Housing the poor is one of the greatest challenges that face governments around the world, especially developing countries. Since its transaction into a democratic state, the housing situation in South Africa is growing more acute and the government is struggling to meet the increasing housing demand. This could be attributed to a number of reasons, amongst them the Conventional Building System (CBS) which is characterised by its slow delivery rate, poor quality, fragmented control and high cost. Although the Industrialised Building System (IBS) is not used widely in South Africa, it is expected to deliver fast, affordable, high quality and sustainable houses that meet or exceed the expectations of end-users. To gain the benefits of both systems, a hybrid system, that utilise the qualities of IBS and CBS, needs to be developed in order to suite the South African context. Adopting such system will achieve the government goals, benefit contractors and satisfy the needs of end- user. This book compares between the two systems and investigate the feasibility of industrialised building systems as a strategic approach for housing the poor in South Africa.

Stefan Conrads, Ayman Ahmed Ezzat Othman
Stefan Conrads (B.Sc. Hons, Const. Management, UKZN, SA) is a site engineer for a multinational pipeline project in South Africa. Dr. Ayman Othman (Ph.D. Const. Management, Loughborough University, UK) is an Associate Professor at the British University in Egypt. Jointly they published a refereed conference paper and a book chapter.

9 783843 357340 978-3-8433-5734-0

Stefan Conrads, Ayman Ahmed Ezzat Othman

Industrialised Low-Cost Housing Projects

Stefan Conrads
Ayman Ahmed Ezzat Othman

Industrialised Building Systems for Low-Cost Housing Projects

Investigating their Feasibility in South Africa

LAP LAMBERT Academic Publishing

Summary

Housing the poor is one of the great challenges that face the South African government. The housing problem could be attributed to a number of reasons, amongst them the slow supply rate in terms of lengthy erection time, cost of construction, adaptability, inadequacy and non sustainability.

This research aims to investigate the feasibility of industrialised building as a strategic approach for housing the poor in South Africa. The research methodology designed to achieve the abovementioned aim consists of literature review, interviews and survey questionnaires. Firstly, literature review is used to: (i) investigate the housing situation in South Africa, the conventional and industrialised building systems and sustainable development; (ii) identify the criteria for comparing between the two building systems, (iii) develop an analysis tool to facilitate achieving informed decision. Secondly, interviews are used to weight the importance of each factor of the identified criteria. Finally, the survey questionnaires are used to apply the developed matrix through rating the performance of conventional and industrialised building systems according to each factor of the identified criteria. Data will be analysed quantitatively and qualitatively to identify the feasibility of either building system for housing the poor in South Africa.

The results of this study aims to inspire the development of an alternative strategy and building technique that will ultimately become a solution to housing the poor in South Africa. Industrialised building is a feasible solution that mitigates the difficulties associated with low cost housing in South Africa. However, job creation, is a major government requirement and is disfavoured by industrialised building systems.

Results of this research are recommended to the government on the feasibility of industrialised buildings as an effective solution for housing the poor in South Africa. This research intended to support the government initiatives for housing the poor in South Africa. The research work presented in this research is genuine and was not done before in the South African context. It is a highly debatable topic because of its importance, relevance to government subsidised housing objectives and the actual implications and performance of IBS for low income housing in South Africa.

Keywords: Social Housing, Conventional Building System, Industrialised Building System, Analysis Tools, Sustainable Development.

"For my parents, Martin and Nydia"

Stefan Conrads

"For my parents, my father & mother-in-law and my beloved family"

Ayman Othman

List of Figures

List of Tables

List of Acronyms	
ANC	African National Congress
BER	Bureau of Economic Research
BNG	Breaking New Ground
CBA	Cost Benefit Analysis
CBS	Conventional Building System
GEAR	Growth Employment and Redistribution Programme
GSH	Government Subsidised Housing
IBS	Industrialised Building Systems
MCCFM	Multi Criteria Comparative Feasibility Matrix
p.a.	Per Annum
PF	Primary Factor
RDP	Reconstruction and Development Programme
SF	Secondary Factor
SMART	Simple Multi Attributable Rating Technique
STATSA	Statistics South Africa
UN	United Nations

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter introduces the research work conducted in this study by providing an overview entailing the research background and problem statement, the research question and hypothesis. In addition, this chapter discusses the research motivation and rationale as well as the aim and objectives of the research. Furthermore, the methodology, originality and achievements of the research are then highlighted. Finally, the research findings, output and recommendations and a guide to the dissertation are presented.

