

All of the cases demonstrate effective means of achieving quality in design and which have the potential to be used in low income housing projects in South Africa. These include providing houses that are appropriate to the occupants' needs by allowing them to participate in the decision-making process as displayed by cases {1}, {2}, {3}, {5}, {6}, {7} and {8}; as well as the provision of a range of housing types so that people can choose according to their needs as in cases {1}, {2}, {5} and {6}; and the provision of modern day amenities such as car spaces, laundries etc. as in case {5}. Case {9} has a novel means of providing dwellings that meet people's needs whereby skeletal structures are built and the occupants complete the dwelling according to their taste and budget which in turn contributes to the reuse of materials and cuts down material costs. Quality in design was also achieved through the provision of features in the housing that is appropriate to the climate and location: such as insulation displayed in case {4} and insect protection displayed in cases {5} and {6}. Different regions of South Africa vary in climate and topography; so too do different areas of a site have varying characteristics which indicates that there is no single sustainable model. Features and designs of dwellings will need to vary accordingly for maximum quality in design. Aesthetically pleasing dwellings are achieved through the elimination of monotony in both settlement layout and the design of the dwellings as displayed by cases {1}, {3}, {5}, {8} and {9}; as well as dwellings that are unobtrusive and sensitive to the surrounding landscape in cases {5}, {6} and {7}.

All of the cases used durable materials but, as noted, under previous principles, not all of the materials used were of low embodied energy or from sustainable sources. This draws attention to the fact that sustainable projects should use materials that strike a balance between these three criteria along with cost. Future low income housing projects can draw on the practices displayed by the evaluated case studies in terms of ensuring quality in occupation. These include: using interesting colours that activate the senses as displayed by cases {1} and {7}, and having natural temperature regulation and natural lighting which is used in cases {1}, {3}, {4}, {5}, {6} and {7}. Other ways of ensuring quality in occupation include: keeping the scale human whereby buildings do not exceed three-storeys as displayed by all the cases, as well as having natural materials and designs that retain links with nature as used in cases {5}, {6} and {7} thereby contributing to overall well-being.

5.1.7 Principle 7: Promote Socio-economic Upliftment

This principle was fulfilled by all of the cases where {1} {3} and {8} are particularly exemplary in the promotion of social and economic upliftment.

The cases demonstrate successful ways of alleviating poverty and creating job opportunities. This is important in the South African context where there are high levels of unemployment. Agriculture, as shown in cases {2}, {3}, {5} and {8}, provides food security as an income generating opportunity. Case {5} demonstrates a successful way of producing food in a small area using the principles of permaculture. The promotion of the sustainable settlements as tourist attractions and as good practice examples of sustainability to advise other projects in cases {3}, {4}, {5} and {7} demonstrate viable economic opportunities as well. Case {4} is particularly notable where the Kutlwanong Civic Integrated Housing Trust (KCIHT) has become a business which contracts for sustainable housing activities. Settlements that include facilities over and above housing and are located near economic opportunities displayed in cases {1}, {2}, {3}, {5}, {8} and {9} as well as settlements that promote skills training and capacity enhancement displayed in cases {1}, {2}, {4}, {5}, {6}, {8} and {9} also contribute effectively to socio-economic upliftment. Case {2} is particularly noteworthy in enhancing the skills of the community. Owner-built dwellings as displayed by {4}, {5} and {6} is arguably one of the most important means of creating social and economic sustainability as it not only enhances skills and lowers building costs, but it creates community involvement to encourage community acceptance as well.

South Africa is attempting to redress the inequalities of its past through a preferential procurement plan for its construction industry as an instrument to effect socio-economic change. Cases {1}, {3}, {4} and {8} promote integration, in addition to offering employment and business opportunities to marginalised sectors of the population as encouraging ways of effecting South Africa's preferential procurement plan (Bowen *et al.*, 2008). Case {4}, for instance, ensures that at least 2 out of 10 building apprentices are women and case {3} promotes a socially mixed community in terms of race and class.

The creation of a sense of community is an important aspect of social upliftment. This has effectively been implemented by eight of the cases as follows: the preservation of a sense of heritage in cases {1}, {6} and {7}, the provision of community facilities such as halls, community gardens, libraries and sports

facilities in cases {1}, {2}, {3}, {5} and {8} along with the promotion of pedestrian over vehicular traffic as displayed in case {3}, and the configuration of dwellings to encourage social interaction in cases {7} and {9}. The encouragement of social activities has also been successfully implemented in case {1}. These are all suitable and viable ways of pursuing social sustainability in South African low income housing. One barrier to bear in mind, however, as was experienced in case {7}, is a low acceptance of the traditional designs that are maintained to preserve the heritage of the area and to create a sense of community where the younger people preferred western, city-type dwellings and perceived them to have greater status. In South Africa, where the opportunity exists to draw upon and preserve many traditional building techniques and designs, it will be important to overcome this barrier. Case {6} exemplifies an encouraging way of dealing with this challenge in that traditional designs are used, but they incorporate sufficient modernity to be accepted by the community.

Involving people in all aspects of development projects that affect them is a fundamental requirement of sustainable development (Sowman *et al.*, 1998). All of the case studies evaluated involved the community throughout the project cycle. It is interesting to note that public participation was not a once off exercise and was part of the housing projects from the outset of the planning process and is ongoing. This is a useful insight into how to address people's needs successfully throughout the construction process and to gain and maintain people's acceptance. Case {8} is a particularly valuable example of the involvement of the community as the project encourages self management by the community residents in all stages and aspects of the project cycle. This has created the space for teamwork; tolerance and dialogue amongst the community as a step towards resolving the tensions and internal conflict in Columbia. This poses an encouraging way of dealing with South Africa's many troubled, intolerant and crime ridden communities.

By definition, the provision of affordable homes is the main thrust for low income housing. Funding can ensure this affordability but is very often a stumbling block in low income development projects as was the case in {5} and {8}. Some encouraging funding schemes were displayed by {1}, {2}, {3}, {4}, {6}, {8} and {9}; with {4} notably showing negotiation with local authorities for both land and subsidy finance. Other ways of ensuring initial affordability include: incremental housing for future expansion and upgrading as shown in {3}, {5}, {8} and {9}, and owner built houses in cases {4}, {5}, {7}, {8} and {9}. While initial affordable is important, so too is the long term affordability so that the target group can meet the expenses to live there. While low embodied energy materials as used in cases {3}, {5}, {6}, {7}, {8} and {9} and energy and water saving measures as used in {2}, {3}, {4}, {5}, {6}, {7} and {9} ensure long term savings, these are often overlooked because of their high initial capital costs and viewed as "luxury" sustainability measures. Cases {3} and {4}, however, show that this can be overcome through "green financing" whereby the additional costs of energy saving measures are covered. According to Irurah (2002), innovative strategies for the channelling of finances into issues of sustainability are emerging worldwide and South Africa is already tapping into such flows whereby ESKOM is subsidising Energy Efficient Lighting through finances from the Global Environment Fund, the World Bank and International Finance Corporation.

5.2 Conclusion

This chapter has discussed developing world sustainable housing practices as were identified in the previous chapter. The case studies' experiences of the practices are reviewed so as to share lessons on how to implement the seven principles of sustainable construction in future low income housing projects in South Africa. The evaluated cases indicate what is possible and the challenges that exist and provide guidance for future South African housing projects.

Many sustainable practices have successfully been implemented in the selected cases and include energy and water efficient systems, the reuse of old buildings, the creation of jobs, the use of solar power, the preservation of natural vegetation and the provision of settlements that are dense and well located. Particular encouragement lies in the fact that the projects have experimented successfully with little known concepts and technologies such as the use of alternative sanitation systems and the use of degraded land labelled "unfit for development". Such innovation provides encouragement for other projects and paves the way for an increased profile for more widespread use. Certain barriers to the implementation of sustainable practices were also identified and include: low levels of user support and acceptability, high initial costs of certain sustainable measures, the non provision of certain services so that communities are ill-equipped to live sustainably beyond the construction stage, and not prioritising sustainable measures from the outset of projects which means that they are difficult, expensive or impossible to implement at a later stage.

While the cases address varying areas of sustainability, their combined evaluation provides lessons on how to address all components of sustainability. As an isolated example, however, the Lynedoch Eco Village (Case {3}) provides a particularly valuable example on how to achieve a sustainable settlement in that it fulfilled the most criteria (40/49) out of all the cases evaluated.

It is important to reiterate that this discussion reviews the experiences of existing sustainable housing projects to draw guidance for future South African projects. No single model is possible and direct transfer of sustainable practices and technologies should be avoided without careful study.

CHAPTER 6

Conclusions and Recommendations

6.1 Overview of the Research

6.1.1 Introduction

This study has investigated sustainable low income housing projects in the developing world where the problem statement was stated in Chapter One as:

The majority of low cost housing schemes promoted by the South African Government have to date not been designed according to principles of sustainability and this is likely to continue because there is a lack of research for generating a knowledge base about approaches and practices for more sustainable housing projects.

The following research questions were framed as guidelines for investigating the problem statement:

- ▶ *What is sustainable construction with particular reference to low income housing in the developing world?*
- ▶ *What are some good practice cases of sustainable construction in housing for low income communities in South Africa and other developing countries?*
- ▶ *How do these cases compare on issues of sustainability?*
- ▶ *What are the achievements, strengths and innovative aspects of the cases in terms of how they address the principles of sustainable construction?*
- ▶ *What lessons are to be learnt from these case studies in terms of the sustainable practices and technologies they used and their potential to deal with South Africa's housing backlog and environmental degradation?*

The hypothesis tested by the research was:

There are lessons to be learnt from developing world examples of sustainable low income housing schemes.

The methodology chosen for the research was divided into two areas and included a literature review and assessment of case studies using an evaluation framework.

The objectives for the research were to:

- ▶ Identify the basic principles of sustainable construction,
- ▶ Gain a better understanding of sustainable construction in South Africa and the developing world,
- ▶ Identify good practice cases of sustainable construction in the delivery and management of housing to low income communities in the developing world,
- ▶ Evaluate each case against a framework of specific criteria of sustainable construction,
- ▶ Assess the degree to which sustainable construction principles have been addressed by the cases, and
- ▶ Draw conclusions and recommendations from the evaluation of the case studies in terms of the practices and technologies used and relating them to the South African context.

This chapter presents the findings of the main research questions, followed by a review of the hypothesis and the achievement of the main research aims and the research objective. Conclusions are drawn from the research findings, followed by the problems experienced in undertaking this study and recommendations for future research.

6.1.2 Findings of the Research Questions

What is sustainable construction with particular reference to low income housing in the developing world?

Sustainable Construction as an aspect of Ecological Design was found in Chapter Two to fall under the ambit of sustainable development and is seen as a holistic process aimed at restoring balance between the natural and built environments, and is applicable to the full range of construction activities from design, through construction, operation and maintenance and finally decommissioning or deconstruction of buildings (Drager, 1996; du Plessis *et al.*, 2002). Due to the extensive impacts of the construction industry on people and the natural environment as outlined in Chapter Two, sustainable construction remains a matter of urgency for the survival of human beings. The developing world, where housing is identified in the literature review as one of the most pressing infrastructure deficiencies due to rapid urbanisation, is in a prime position to base all its future development on the principles of sustainable construction.

What are some good practice cases of sustainable construction in housing for low income communities in South Africa and other developing countries?

While sustainable construction in the delivery and management of low income houses across the developing world is still not commonplace, the literature review assisted in identifying cases that do exist. Those identified are listed in Appendix C. Nine cases were chosen for evaluation purposes according to the case study design outlined in Chapter Three. These nine cases are namely: {1} Douglas Rooms (RSA), {2} Cato Manor (RSA), {3} Lynedoch Eco Village (RSA), {4} Kutlwanong Eco Houses (RSA), {5} Thlolego Development Project (RSA), {6} Improved Traditional Housing (Papua New Guinea), {7}, Yaodong Cave Dwellings (China), {8} Eco Barrio Suerte 90 (Colombia) and {9} Janapur Slum Resettlement Scheme (India). These housing projects provide an important foundation for others to follow as sustainable interventions in the built environment become more crucial.

How do the cases compare on issues of sustainability?

Chapter Four used an evaluation framework consisting of the seven principles of sustainable construction against which to test all nine of the cases. The evaluation reflected the degree to which sustainable construction principles had been addressed by the cases and therefore allowed for their comparison on issues of sustainability. The results were displayed in a matrix format and a summary was given in terms of the number of criteria the case addressed per principle and out of a possible total of 49, as well as the number of principles it fulfilled out of a possible 7. A principle was deemed fulfilled if more than half the respective criteria are addressed. Out of the nine case studies evaluated, Lynedoch Eco Village {3}; Thlolego Eco Village {5}; Eco Barrio Suerte 90 {8} and the Janapur Slum Resettlement Scheme {9} fulfilled the most number of sustainable construction principles (6/7). Lynedoch Eco Village {3}, however, as it fulfilled the most criteria (40/49), is deemed the “most sustainable” case study. The “least sustainable” case study, according to the evaluation, is the Kutlwanong Eco Houses {4} as it only addressed 18 criteria and 3 sustainable construction principles.

What are the achievements, strengths and innovative aspects of the cases in terms of how they address the principles of sustainable construction?

The results of the evaluation in Chapter Four demonstrated what sustainable initiatives have been used in the cases; what is possible and the challenges that exist. While most of the cases only addressed certain areas of sustainability; their combined evaluation highlighted innovative ways of addressing all components of sustainability. Chapter Four lists the sustainable achievements of each of the cases which include the reuse of derelict buildings, high density settlements, water conservation, energy-saving measures and job creation.

What lessons are to be learnt from these case studies in terms of the sustainable practices and technologies they used and their potential to deal with South Africa's housing backlog and environmental degradation?

Drawing from the sustainable initiatives identified in Chapter Four, Chapter Five discussed the lessons learnt from these initiatives and their potential to deal with South Africa's housing backlog and environmental degradation. The literature review in Chapter Two identified certain challenges to the implementation of sustainable settlements as lessons for the South African situation.

The following lessons were gleaned from the evaluated cases for the South African context:

Low income housing projects should protect the earth and its resources from over-exploitation or over-consumption as well as to protect the occupants and users of the settlements and, at the same time, remain affordable. South Africa should strive for settlements that are vibrant, distinctive and unique with a definable character. A range of housing options should be provided with differing housing types and tenures. The layout should be compact and multi-functional to ensure efficiency and convenience, and encourage non-motorised transport along with easy access to economic opportunities. The scale and design of houses should be kept humane and comfortable; maintaining links with nature and a sense of heritage and tradition. Streets, public spaces and community facilities should be pleasant places in which to spend time and encourage social interaction and create a sense of community. The protection

and enhancement of the natural environment should be of extreme importance: whereby natural resources are conserved and reused, renewable or recyclable/recycled resources are used, and indigenous vegetation particularly in public space is maintained, and communal farming areas are perhaps even created. Such sustainable settlements would help to mitigate the harmful impact the construction industry has on people and the environment as were identified in Chapter Two.

The level of user support and acceptability is vitally important for the successful creation of sustainable settlements. This will require the participation of residents throughout the construction cycle so that they are key decision-makers right the way through and the project answers their needs and reflects modernity. It will also require campaigns that, on the one hand, inform the public regarding the benefits of sustainable construction practices and, on the other, encourage a change in consumer habits towards more sustainable ones. Funding is very often a stumbling block for the implementation of sustainable systems where there are high initial capital costs involved; however, funding is indeed available especially in light of the global push for sustainable initiatives. Full "life cycle costing" should also be argued as a parameter to determine the value of sustainable designs and the obtaining of funding. It is also important to prioritise sustainability issues from the outset of a project as it is more difficult and expensive to retrofit sustainable measures. Services and facilities that encourage sustainable lifestyles should be provided so that communities are equipped to protect the environment and lead a high quality of life beyond the construction stage.

Certain challenges to the implementation of sustainable settlements in South Africa were identified in Chapter Two and are valuable lessons that can be acknowledged for future sustainable housing projects. These challenges include political agendas that put more emphasis on the number of houses built than sustainability, a lack of capacity, consciousness and interest by the construction industry in the issue of sustainability, and a lack of mechanisms and guidelines for translating policy principles into action (Sowman *et al.*, 1998; du Plessis *et al.*, 2002). These identified challenges confirm that some of the fundamental assumptions in housing delivery will have to be questioned and challenged in South Africa in order to attain sustainability in low income housing projects (see also Crane *et al.*, 2008).

6.1.3 Validation of the Research Hypothesis

The findings of the final research question as discussed above, validate the research hypothesis in this study: There are indeed lessons to be learnt from developing world examples of sustainable low income housing schemes.

6.1.4 Achievement of the Research Aims and Objectives

The objectives of this dissertation were achieved through the research method employed in the study; that of a literature review and evaluation framework.

The aim of this research study was to investigate developing world examples of sustainable housing to gain lessons for South African housing projects; and while this aim was achieved, it is important to be

mindful of the fact that sustainable initiatives used in housing projects may not be directly transferable to others without further research.

6.2 Conclusion

There are lessons to be learnt from the experiences of developing world sustainable settlements for South Africa. While the sustainable practices used, may not be directly transferable to other projects without further research, the lessons learnt from the projects can be used to guide good practices in future South African projects in the hope that the sharing of knowledge can help to promote sustainable initiatives as common practice in housing projects. Benchmarking and assessing sustainable construction practices and technologies are also vital for a better understanding of sustainable construction.

In light of the global push for sustainability and South Africa's current electricity crisis, its legacy of separatist planning, urban sprawl and environmental degradation, its increasing Ecological Footprint and the existing thrust for the delivery of low income housing; it is a matter of urgency and a timeous opportunity to ensure that future housing projects are sustainable. South Africa needs to move away from its existing poor environmental and housing conditions in the informal and low income settlements and address its housing backlog by considering all principles of sustainable construction. This will enhance the quality of people's lives by ensuring a healthy built environment in balance with the natural environment, thereby ensuring lasting social, economic and environmental benefits.

It is time that South Africa addressed the housing needs of the poor using a comprehensive sustainability approach. The funds are there, the policies are in place, pertinent literature on 'sustainable cities' is at hand, invaluable discussion documents such as *Agenda 21 for Sustainable Construction in the Developing World* are available, the legal powers exist and the foundations have been laid by other projects for South Africa to follow.