1.2 Background to Research

South Africa, at the dawn of the new government in 1994, there was 1 formal brick house for every 43 Africans. Thus, the new South Africa inherited an estimated housing backlog of 1.5 million units. In 1994 the African National Congress (ANC) adopted Reconstruction and Development Programme (RDP) which is a policy framework for socio-economic integration, targets were set at 320,000 houses to be built per year and at least 1million houses over five years (Knight, 2001). Between 1994 and 2001 about 1.129 million houses have been built, despite these efforts 2 to 3 million houses were still needed (Department of Housing, 2001). Mthembi Mahanyele, the former housing minister, stated that the housing delivery would slow down due to quality issues and tenure difficulties (Streek, 2001). This shows that government housing initiatives had realised housing difficulties in sustainable production, quality and tenure.

In 2004, the department of housing provided a 'White Paper' legislation entitled 'A New Housing Policy and Strategy for South Africa', reflecting on pertinent issues on the low cost housing situation in South Africa. This document highlighted the issue of inadequate supply of housing, indicated its constraints and provided for further development initiatives as well as indicating the need for more rapid construction of houses.

It is difficult to define the term 'Industrialised Building' as any construction process includes materials and items that have been machined or pre-built off site, for example; a brick is made in a factory and so is a roof truss, even a nail could be classified as industrialised. A suitable definition; 'An Industrialised Building System (IBS) is one of which the major components of a building are manufactured and erected by mass production technique.' (Reddy, 1987).

John Manning, an Englishman from the 1830s, manufactured 'Portable Colonial Cottages' for the West coast area of Australia (Herbert, 1984). A desperate need for housing followed the Second

World War; this initiated the mass production of prefabricated multi level houses. However, these buildings were dull and very basic creating a negative stigma amongst its residence. Furthermore, in the 1960s, parts of England, Germany, USSR, and Japan heavily engaged in the production of industrialised high rise low cost housing, which painted a grey impression of the neighbourhood and in some cases reports of collapsing panels rendered this building system unfavourable (Gelman, 1988).

In Pakistan, during the 1970s and early 1980s, prefabricated low income housing was introduced, the quality and safety was substandard and the projects became a huge failure (Associated Press of Pakistan, 2002). The Self Contained Housing Delivery System (SCHD) is a type of semi industrialised building process that has been developed by the Asian Institute of Technology Bangkok (AIT) this system had been successfully used for low income housing projects in developing countries (MOST Clearing House, 2005). Local studies include economic and technical evaluations on Industrialised Building Systems (IBS), Conventional Building System (CBS) and the low income housing situation in South Africa. International studies on this topic include third and first world housing issues, a wide history on industrialised housing in developed countries and technical studies on prefabricated houses. So far no found literature has linked South Africa's low cost housing problem with industrialised building systems, providing a gap in South African literature.

1.3 Problem Statement

Housing the poor is one of the greatest challenges facing the South African Government. Despite government initiatives the problem of maintaining the supply and quality of housing persists. This problem could be attributed to a number of reasons; Labour, Materials, Control, Governmental, Technological and Economical.

- Factors contributing to the labour problems are: skills shortage, low education levels, labour productivity and inadequate artesian training.
- Factors of the material problems are: cement shortages, material price hikes, delivery costs, wastage and material related delays.
- Factors of the control and management problems are: on site supervision and quality control, project progress control and budget control.
- Governmental issues involve the controlling and management procedures as well as labour, these issues are focused on: skills training initiatives, corruption in housing subsidies and tenure, housing policy implementation, appropriate land use, planning schemes, community

based organisations and corporate social responsibility structures (Department of Housing, 2006).

- Technological issues involve; the building production rates, implementing new technological advancements for construction and building efficiency.
- Economical issues involve building material and labour factors, these include; land and house prices, general building production and fiscal policies (ABSA, 2007). Material prices inflate building costs as cement prices have increased 7.2 percent, timber by 12.5 percent, aggregate crushed stone by 9.5 percent and basic forms of aluminium lifted 29.6 percent (Jacks, 2006).