6.3 Problems Experienced in Undertaking this Study

- ▶ The task of finding relevant case studies did not prove to be simple, as "sustainable housing" is a relatively new and unidentified field in developing countries and has only marginally been introduced. There were even certain case studies that professed to have a sustainability agenda and, in fact, addressed very few areas of sustainability.
- ▶ Access to sufficient information, particularly for projects outside of South Africa proved to be a problem, hence the larger number of South African case studies. Language proved to be the largest hurdle where correspondence with stakeholders for the foreign case studies proved virtually impossible.

- ▶ While striving to evaluate best practice examples of sustainable low income housing projects, no programmes or projects had all aspects of sustainability incorporated. Most projects concentrated on specific aspects/issues of sustainability. Some projects were also building schemes as opposed to isolated sustainable settlements, which counted against them in the evaluation procedure.
- ▶ Financial and time restraints meant that site visits to all the case studies were not possible. This restricted direct observation and first hand information.

6.4 Possibilities for Future Research

This study promotes further research in the area of the specific sustainable technologies and practices identified. While this dissertation provided an overview of a range of housing projects from the developing world and the ways in which they address the seven principles of sustainable construction; more detailed research into the specific technologies and practices would give clearer insight into their transferability to the South African context.

Certain sustainable practices such as the adobe or (earth brick) as used by the Thlolego Development Project {5}, although inexpensive with good insulation properties, may not be suitable for wetter climates. Communal ablutions and “through cluster” designs as was employed by the Janapur Slum Resettlement Scheme {9}, may not be a desirable design for all low income communities; despite its cost savings and enhancement of social interaction.

Direct transfer of any concept can be dangerous and should be avoided unless based on careful study.

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Appendix A

Process-Oriented Principles of Sustainable Construction

(Hill *et al.*, 1997)

University of Cape Town

PROCESS-ORIENTED PRINCIPLES OF SUSTAINABLE CONSTRUCTION

Over-arching principles indicating approaches to be followed in evaluating the applicability and importance of each 'pillar', and its associated principles, to a particular project.

- | | | |
|--|---|--|
| <ul style="list-style-type: none"> ○ Undertake prior assessments of proposed activities ○ Timeously involve people potentially affected by proposed activities in the decision-making process ○ Promote interdisciplinary collaborations and multi-stakeholder partnerships | <ul style="list-style-type: none"> ○ Recognize the necessity of comparing alternative courses of action ○ Utilize a life cycle framework ○ Utilize a systems approach ○ Exercise prudence ○ Comply with relevant legislation and regulations | <ul style="list-style-type: none"> ○ Establish a voluntary commitment to continual improvement of performance ○ Manage activities through the setting of targets, monitoring, evaluation, feedback and self-regulation of progress ○ Identify synergies between the environment and development |
|--|---|--|

PILLAR ONE: SOCIAL SUSTAINABILITY

- Improve the quality of human life, including poverty alleviation
- Make provision for social self determination and cultural diversity in development planning
- Protect and promote human health through a healthy and safe working environment
- Implement skills training and capacity enhancement of disadvantaged people
- Seek fair or equitable distribution of the social costs of construction
- Seek equitable distribution of the social benefits of construction
- Seek intergenerational equity

PILLAR THREE: BIOPHYSICAL SUSTAINABILITY

- Extract fossil fuels and minerals, and produce persistent substances foreign to nature, at rates which are not faster than their slow redeposit into the Earth's crust
- Reduce the use of the four generic resources used in construction, namely, energy, water, materials and land
- Maximize resource reuse, and/or recycling
- Use renewable resources in preference to non-renewable resources
- Minimize air, land and water pollution, at global and local levels
- Create a healthy, non-toxic environment
- Maintain and restore the Earth's vitality and ecological diversity
- Minimize damage to sensitive landscapes, including scenic, cultural, historical, and architectural

PILLAR TWO: ECONOMIC SUSTAINABILITY

- Ensure financial affordability for intended beneficiaries
- Promote employment creation and, in some situations, labour intensive construction
- Use full-cost accounting and real-cost pricing to set prices and tariffs
- Enhance competitiveness in the market place by adopting policies and practices that advance sustainability
- Choose environmentally responsible suppliers and contractors
- Invest some of the proceeds from the use of non-renewable resources in social and human-made capital, to maintain the capacity to meet the needs of future generations

PILLAR FOUR: TECHNICAL SUSTAINABILITY

- Construct durable, reliable, and functional structures
- Pursue quality in creating the built environment
- Use serviceability to promote sustainable construction
- Humanize larger buildings
- Infill and revitalize existing urban infrastructure with a focus on rebuilding mixed-use pedestrian neighbourhoods

APPENDIX B

Principles of Sustainable Construction

The purpose of this appendix is to contextualise and discuss the main principles of sustainable construction. As discussed in Chapter Two, a number of authors have formulated principles of sustainable construction (see Kibert, 1994b; Hill *et al.*, 1994a; Hill *et al.*, 1995; Hill *et al.*, 1997; Woolley *et al.*, 1997). Addressing the issues inherent in each of them allows for the realisation of sustainable construction. The principles are meant as a guideline to members of the construction industry in order to achieve more sustainable buildings and settlements (Drager, 1996) and therefore mitigate the harmful impact of the construction industry as discussed in Chapter Two of this dissertation. Kibert (1994) formalised sustainable construction concepts by devising six principles of sustainable construction which covered environmental and technical sustainability. Hill *et al.*, (1995) added a seventh principle to incorporate economic and social sustainability in order to meet the requirements of the South African Reconstruction and Development Programme. The seven principles presented in this appendix are based on the principles listed by Hill *et al.*, (1995) as follows:

1. Minimise resource consumption.
2. Maximise resource reuse.
3. Use renewable, recyclable and recycled resources.
4. Protect the natural environment.
5. Create a healthy, non-toxic environment.
6. Pursue quality in the built environment.
7. Promote socio-economic development.

It is important to note that some of these principles and the issues inherent within them cannot occur entirely in isolation and do have a 'knock on' effect or overlap with other principles of sustainable construction. For instance, the reuse of materials (Principle 2) will reduce the need for landfill sites as there will be less wastage which will, in turn, conserve land (Principle 2) and also protect the natural environment (Principle 4). However, it is also not always possible to optimise each principle; and trade-offs and compromises may be necessary (Hill *et al.*, 1997).

The remainder of this appendix discusses each principle of sustainable construction in greater detail with particular relevance to low income housing.

Principle 1: Minimise Resource Consumption

Resource consumption refers specifically to the way the earth's resources are used by man and his activities (Hill *et al.* 1995). In the construction industry, these resources include: materials, energy, land, and water (Hill *et al.*, 1997). The aim of this principle is therefore to reduce the consumption of these generic resources used in construction. The essence of this principle is conservation and it addresses the underlying causes of much environmental degradation: over consumption of resources (Kibert,

As described in Chapter Two, minimising the use of energy and water are of particular importance in South Africa. Minimising energy use requires a reduction in both embodied and operating energy (Loftness *et al.*, 1994 cited in Hill *et al.*, 1997:229). Embodied energy of construction materials is the total energy used in the production, extraction and the final delivery of a material while operating energy is the energy used to moderate temperatures and light buildings as well as to heat water (Hill *et al.*, 1997).

Ways of minimising embodied energy in materials used for low income housing include using locally sourced materials, materials found on site and materials that need little processing, along with minimising the use of imported materials (Woolley *et al.*, 1997). Natural materials for instance such as clay dug from the building site and used as an unbaked brick require almost no energy; this is in contrast to synthetic and processed materials such as plastics, aluminium, steel, glass and oven-fired bricks which require large amounts of energy to manufacture and to transport (Pearson, 1998). The figure below illustrates the embodied energies of different building materials.

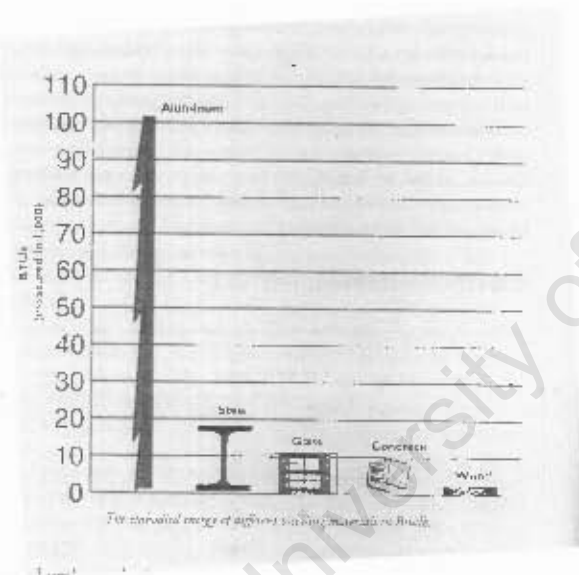


Figure A.1: The embodied energy of different building materials

Source: Barnett *et al.*, 1995:52

Reducing operating energy consumption includes 'passive thermal design measures' whereby a building is designed in harmony with the climate in order to ensure natural heating, cooling and lighting (Sowman *et al.*, 1998). For low income housing, a dwelling's orientation to the sun, the position of windows, use of certain materials, the dwelling's surface area, its position on the site and the design of the roof all make a difference (Pearson, 1998; Sowman *et al.*, 1998). Greater energy efficiency ensures that less costs are incurred which is particularly pertinent for low income communities. 'Passive thermal design measures' also ensure that the dwellings' occupants are able to enjoy healthy, well ventilated, light indoor environments of a constant and comfortable temperature.

A reduction in operating energy can also be achieved through the improvement of insulation and of systems and fixtures such as air-conditioning and heating (du Plessis *et al.*, 2002). In South African low income housing, the amount of money spent on energy for heating in winter can be drastically reduced by using insulating materials (Sowman *et al.*, 1998) and low energy lighting fixtures such as the

Efficient use of water can be achieved through the use of certain household devices and fittings incorporated into the design of a building. These include water conserving toilets, low-flow showerheads and tap aerators, flow restrictors fitted onto taps, dual flush toilets or low flush cisterns (Pearson, 1998; Sowman *et al.*, 1998). Water efficient plumbing systems reduce the load at sewage treatment plants while helping to protect riverine ecosystems (Barnett *et al.*, 1995). Water also contains large amounts of embodied energy as energy is needed to pump it and treat it at sewage plants; therefore the conservation of water also means the conservation of energy (Barnett *et al.*, 1995). The current thrust for the provision of low income housing in South Africa warrants a timeous opportunity to ensure that they are fitted with water saving devices (Dalgliesh *et al.*, 1997). Other ways of minimising the use of water include the harvesting of rainwater by collecting runoff from roofs in a storage tank and using it for purposes such as irrigation (Chemaly, 2007). Water efficient landscaping, such as the selection of drought-resistant and indigenous plant species, proper irrigation equipment and irrigation scheduling, can also drastically reduce water consumption (Barnett *et al.*, 1995). The use of water on construction sites and in the production of materials should also be carefully monitored (du Plessis *et al.*, 2002).

Ensuring the efficient use of materials includes the use of durable materials that have long lifetimes and require low maintenance (Kibert, 1994b). So too, certain design measures such as buildings that share common walls and are an appropriate size to what is needed, economise on materials. South African low income houses, in theory, largely comply with this principle as small houses use few resources; their collective utilisation of resources, however, is not as efficient because one plot per freestanding unit often takes preference over cluster alternatives (Dalgliesh *et al.*, 1997). According to Sowman *et al.* (1998), cluster houses with shared walls in fact also conserve energy as they are less exposed to climatic extremes. The amount of packaging used for building materials should also be considered when trying to conserve materials. Not only does unnecessary packaging consume material resources, it also consumes energy in its manufacture (Hill *et al.*, 1997).

To achieve more efficient land use, high density forms of housing should be considered. Terrace houses and courtyard houses should be considered over free-standing, individual houses. Urban open space should also be utilised for housing (Dalgliesh *et al.*, 1997). Linked houses are more affordable, provide better protection and social support and use less land which leaves more land available for green areas, community and sports facilities (Sowman *et al.*, 1998). The efficient use of land, however, needs careful planning and a fine balance as high-rise, high density living can encourage vandalism and disturbed behaviour (Heron, 2003).

Summary of main criteria:

The following points summarise the main criteria under principle one of sustainable construction:

- ▶ *Minimise energy consumption.*
- ▶ *Minimise water consumption.*
- ▶ *Minimise materials consumption.*
- ▶ *Minimise land use.*

Principle 2: Maximise Resource Reuse

This principle refers to the reuse of resources already extracted. This would contribute to Principle 1 as it would reduce the over-consumption of virgin resources such as land, water and materials, and would also lead to a reduction in waste, therefore reducing the need for new landfill sites (Kibert, 1994b; Hill *et al.*, 1997). Reuse differs from recycling in that items are not reprocessed and reduced to raw materials but rather used in their existing state (Kibert, 1994b).

The reuse of materials would include, for instance, the use of reclaimed wood, glass off-cuts and various architectural items such as doors and windows salvaged from demolition sites (Kibert, 1994b; Anonymous, 2007c). The reuse of materials reduces construction and demolition waste, therefore reducing the need for landfill and disposal sites so that this land can possibly be made available for low income housing (du Plessis *et al.*, 2002). Reusing materials also offers a cheaper alternative to new materials which is particularly beneficial to low income communities (du Plessis *et al.*, 2002). It is interesting and paradoxical to note that the 'shack', which is the dominant informal building type for low income communities across the developing world, while demonstrating much of what is unsustainable in construction, epitomises the maximisation of resource reuse (Irurah, 2002) as is illustrated in the figure below:



Figure A.2: Reuse of materials and components in shacks

Source: Irurah (2002) Photo by Lyndsey Bremner, Slide Library, School of Architecture and Planning, University of the Witwatersrand

Shacks are also easy to deconstruct and reassemble as required, which facilitates the reuse of resources. Low income houses should therefore be 'designed for disassembly' (Hendriks *et al.*, 2003). Another example of reuse is the renovation of existing buildings for a new function (retrofitting) or using a building for more than one purpose (Hill *et al.*, 1997) such as using public sites such as schools for community centres after hours (Sowman *et al.*, 1998).

"By retrofitting a 100-year-old building, rather than erect a new one, the National Audubon Society saved US\$9 million in construction costs. This retrofit also "saved" 300 tons of steel, 9000 tons of masonry, and 560 tons of concrete." (Randolph R. Croxton, architect, 1993 cited in Barnett *et al.*, 1995:54)

Reusing water can be achieved through the use of grey water systems whereby washing machine, bath and shower water is filtered and redirected for use in the garden resulting in more efficient water usage (Anonymous, 2007c). Although the capital cost of many commercial grey water systems available are high, the long term savings on water costs are substantial (Sowman *et al.*, 1998).

Other resources such as land can be reused by considering old, used or degraded sites know as “grey zones” (Kibert, 1994b). This would help to ensure that prime agricultural land or land with natural beauty or value is not encroached upon.

Summary of main criteria:

The following points summarise the main criteria under principle two of sustainable construction:

- ▶ *Reuse materials.*
- ▶ *Reuse water.*
- ▶ *Reuse land.*

Principle 3: Use Renewable or Recyclable Resources

Kibert (1994) maintains that this principle refers to the fact that renewable resources and those that are recyclable, or have been derived from recycled content, must have priority over other resources. This principle can be applied to both energy and building materials.

Renewable energy sources should be given preference over energy derived from coal or natural gas powered plants (Barnett *et al.*, 1995). Renewable energy sources include solar power, wind power, geothermal energy and organic waste (van den Akker *et al.*, 1977). Wood, however, although a renewable energy source if not used too rapidly, is hazardous to human health and the environment when burnt (Sowman *et al.*, 1998). Hydroelectric power is not considered as a renewable energy source for the purposes of this dissertation as such projects are known for destroying the natural environments of rivers and lakes with large dams and reservoirs (Baggs *et al.*, 1996). The same can be said for the nuclear alternative where radioactive waste and the fact that nuclear power stations are impossible to decommission, remain a threat to the environment (van den Akker *et al.*, 1977).

Renewable energy sources have high initial capital costs and some do not always cover all electricity needs; they are therefore not often considered for low income housing. The long term environmental and financial gains of renewable energy, however, need to be taken into account as they are often substantial (Barnett *et al.*, 1995). Some form of subsidy may, however, still be necessary if renewable sources are to be used extensively in low income housing (Dalgliesh *et al.*, 1997). There are nonetheless a number of low cost ways to make use of renewable energy in low income housing, such as the solar cooker designed to use the sun's energy to cook food (Sowman *et al.*, 1998). Ultimately, the rising price of grid electricity and the heavy reliance of countries like South Africa on fossil fuels as a primary energy source will make renewable energy sources an economical and necessary alternative (DME, 2002).

An energy economy in which modern renewable energy increases its share of energy consumed and provides affordable access to energy throughout South Africa, thus contributing to sustainable development and environmental conservation (The South African Government's overall vision for the role of renewable energy in its energy economy; DME, 2002:1).

This principle also refers to materials: where materials used in construction should be renewable and given preference over non-renewable resources. Wood, for instance, derived from sustainable forests is a suitable renewable material (Kibert, 1994b). Other innovative renewable building materials include straw bales and sandbags which offer easy, affordable alternatives to non-renewable, energy-intensive bricks and cement (Sowman *et al.*, 1998; Anonymous, 2007b; Stemmet, 2008).

Recycled building materials should be used and these include recycled aggregate from crushed concrete, agriboard panels and tiles with recycled glass amongst others (Kibert, 1994b; Edwards, 1996). Low income housing should also be designed for recycling, which means using fewer materials; using parts that can be easily dismantled; using materials that are recyclable; marking all the parts used so that they can be readily identified during dismantling and can be easily separated for further processing (Hendriks *et al.*, 2003). Construction waste such as plastic, steel, copper pipes and leftover paint can all be minimised through jobsite recycling. This would require educating construction workers about recycling and installing bins for sorting the waste (Barnett *et al.*, 1995; Hill *et al.*, 1997). Recycling has several environmental advantages: it reduces consumption of natural resources, it reduces the infill of landfill sites, and it reduces the energy consumption of new material production and its associated pollution (du Plessis *et al.*, 2002). Recycling of construction waste should set the precedence and encourage recycling of household waste.