In 1994 the new South African government made a commitment to reduce the housing shortage. The government promised to build one million houses a year but consistently falls short of its commitment. By July 2001 approximately 1.43 million as opposed to 3 million houses were completed (Radikeledi, 2006). This implies that the government severely underestimated the actual housing production rate. Labour, materials and control have proven problematic for conventional construction, yet how would these factors fare for IBS? To reduce the housing backlog the productivity rate needs to exceed the demand rate for housing, thus setting time as a main objective. However, quick conventional construction and poor workmanship greatly compromises quality and as a result poorly constructed houses are produced.

1.4 Research Question

Could industrialised building systems be a feasible alternative for housing the poor in South Africa? This question is the initial singular component that drives this research. The process of research allows this question to disseminate into certain avenues and sub-questions, which when all have been answered will provide an answer for this research question.

1.5 Research Hypothesis

The research hypothesis provides a test to the research. It poses a single question that should provide a simple answer by either stating the hypothesis true or false. For this research the hypothesis is taken from the research aim as it should the question that drives this research. The hypothesis is taken in the negative form as it provides a stronger form of testing. The hypothesis is stated: Industrialised building is not a feasible alternative for housing the poor in South Africa. This hypothesis is tested both quantitatively and qualitatively as the analysis regards both forms of testing.

1.6 Research Motivation and Rationale

The motivation and rationale of this research emerges from the need to support government initiatives towards solving the housing problem for the poor. In addition, the conventional building system currently used proved to produce a substandard product that fails to meet the needs of the increasing demands or satisfies their users.

The motivation of this research is to introduce and utilise the characteristics of industrialised building systems in terms of a quality product, fast supply, reduced labour intensiveness, less skills requirements and better control procedures (Reddy, 1987). This is posed as an approach for solving the housing problem for the poor in South Africa.

In addition the research obtains its significance from responding to government call for an increased research for finding innovative solutions for housing the poor in South Africa. Furthermore this research aims to cover an area of study that received scant attention in construction literature.

1.7 Research Aim and Objectives

This research aims to investigate the feasibility of industrialised building as a strategic approach for housing the poor in South Africa. In order to achieve this aim a research methodology, consists of literature review, interviews and survey questionnaires, is designed to accomplish a number of objectives:

Firstly, literature review is used to:

- Build a comprehensive background of the housing situation in South Africa, the conventional and industrialised building systems with regard to low income housing projects and sustainable development.
- Develop an analysis tool to facilitate reaching an informed decision.
- Identify the criteria for comparing between the conventional and industrialised building systems.

Secondly, interviews are used to weight the importance of each factor of the identified criteria. Three different perspective groups namely: government (initiator and developer), contractor (service provider) and end-user (resident) are interviewed to weigh their own criteria respectively. Survey questionnaires are used to rate the performance of conventional and industrialised building systems according to each factor of the identified criteria. The questionnaires are sent to a sample of

contractors who are directly involved with industrialised and conventional building systems in South Africa.

Finally, the data collected from the interviews and questionnaires are applied to the developed analysis tool to derive a feasibility analysis of the either building system for housing in South Africa.

1.8 Research Methodology

The aim is to investigate the feasibility of industrialised building systems as an approach for housing the poor in South Africa. The research methodology is designed to achieve the above mentioned aim and objectives which consist of literature review, interviews and questionnaires.

1. Literature review is used to review the following topics:
    - The government housing situation in South Africa in terms of: the housing shortage, the rate of the housing demand and housing delivery performance.
    - Conventional Building Systems for low income housing in terms of the following aspects: production rate, physical implications and the problems facing this building system for housing in South Africa.
    - Industrialised Building Systems low income housing in terms of the following aspects: its conceptual theory, advantages, disadvantages, its use in other countries and its potential application in South Africa.
    - Sustainable development with regard to its implications on conventional and industrialised building systems with respect to the following three areas: environmental, economical and social sustainability.
    - The analysis tool is developed so that it achieves the aim of this research. Developing an analysis framework for this study involves investigating and selecting suitable decision making tools. Once an appropriate tool has been selected it is then developed and adapted so to achieve the purpose of this study.
    - Identifying the criteria for the study of each role player in government subsidised housing in South Africa. The criteria is selected in terms of the requirements of each role player and the implications of both building systems with respect to each role player. Identifying the criteria is based on the developed analysis framework.