Figure A.3: Demolished steel sorted for recycling, South Africa
Source: Irurah (1999) cited in Irurah (2002)

Summary of main criteria:

The following points summarise the main criteria under principle three of sustainable construction:

- ▶ *Use renewable energy sources.*
- ▶ *Use renewable materials.*
- ▶ *Give priority to materials that are recyclable and design for recycling.*
- ▶ *Give priority to materials that have been derived from recyclable content.*
- ▶ *Recycle construction waste and household waste.*

Principle 4: Protect the Natural Environment

Every site, particularly an urban one, should have some wilderness character. It's time to stop paving meadows and putting streams into culverts (Lesley Sauer, landscape architect, 1990 cited in Barnett et al., 1995:36).

As discussed in Chapter Two, the construction industry places considerable demands on the natural environment and as a result often negatively affects it. This principle refers to the minimisation of those negative impacts in addition to the rectification and restoration of degraded environments (Kibert, 1994b). This principle is of particular significance to low income housing as such developments are often on a large scale, where quantity and lowering of costs are given greater priority than protecting the environment.

Minimising the construction industry's harmful impact on the natural environment "acknowledges the human power to destroy the world's complex ecological systems and reminds us that we must tread carefully lest we destroy ourselves in the process" (Kibert, 1994b:8). Environmental effects can be minimised through informed decision making when acquiring materials: materials should be from reputable sustainable sources, have low embodied energy, capable of being reused or recycled and cause little environmental impact when extracted (Kibert, 1994b; Pearson, 1998). Materials should also be durable, as according to Barnett *et al.* (1995), in many cases the environmental ramifications of the disposal of a material are often far worse than its actual use. Products such as plaster and cork are known to be more environmentally friendly than many modern substitutes (Barnett *et al.*, 1995). Impacts such as air, land and water pollution can be minimised by using construction materials and products that do not cause pollution during their extraction, production and operation (Hill *et al.*, 1997). Noise, odour and dust pollution, along with solid and sanitary waste produced during the actual construction process, can further be minimised through management procedures during construction operations (Hill *et al.*, 1997). Environmental Management Systems (EMS) should be used as guidance for this, where the ISO 14 001 standard for EMS provides comprehensive checklists for the improvement of environmental management in construction (Hill *et al.*, 2002). Environmental Impact Assessments (EIA's) should be carried out to minimise the damage to sensitive landscapes during construction, to evaluate alternative sites to avoid sensitive environments, site a building with the least visual disturbance to the landscape, and to protect vegetation, water sources, animals and other organisms (Hill *et al.*, 1997; Hill *et al.*, 2002). The World Bank Sectoral Guidelines (1991) offers a list of mitigatory measures to ensure the protection of the natural environment in the design of housing (Dalglish *et al.*, 1997). Sanitation systems should also be suitable to the natural environmental conditions so as not to cause serious environmental damage, pollution and a health risk (Sowman *et al.*, 1998).

The employment of high density development as well as multi-functional and mixed-use environments in low income communities will also contribute to this principle of protecting the natural environment as such layouts promote more efficient and less energy consuming transport measures; and minimise the need to utilise further valuable ecological and agricultural land (Hill *et al.*, 2002; du Plessis *et al.*, 2002).

The restoration of degraded environments is a complex issue as it is difficult to define what a natural environment is or what the previous state of the environment was (Drager, 1996). Nonetheless, there are various environmental improvement measures and “intelligent interventions” (Kibert, 1994b:8) which are of particular importance for low income communities which are often characterised by poor environmental quality and thus poor quality of life for the residents. These measures could include the re-planting of vegetation to prevent the loss of topsoil; where the vegetation could include food gardens, permaculture, and community planting schemes to address poverty and poor nutrition in low income communities (Sowman *et al.*, 1998). Other measures could include the clearing and recycling of waste from the land, recomposting poor soil, introducing water conservation measures as discussed above, and flood control measures which would include diversion ditches and stormwater channels (Barnett *et al.*, 1995; Sowman *et al.*, 1998). Low income housing should also be provided with appropriate services so that communities can manage the environmental problems such as litter (Dalglish *et al.*, 1997).

Summary of main criteria:

The following points summarise the main criteria under principle four of sustainable construction:

- ▶ *Minimise the harmful impact of construction activities (minimise air, land and water pollution, choose environmentally friendly materials, carry out EMS's and EIA's, incorporate the natural environment into building design, suit sanitation to the natural environmental conditions).*
- ▶ *Employ high density, multi-functional and mixed-use settlements.*
- ▶ *Restore degraded land and provide suitable services.*

Principle 5: Create a Healthy, Non-Toxic Environment

The aim of this principle is to avoid what Day (1990) and Pearson (1998) refer to as ‘sick buildings’ wherein synthetic materials, poor design, lack of ventilation, poor choice of site, fixtures and appliances in buildings affect the physical and psychological health of the occupants.

This principle can be achieved by eliminating the use of hazardous and toxic materials, products and appliances in construction. These include wood treatments, insulation, oil-based paints, vinyl floor coverings, and wiring circuits amongst others (Barnett *et al.*, 1995; Pearson, 1998). The vapours and radiation released from such products are very often not able to escape due to the impermeable nature of building materials. Buildings should therefore ideally be comprised of non-polluting, non-toxic, renewable and permeable natural materials that have good sound reduction properties, are electromagnetically safe and do not allow the build up or conduction of static electricity (Baggs *et al.*, 1996; Pearson, 1998). Such materials include timber and earth (Pearson, 1998). Adequate ventilation in buildings is also crucial, and this is often overlooked in low income housing (Barnett *et al.*, 1995; Sowman *et al.*, 1998). Clean water and appropriate sanitation should be provided to avoid diseases such as cholera and dysentery (Dalglish *et al.*, 1997). Outdoors, this principle requires minimising the use of pesticides, and fertilisers to prevent soil and water contamination; which can be achieved through indigenous landscaping (Kibert, 1994b; Hill *et al.*, 1997). In addition, measures must be taken to reduce dust, noise, vibration and odours from construction operations (Hill *et al.*, 1997).

An appropriate site, void of negative energies such as geological faults, away from hazardous infrastructure such as power line servitudes and one that has a pleasant look, smell and sound needs to be considered in order to create a healthy built environment (Baggs *et al.*, 1996; Pearson, 1998). A suitable position on the site in terms of the microclimate, topography, hydrology and geology should also be considered to maximise human health and comfort (Barnett *et al.*, 1995; Sowman *et al.*, 1998).

A healthy environment can also be achieved through structurally sound buildings that are appropriately designed for the given environment and designed in direct accordance with the types of activities occurring within them as this determines whether a building is safe for human occupation particularly in adverse conditions (Hill *et al.*, 1997).

As mentioned, this principle also refers to psychological health. So as to contribute to the mental well-being of occupants, settlements should be designed to create vibrant living environments that create a sense of place and harmony. The current practice of “sterile rows of freestanding boxes” in many South African low income settlements should instead be planned with a degree of flexibility and allowed to grow more gradually in response to people’s needs and to the surroundings (Sowman *et al.*, 1998: 49). Natural landscape features, such as rocky outcrops and the cultural and historical significance of a site should be retained, so that its unique character and existing sense of place is not lost (Sowman *et al.*, 1998). Green and open spaces should be encouraged as people need places where they can relax from the stresses of daily life (Barnett *et al.*, 1995; Sowman *et al.*, 1998). Building designs should be free of monotony, sterility and harshness which often result in sensory deprivation and negatively effect people’s psyches (Day, 1990; Pearson, 1998). High rise flats with very high densities should be avoided (Heron, 2003). Light, colour, sound, smell and textures should all be considered in building design as they all have a profound impact on people’s feelings and thoughts (Pearson, 1998). The transitions between spaces are also very important for human psychological health (Pearson, 1998). Links between indoor and outdoor environments should be strong so as to avoid artificial substitutes for natural systems indoors (Day, 1990). According to Barnett *et al.* (1995), natural daylit buildings reduce operating costs, increase productivity, health and well-being of the occupants, and provide a superior quality of light. It is also important for people to have control over their environmental conditions to curb stress and irritation levels; this would include the installation of windows that can be manually operated (Day, 1990).

Summary of main criteria:

The following points summarise the main criteria under principle five of sustainable construction:

a) Physical health:

- ▶ *Use non toxic products and materials for both indoor and outdoor environments.*
- ▶ *Ensure buildings are well ventilated and consist of permeable, natural materials.*
- ▶ *Create a safe built environment.*
- ▶ *Minimise pollution over the entire construction process.*
- ▶ *Choose an appropriate site and position on the site.*

b) *Psychological health:*

- ▶ *Retain a site's existing character.*
- ▶ *Create green and open spaces.*
- ▶ *Create interest, contrast and flexibility in building design and settlement planning.*
- ▶ *Have strong links between indoor and outdoor environments.*
- ▶ *Allow for human control of environmental conditions.*

Principle 6: Pursue Quality in the Built Environment

Quality in the built environment is an important principle in sustainable construction as a quality structure and settlement will not only have a long lifespan, but will also be valued by its occupants and not fall into disuse and disrepair (Kibert, 1994b; Hill *et al.*, 1997). In low income housing, this principle requires a fine balance between cost and quality (Dalglish *et al.*, 1997).

Quality in the built environment includes settlement planning, in addition to a building's design, construction and occupation (Kibert, 1994b) and is in accordance with the fourth 'pillar' of sustainable construction: 'technical sustainability' as detailed in Chapter Two (Hill *et al.*, 1997).

A quality settlement will provide good quality of life through the employment of a multi-functional and mixed-use environment, a compact layout, less automobile-dependence and the provision of social infrastructure along with the protection and enhancement of the natural environment (Kibert, 1994b; Hill *et al.*, 1997; Swilling, 2006).

A building should be designed so that it is aesthetically pleasing but at the same time appropriate for its function, the climatic conditions, the occupants' needs and the surrounding environment. A competently designed and constructed building will also help to ensure its durability, thus reducing the need to replace it, and thus saving energy and waste (Hill *et al.*, 1997). Excellence in design and construction includes the selection of quality materials, technology and energy systems (Kibert, 1994b; Sowman *et al.*, 1998). This may require a shift in consciousness from conventional 'quality' building methods and materials such as bricks and mortar to alternative, environmentally responsible methods such as sandbag building (Anonymous, 2007a). Durable, appropriate, functional and reliable buildings that are pleasant on the senses are in turn cared for and maintained because they are cherished (Kibert, 1994b).

Quality in the built environment also includes the attempt to 'humanise' buildings so that they are in tune with human needs so that they may contribute to human well-being and quality of life (Day, 1990). Hill *et al.* (1995:15) indicates that "cherished spaces are cared for while dehumanising structures are prone to vandalism". Heron (2003) validates this statement and highlights the importance of residential satisfaction in terms of the social and physical character of an area, as it has a proportionate effect on crime levels. How the built environment affects human spiritual, psychological and physical health is discussed in greater detail under principle 5 above and includes an understanding of how humans experience buildings in terms of their layout, the use of light and colour, fragrances, textures, the use of space and the transition between spaces (Pearson, 1998)

Summary of main criteria:

The following points summarise the main criteria under principle six of sustainable construction:

- ▶ *Pursue quality settlements (compact, independent of automobiles, green spaces, social infrastructure etc.).*
- ▶ *Pursue quality design (aesthetically pleasing, durable, appropriate technology, functional, safe).*
- ▶ *Pursue quality in construction (durable structure, materials and building methods).*
- ▶ *Pursue quality in occupation (humane, healthy, non-toxic environment).*

Principle 7: Promote Socio-Economic Development

Sustainable construction falls under the broader framework of sustainable development; its principles therefore need to include sustainable development's economic and social 'pillars' as well (Hill *et al.*, 1994a). This principle therefore refers to the achievement of a socially and economically sustainable built environment. There is often an overlap between social and economic issues hence their being grouped under one principle of sustainable construction, and it is only for ease of explanation that they have been separately discussed below.

The social element of this principle refers to improving the quality of human life by promoting community involvement and responsibility and by creating a sense of community and safety, therefore contributing to the physical and psychological well-being of people (Sowman *et al.*, 1998). Improving quality of human life would entail, for example, alleviating poverty in order to ensure that people's basic needs are met through initiatives such as food gardens (Barnett *et al.*, 1995; Yap, 1989 cited in Hill *et al.*, 1997), and promoting well-being through the creation of a non-toxic, safe and healthy built environment (Hill *et al.*, 1997). Materials used in construction should also be produced via socially fair means which would include good working conditions and equal opportunities (Pearson, 1998). The social benefits such as employment opportunities as well as the social costs of construction should be fairly distributed and a project should aim towards empowering socially excluded and previously disadvantaged groups, and establishing equal gender, class and race relations (Hill *et al.*, 1997; Habitat, 2008). South Africa is redressing the inequalities of its past by adopting a preferential procurement plan for its construction industry as an instrument to effect socio-economic change through the promotion of employment and business opportunities to marginalised sectors of the population (Bowen *et al.*, 2008).

Involving future occupants in all aspects of planning and development, so that they may actively shape their futures is essential for the long-term sustainability of the built environment and low income housing projects in particular (Sowman *et al.*, 1998). Community participation would ensure that people's needs are sought and addressed, thus potentially avoiding conflict situations, empowering people, and instilling a sense of ownership so that people are more likely to support, maintain and help develop a project (Sowman *et al.*, 1998). Labour intensive construction methods and the implementation of skills training during the actual construction process for instance would contribute to community involvement and empowerment and would therefore "ensure that development of human resources is a lasting legacy of construction, in addition to the physical presence of facilities" (Hill *et al.*, 1997:227).

Creating a sense of community and social unity can be achieved through shared community facilities such as markets, libraries, and sports fields. These help to create a sense of belonging and increase communication and acceptance of others as neighbours interact in their day to day activities (Sowman *et al.*, 1998). Another important aspect is to protect the historical, cultural and religious importance of a site to create a sense of place and common heritage (Sowman *et al.*, 1998). Outward appearance of the built environment also contributes to how people interact and gives a place its own feeling and appeal; care should be taken in planning to ensure that the character of a settlement instils a sense of community and pride in the environment (Sowman *et al.*, 1998).

The economic element of this principle refers to the issue of financial affordability for the intended beneficiaries in addition to the promotion of employment opportunities (Hill *et al.*, 1997; Sowman *et al.*, 1998). Any new development, particularly housing for low income communities, should aim to reduce costs (Sowman *et al.*, 1998) without compromising the other principles of sustainable construction. It is important to note that costs include both initial capital costs and long term operation and maintenance costs. Many 'green buildings' may have longer term cost savings through indirect means such as water efficient toilets, despite a larger initial outlay (Barnett *et al.*, 1995; Sowman *et al.*, 1998). Land ownership is an important economic consideration, particularly in the identification of land for low income housing where municipally owned land is often the fastest and cheapest way to acquire land for low income development (Sowman *et al.*, 1998).

The use of labour intensive construction ensures that jobs are created in communities, the financial benefits of construction remain in the community and people are empowered with skills (Hill *et al.*, 1997). Other considerations such as a development's proximity to jobs, shops, markets and public transport influence access to employment opportunities (Sowman *et al.*, 1998). In low income communities, housing should at least be close to informal trading opportunities and public transport as few people own cars.

Another economic factor of sustainable construction is the support of environmentally responsible suppliers and contractors (Day, 1990; Hill *et al.*, 1997).

Summary of main criteria:

The following points summarise the main criteria under principle seven of sustainable construction:

- a) *Social factors*
 - ▶ *Poverty alleviation.*
 - ▶ *Protect human well-being.*
 - ▶ *Promote social equality and fairness (socially fair materials, equal distribution of the social benefits and costs of construction, empowerment of previously excluded social groups and promotion of integration).*
 - ▶ *Community participation.*
 - ▶ *Create a sense of community and social unity.*

b) Economic factors

- ▶ *Ensure financial affordability for the beneficiaries.*
- ▶ *Promote employment opportunities.*
- ▶ *Choose environmentally responsible suppliers.*

Conclusion:

This appendix has elaborated on seven principles of sustainable construction with particular relevance to low income housing and suggested ways to address the issues inherent in each of them. These principles make up the four 'pillars' of sustainable construction (biophysical, technical, social and economic), so for any low income housing project to be sustainable, it must adhere to all of the principles. It is important, however, to be mindful that optimising each principle is not always feasible and trade-offs and compromises may be necessary. While the seven principles serve as a guideline for built environment professionals to achieve sustainable construction, they are also used as a framework against which to evaluate the case studies introduced in Chapter Four of this dissertation.

Appendix C: Initial Case Studies considered for evaluation in this dissertation

Case Study	Chosen for evaluation purposes	Comment
All Africa Games Village	X	While demonstrating innovative energy-saving initiatives, the other South African examples displayed broader sustainable initiatives.
Bioclimatic Housing area, Tunisia	X	Insufficient available information.
Carr Gardens, Johannesburg, RSA	X	Case demonstrated only a limited area of sustainability (namely, socio-economic).
Co-op UFAMA, Uruquay	X	Addresses similar sustainability issues to SA e.g. Douglas Rooms for which there was more information.
Douglas Rooms (JHC), Johannesburg RSA	√	Although the building has mixed income occupants; over half are low income. The case study was therefore deemed to fall within the criteria of the case study design.
Eco barrio Suerte 90, Columbia	√	Complied with the case study design.
Ecologically Sustainable Low Income housing, Costa Rica	X	Insufficient available information.
Energy Efficient Straw Bale housing, China	X	Despite innovative sustainability practices, this case is a building scheme (implemented in an ad hoc manner in villages in NE China), as opposed to a 'sustainable settlement'. This would count against it in the evaluation procedure & thus the other Chinese case (Yaodong cave dwellings) was deemed more appropriate.
Improved traditional housing systems, Papua New Guinea	√	This case study is a building scheme (promoted across Papua New Guinea), as opposed to a 'sustainable settlement'. This counts against it in the evaluation procedure. It is, however, still deemed appropriate in this dissertation for the sustainability practices it demonstrates.
Janapur Slum Resettlement Scheme India	√	Complied with the case study design.
Kampung improvement programme, Indonesia	X	While demonstrating noteworthy sustainable improvements to the settlement as a whole, the programme did not include improvement of the dwellings themselves thus rendering it an inappropriate case study for this research project.
Khaokho resettlement, Thailand	X	Insufficient available information.
Kutlwanong, Kimberley, RSA	√	Complied with the case study design.
Living Better Jardim, Brazil	X	Insufficient available information.
Lynedoch Eco Village, Stellenbosch, RSA	√	The settlement houses occupants from mixed income groups. There are however, low income houses which are the focus of the evaluation. The case study was still deemed to fall within the criteria of the case study design.
Masithembane housing project, Khayelitsha, Cape Town, RSA	X	Excess of South African examples; and case only demonstrated a narrow area of sustainability.
Midrand Eco City, Jhb, RSA	X	Excess of South African examples; and case displayed narrower area of sustainability than others.
Missionvale Community Housing, Port Elizabeth, RSA	X	While demonstrating innovative high density units as well as community participation and ongoing environmental management, the case did not demonstrate a broad enough spectrum of sustainability initiatives for evaluation.
Programa de Vivienda Popular, Mexico	X	Case Study displayed too narrow a spectrum of sustainability practices for evaluation purposes.
Self managed vertical housing, Brazil	X	Case covers too limited an area of sustainability for evaluation.
Springfield Terrace, Cape Town, RSA	X	Due to an excess of South African examples and a limited area of sustainability addressed, this case was not chosen for evaluation.
Tiholego Eco Village, Magaliesburg, RSA	√	Complied with case study design.
Vikas Community, Auroville, India	X	Other Indian case (Janapur) displayed more sustainable initiatives and had more available information.
Yaodong Cave Dwellings, China	√	Complied with case study design.