The purpose of this objective is to develop an understanding and gaining sufficient knowledge to conduct a relevant study for investigating the feasibility of industrialised housing in South Africa.

2. The study surveys are based upon the developed analysis framework. This framework must achieve the research aim, thus it must investigate the feasibility of industrialised building systems for housing the poor in South Africa. The purpose of these surveys is to value the criteria in terms of importance (interviews) and value the comparative objects with respect to the criteria in terms of the performance (questionnaires). The interviews are aimed at representatives of each role player; government housing department, housing contractors and community housing officials. The questionnaires are sent to contractors who are directly involved or have a sufficient background on both industrialised and conventional building systems. The surveys are sent and conducted and the responses are collected.

3. The application of the developed analysis tool is processed. The data from the surveys are placed into the tool so that it can derive an overall evaluation of IBS and CBS in terms of the criteria. As mentioned above the interviews reflect the importance of the criteria while the questionnaires reflect the performance of the building systems in terms of the criteria. The results of the interviews are inserted into the analysis tool purely reflecting a value of importance of each factor of the identified criteria. The results of the questionnaires are inserted into the analysis tool as values reflecting the performance of each building system analysed with respect to each factor of the criteria. Once these values have been inserted the tool will multiply the values of importance with the values of performance to derive a score for each factor of each building system. The building system with the highest score is deemed the better option. This is done for each perspective group's table (government, contractor and end-user). The analysis involves the direct comparison of the results of the analysis framework so to formulate a quantitative analysis. The results between CBS and IBS of the analysis framework are commented and reasoned so to provide a qualitative aspect of the analysis.

The validity and reliability is of importance to this research as data collected from interviews will be integral to the analysis. The validity and reliability will be increased by obtaining facts by quantitative data rather than subjective issues and relying on a wide spread of sources.

This research is limited by the three perspective groups and the criteria identified. The interview sample will be limited to the eThekwini municipal range. Since government subsidised housing is governed by national government the results could be applied to the rest of the country. The sample of the questionnaires will be limited to the housing contractors involved or knowledgeable in both IBS and CBS for housing in South Africa. Potential variances of other areas throughout the country will be considered and will therefore not affect the quality of the research.

1.9 Research Originality and Achievements

Low income housing developments in South Africa are built using inefficient conventional building methods as the production is too slow and provides poor quality houses at high costs. Industrialised building systems could pose as a more practical and effective approach. IBS is a familiar concept and has been proven to be relatively successful for low cost housing schemes in Japan, Soviet Union and Germany in terms of production rate and housing supply (Gelman, 1988). The South African government have favoured labour intensive approaches due to job creation and cheap labour, thus neglecting industrialisation. So far no evident study has investigated industrialised building systems as an approach for low income housing in South Africa. The industrialised low income housing schemes in Japan, USSR, England and Germany have developed high rise apartment blocks, however, industrialised singular houses have generally been unpopular (Herbert, 1984). This adds relevance and interest to the topic as how will singular housing is viewed in developing countries. This study will investigate the feasibility of implementing industrialised low income housing as a new approach for South Africa.

1.10 Research Findings and Recommendations

This research will provide a recommendation on whether industrialised building will pose as a feasible approach for low income housing in South Africa. The results of this study will direct the government to a feasible approach for housing the poor in South Africa. The analysis shows that IBS is more favourable for housing than CBS, which means that IBS offers more advantages than CBS. The main advantages that IBS can offer are: higher delivery rate, better production control, better quality control and a higher standard of adequate services. The main advantages that CBS offers in terms of social housing in South Africa are job creation, socio-economic growth and diverse design and aesthetics. For the government criteria, IBS offers to be most successful in housing delivery and durability, and a hindrance towards job creation. For the contractor criteria, IBS offers the strongest advantage for production cost and product quality, and a hindrance towards initial capital outlay and design flexibility. For the end-user's criteria, IBS offers to be the most advantages towards adequate services and delivery period, and a disadvantage for diverse design and aesthetics.

Further research recommendations are:

- Developing an appropriate Industrialised Building Design for the South African low income housing industry.