Appendix D

This appendix displays the results of the evaluation of the nine cases in a matrix format. There is a separate matrix for each of the seven principles of sustainable construction, tested against all nine of the cases. These matrices are elaborated upon in Chapter Five to expand upon the short notes confined within them as well as to provide any additional comments that are not accommodated in the matrices. A summary of each case's performance is given in Chapter Five and is given in terms of the number of criteria it addresses per principle and out of a possible total of 49, as well as the number of principles it fulfils out of a possible 7. A principle is deemed fulfilled if more than half the respective criteria are addressed. Innovative aspects gleaned from the evaluations are also listed in the summaries.

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Principle 1: Minimise resource consumption (Conserve)

CASE STUDIES	CONSERVE									TOTAL (9)
	Minimise energy consumption			Minimise water consumption			Minimise materials consumption		Minimise land use	
	Passive design measures	Low embodied energy (material etc)	Energy efficient systems	Water efficient systems	Water efficient landscaping	Water harvesting	Durable materials	Economical design (scale of structure, amount of materials, waste etc)	High density	
1) Douglas Rooms (UHC)	No	No	Energy efficient solar & sky-light systems, reduction of doors & opening of glass walls	No	No	No	Building made from high quality, durable materials (life over 100 years old)	Shared walls	Yes	4
2) Calo Mario	Earth enclosure	No (stone walls of bricks and mortar)	Energy efficient light bulbs, currently being installed	No	No	No	Yes	Small, compact houses Other structures (e.g. library & hospital) were built first Some design/construct elements & started screening metres	Plot sizes reduced to increase density Reduced site & infrastructure	5
3) Lyedoch Eco Village	North-south orientation Insulation Water coverings Thermal mass	Adobe bricks (sun-dried earth blocks)	Energy efficient light bulbs, solar panels, solar water heaters, geothermal, only low-power appliances	Low flow shower heads Waste-water treated on site Dual flush toilets Low flow washers	Indigenous plants used Rain water for irrigation Water for irrigation Water for irrigation	Cylindrical roof structure but strongly pitched	Yes	Concrete structure Shared walls Dual purpose infrastructure (e.g. grey-water & rain water supply system combined)	Yes	8
4) Kuliwanoq	Roof overhangs for summer shade North-south orientation Insulation Thermal mass	Structures built with low temperature resistant materials (e.g. stone, brick, concrete, stone & steel frames)	Efficient fluorescent light bulbs	No	No	No	Yes, although some inefficient energy, they are robust & durable	Small houses 60-70	High density, high density, low use of land	4
5) Tholegu Development Project	Earth bricks (high thermal mass) Insulation Thermal mass	Earth bricks (local material) or carbon emissions for manufacture	No	No	Thermocline regulates the temperature down to the local geothermal water source	Water - well installed in houses, has a gutter system	Insulated Dimension of 100m x 10m for houses to last longer than others (but with conventional structures)	45 m ² of concrete used for dual purpose (e.g. concrete in contact with rain driving rain to be used for agriculture)	No	6
6) Improving Traditional Housing	Thermocline Insulation	Thermocline Insulation	No	No	No	Yes (thermocline is used to regulate the temperature)	High density on hillside	Small houses, from 50 m ²	No	5
7) Yaodong Cave Dwellings	Earth sheltered roofs Thermal mass Insulation	Building materials sourced locally	No	No	No	No	Yes	Use local topography to provide housing structure, so reduced need for roof top construction materials Shared walls & low density	High density & by using less floor area, and suitable for agriculture & general Density increases building space while screening and use	5
8) Coimbra, Suerle 90	No	Locally available waste products as the materials	No	No	Recycled plastic glass etc	No	Recycled earth Local material	Shared walls 400 m ² single story 60-70 including upper 2 stories	Yes	5
9) Nahar Bum Resettlement	No	Locally produced & because efficient, efficient & because efficient	No	Storage & wastewater treatment on site	Landscaping designed to be attractive to people (e.g. trees)	No	Functional shell Durable Durable Durable	Designed in clusters with shared walls Sharing of amenities (e.g. pool, etc) in cluster of 5 dwellings Small dwellings, 31 m ²	High density, high density	6

Principle 2: Maximise resource reuse

CASE STUDIES	CRITERIA					TOTAL (5)
	Reuse materials			Reuse water	Reuse land	
	Design for disassembly	Reuse waste materials	Reuse of old building	Grey water systems	Use of 'grey' land	
1) Douglas Rooms (JHC)	No	New materials used for initial construction	Derelict & overcrowded building refurbished	No	No	1
2) Cato Manor	No	New materials used	New houses built	No	No	0
3) Lynedoch Eco Village	No	New materials used	New houses built	Grey water used for irrigation & flushing	No	1
4) Kutlwanong	No	No	New houses built	No	No	0
5) Thlolego Development Project	No	New materials used	New houses built	Grey water used for agriculture	Land previously degraded and eroded	2
6) Improved Traditional Housing	No	New materials used	No	No	No	0
7) Yaodong Cave Dwellings	No	New materials used	No	No	Houses cut into hill terraces on land that is hard to farm or infertile	1
8) Ecobarrio Suerte 90	No	Materials include micro-concrete & cement made from pieces of rubble	New houses built	No	No	1
9) Janapur Slum resettlement	No	<ul style="list-style-type: none"> • Roofs built with waste stone quarried locally • Skeletal structures provided: residents complete it reusing materials from previous homes 	No	Water reused for fruit plantations	Land degraded as a result of quarrying	3

Principle 3: Use Renewable, Recyclable or Recycled resources

CASE STUDIES	CRITERIA					TOTAL (5)
	Energy	Materials				
	Renewable energy (Solar, wind etc.)	Renewable materials (e.g. timber)	Use of recyclable materials/design for recycling	Use of recycled materials	Recycle construction waste & other	
1) Douglas Rooms (JHC)	No-although another JHC building; Smithoffi has a Solar energy system used to heat water which is stored in insulated tanks	No	No	No	No	0
2) Cato Manor	No	No	No	No	No	0
3) Lynedoch EcoVillage	Solar water heaters; Biogas digester used for 3 houses	Earth bricks & sustainable hardwoods used for frames & windows	Materials can be recycled	No	Construction waste and domestic waste recycled	4
4) Kutlwani	Solar cookers promoted & available at affordable rates	No	No	No	No	1
5) Tholego Development Programme	Solar water heaters	Earth bricks	Materials used offer ease of recyclability	No	No	3
6) Improved Traditional Housing	Solar water heaters	Timber & bamboo	Materials used offer ease of recyclability	No	No	3
7) Yaodong Cave Dwellings	No	No	No	Recycled materials used wherever possible	No	2
8) Ecobarrio Suerte 90	No	Cement, bricks & blocks made from sugar cane ash & recycled debris	Materials can be recycled	Cement, bricks & blocks made from recycled debris	Domestic waste recycled	4
9) Janapur Slum resettlement	No	No	No	No	No	0

Principle 4: Protect the natural environment

CASE STUDIES	CRITERIA								TOTAL (8)
	Minimise harmful impact on environment						Restore degraded land		
	Environmentally friendly materials (sustainable, low embodied energy etc.)	Environmental Impact Assessments, Environmental Management Systems	Suitable sanitation systems	Mixed-use, high density layout	Design with nature (Preserve natural vegetation)	Produce little waste (recycle, reuse etc.)	Replant vegetation	Restoration of natural systems (e.g. rivers) and other	
1) Douglas Rooms (JHC)	No	None	Conventional sanitation system-high water usage & high initial & ongoing costs	High density	No	No	Plans underway to develop green areas	No	2
2) Cato Manor	No	None	Conventional sanitation systems-high water usage & high initial & ongoing costs	Mixed use & high density	Natural vegetation and open areas preserved where possible	No	<ul style="list-style-type: none"> Green & open areas developed Urban agriculture occurring 	Maintaining open space=preservation & restoration of watercourses & ecosystems	4
3) Lynedoch EcoVillage	Earth bricks & Sustainable hardwoods	None	Septic tanks, biolytic filter, Vertically constructed wetland, biogas digester	Mixed use & high density; pedestrian friendly environment	<ul style="list-style-type: none"> Vegetation preserved in a way that connects nature to the buildings (e.g. stormwater channels planted with kikuyu grass; minimal hard surfacing) Organic agriculture practiced 	Household refuse separated & recycled/reused	Indigenous plants replanted	No	6
4) Kutlwanong	No	None	Conventional sanitation systems	No	No	No	No	No	0

5)Thlolego Development Project	Earth bricks	None	Composting toilets	No	Natural vegetation preserved and restored & permaculture integrates farming closely to natural ecosystems	No	Permaculture has included useful trees and perennial plants	<ul style="list-style-type: none"> •Planting of vegetation has allowed for a habitat for small animals •Mulching of soil & composting toilets have improved quality of soil 	5
6)Improved Traditional Housing	Locally sourced, sustainable, natural materials	None	Composting toilets	No	No	No	No	No	2
7)Yaodong Cave Dwellings	Locally sourced materials	None	Conventional sanitation system	High density & high rise	Design with the topography and green roofing.	No	Roof planting	No	4
8)Ecobarrio Suerte 90	Locally available waste products utilised	None	On site sewerage treatment	Mixed use (shops, community facilities)& high density	Preservation of rare plant species	Domestic waste separated for recycling	Establishment of green areas	Yes	7
9)Janapur Slum resettlement	Use of steel & cement minimised	Yes	Sewerage & wastewater treated on site:soil absorptive	High density	No	No	Areas reserved for social forestry	Restoration of degraded land	6

Principle 5: Create a healthy, non toxic environment

CASE STUDY	CRITERIA						TOTAL (6)
	Physical health			Psychological Health			
	Non toxic products/safe appliances	Natural, permeable materials & a well ventilated structure	Appropriate site and position	Green & open spaces	Flexibility, Interest and contrast in design/lack of monotony	• Link between indoor and outdoor environments • retain site's existing character • human control over environment	
1) Douglas Rooms (JHC)	Toxic paints utilised	No	Appropriate site and position	Plans underway to develop green areas	Interesting design, free of monotony • Different size apartments	Naturally lit & able to open windows manually	4
2) Cato Manor	Ferrets utilised	Well ventilated structures	Appropriate site and position	Yes	Range of housing typologies, detached, semi detached & attached.	Small windows & lack of insulation in roofs-lack of human control over environment & uncomfortable indoor temperatures	4
3) Lyndoch EcoVillage	Non toxic paints, wood treatments & fixtures utilised	Natural, permeable materials & suitable windows for good ventilation	Appropriate site and position	Community gardens, landscaped areas & village green	Five housing types range from single to semi-detached to terrace housing	Naturally lit, ventilated houses with manual windows & natural earth bricks to complement natural character.	5
4) Kutiwani ng	• Monitoring of appliances to maintain healthy air quality • Materials harmful to health were avoided • Face brick-no paint necessary • Solar cookers promoted	Well ventilated structures	Appropriate site and position	No	No	Large windows for natural lighting, manually operated.	4
5) Tholego Development Program	Use of turpentine to spray walls water resistant toxic	Earth bricks	Appropriate site and position	Permaculture in addition to food security, has increased green living environment	• Plenty of flexibility for owners to allow for designs to differ • 3 prototype houses for diversity	• Able to open windows manually • Natural earth bricks maintain the existing character of the site	5

6) Improved Traditional Housing	Woods-treated	Natural, permeable materials and a well ventilated structure	Appropriate site and position	No	<ul style="list-style-type: none"> Houses range in size Ongoing involvement of user means that they shape housing designs 	<ul style="list-style-type: none"> Single lined wall frames & latticed infilling - natural daylight & good ventilation 	4
7) Yaodong Cave Dwellings	Toxic paints utilised	Yes	Appropriate site and position	Roof painting	<ul style="list-style-type: none"> Interesting designs, roof painting and various paint colours used 	<ul style="list-style-type: none"> Housing naturally ventilated with high daylight levels Building into the landscape maintains the site's existing character 	5
8) Cobarrío Suerte 90	Paints utilised	Natural materials	Appropriate site and position	Green areas + recreational parks	Yes	Naturally ventilated buildings	5
9) Janapur Slum resettlement	Paints utilised	Adequately ventilated	Appropriate site and position	Green central area	<ul style="list-style-type: none"> Picks-placed diagonally for interest Skeletal structures - families complete as desired which creates control & flexibility 	<ul style="list-style-type: none"> Through cluster layout - cross ventilation 	5

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Principle 6: Pursue Quality in the Built Environment

CASE STUDIES	CRITERIA						TOTAL (6)
	Quality settlements		Quality in design		Quality in construction	Quality in occupation	
	Compact & efficient layout	Social infrastructure & mixed usage	Functional & appropriate to occupant's needs/environment/climate etc.	Aesthetically pleasing	Durable materials and structure	Humane building contributing to overall well-being (activates senses, links to natural systems etc.)	
1) Douglas Rooms (JHC)	High density, medium rise building close to amenities & employment	Building has its own crèche; CBD's amenities-close & parks are being made for convenience stores, green spaces etc.	<ul style="list-style-type: none"> • Sensitive to needs of tenants as they actively participate in the management and maintenance processes • Appropriate building for the Jhb climate 	Well maintained and interesting paint colour makes for a stylish and pleasant building	The original structure was built according to superior standards using durable, high cost material	The thorough restoration & interesting use of colour has ensured that senses are activated, & the building has a pleasant look and feel. The scale of the building is human	6
2) Cato Manor	High density housing close to CBD & other facilities	Road, transport, health centres, schools, shops, industrial zones, recreational space & community buildings	<ul style="list-style-type: none"> • Variety of housing provided means that occupants are able to choose according to needs • Occupants part of decision making process 	Monotonous colour & uninteresting designs	Yes-bricks and mortar utilised	<ul style="list-style-type: none"> • Buildings sterile in terms of colour & design • Roof's-uninsulated-dangerously hot in summer & cold in winter 	4
3) Lynedoch Eco-village	High density pedestrian friendly environment	School, commercial space & community hall	<ul style="list-style-type: none"> • Appropriate to high summer temperatures & winter rainfall • Residents actively participate to voice needs 	Tasteful designs, complementing natural character of the landscape	Yes	Natural temperature regulation & light contribute to well-being. Natural earth bricks maintain links with nature <ul style="list-style-type: none"> • Human scale; maximum two storeys 	6
4) Kulwanong	Low density & land use not optimised	No social amenities like schools, clinics or recreation	<ul style="list-style-type: none"> • Thermally efficient building techniques-appropriate to Northern Cape winters • Culturally & socially acceptable housing 	Monotonous, facebrick structures	Durable and robust materials used	<ul style="list-style-type: none"> • Natural temperature regulation through passive thermal design + large windows for natural light contributes to well-being • Scale of building not too big 	3
5) Thiolego Development Program	None	School and agriculture	<ul style="list-style-type: none"> • Owners able to make decisions on materials according to their needs & ability to afford • Different size houses available • Units fitted with functional & appropriate features (terrace protection, insect screening, laundry etc.) 	Tasteful designs in harmony with the natural surroundings, high quality finishes in attractive colours	Important dimension of TDP is that houses to last longer than those built with conventional materials	<ul style="list-style-type: none"> • Retain links with nature through the use of natural earthbricks. Neutral colours like calming and the attention to detail activates the senses • Human scale 	4

6) Improved Traditional Housing	NA	NA	<ul style="list-style-type: none"> Improvements to traditional housing - mosquito proofing, sanitation, privacy, space for cars Houses rings in stone Residents involved in design process so their needs are responded to Appropriate for humid Papua New Guinea climate 	Natural & traditional building materials make for eye catching designs	Emphasis on durability	<ul style="list-style-type: none"> Traditional designs create a sense of pride and belonging Natural materials - carving Natural temperature control - links to nature Human scale 	4
7) Yaodong Cave Dwellings	Yes	No	Residents involved in design and construction process	Houses - unobtrusive and serendivory form part of the landscape	Yes	<ul style="list-style-type: none"> Houses form part of the landscape and thus retain links with nature Human scale Interesting and varying colours activate the senses 	5
8) Ecobarrio Suerte 90	Yes	Community centre, pharmacy, restaurant & shops	<ul style="list-style-type: none"> Buildings built to withstand area's seismic activity Residents involved in decision-making 	Tasteful designs with interesting use of recycled & natural materials	Earth quake resistant materials	<ul style="list-style-type: none"> Tasteful use of natural and recycled materials activate the senses Human scale 	6
9) Janabur Sun residential	Cluster housing close to city's amenities	Retail space, health centre + amphitheatre	Skewed structure provided; residents complete it according to their needs	Interesting cluster designs; attractive interior finishes with waste stone	<ul style="list-style-type: none"> Funicular shell roofing - durable Wasting blocks - non erodible 	<ul style="list-style-type: none"> Human scale Attractive waste stone finishes Well ventilated through cluster design 	6

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