- Proposing the most suitable method of implementing IBS for housing the poor in South Africa.
- Investigating the feasibility of Industrialised Building Systems for town house estate developments.
- Optimising Building efficiency through pre-cast concrete panel construction.
- Standardised Quantitative Quality Assessment Techniques.
- Developing systematic quality control procedures through work package management.
- Investigating the efficiency of automotive modular construction for high rise buildings: a property developer's perspective.

1.11 Research Publications

This research resulted in publishing a research paper and book chapter. Copy of each publication is attached in the appendix section and details are below:

- Conrads S.M., Othman A.A.E. (2008) Industrialised Building: Investigating its Feasibility for Housing the Poor in South Africa. *South African Council of the Quantity Surveying Profession (SACQSP) Quantity Surveying Conference 2008 QS + 20/20 Vision Beyond 2010. Midrand, South Africa. 10 October 2008.*
- Othman, A.A.E., Conrads, S.M. (2009) Investigating the feasibility of Industrialised Low-Cost Housing In South Africa. In: Kazi, A.S., Hannus, M. and Boudjabeur, S. (eds.) Open Building Manufacturing: Key Technologies, Applications and Industrial Cases. ManuBuild, pp. 103-127.

1.12 Guide to the Dissertation

- **Chapter 1 – Introduction**

  This chapter introduces the work done in this research. It outlines the background of the topic, the problem statement, relevant assumptions, aim and objectives, relevance of study, research limitations and research methodology.

- **Chapter 2 – Research Methodology**

  This chapter describes the procedures taken to achieve the research aim and objectives. This involves describing the process of conducting the literature review, developing the analysis tool, developing and conduction the surveys, applying the analysis tool, and lastly analyzing the results.

- **Chapter 3 –Literature Review**

  This chapter contains local and international literature from previous written works, research and publications that is relevant to this topic. The literature reviewed contains topics on the housing situation South Africa, CBS, IBS, sustainable development and criteria identification.

- **Chapter 4 – Multi Criteria Comparative Feasibility Matrix**

  The Multi Criteria Comparative Feasibility Matrix (MCCFM) is the analysis tool that is developed for the purpose of achieving the aim of this research. The appropriate analysis tools are investigated and the appropriate one that meets the research requirements is chosen. The steps followed to develop the tool as well as the methodology and application procedure are described.

- **Chapter 5 – Data Analysis**

  This chapter presents and interprets the data collected from the survey questionnaire and interviews. Furthermore, the results of the analysis framework are revealed. These results are analysed quantitatively by direct comparison between IBS and CBS which is shown through graphs. The results are also analysed qualitatively through commentary and reasoning.

- **Chapter 6 – Conclusions and Recommendations**

  This chapter summarises the research work done in this research. Its emphasis is based on the overall findings of the analysis and the application of this research in industry. The recommendations are made to the government housing department, the housing contractors, the home owners and to researchers.

CHAPTER 2

RESEARCH METHODOLOGY

2.1 Introduction

This chapter presents the research methodology designed to achieve the research aim and objectives. It is comprised of the following sections:

- Research Aim and Objectives – stating the aim of the research and describing the objectives that will lead to achieving the aim.
- The Research Process – Provides a definition of this research and explains the process of the methodology.
- The Research Methodology and Methods – Explains the relationship between the methods and the objectives.
- Surveys and Sampling Methodology – This section defines and explains the purpose, reason and sample of both questionnaires and interviews.
- Reliability and Validity – This defines the extent of reliability and validity of the data collected in this research.
- Conclusion – This summarises the research methodology of this research.

2.2 Research Aim and Objectives

The first objective entails review of relevant literature to establish sound background and understanding on the areas and aspects directly related to this research. The literature review is comprised of five aspects, shown in diagram 2.1.

The first three aspects, namely the South African social housing situation, conventional housing and industrialised housing, deal with the areas of the research. The research combines these three areas in order to investigate the feasibility and must therefore be reviewed extensively. The fourth aspect, Sustainable development, applies to all three of the previous aspects. The purpose of this aspect is that the previous three aspects deal with their current, potential situations and direct future implications, where sustainable development deals with the indirect future implications of all the three aspects.

This is an important aspect to consider as social housing has many crucial and severe indirect implications. The fifth aspect deals with the development of the analysis framework. This aspect entails the investigation of appropriate analysis tools and its adaptation to this research. The following aspects and objectives are based on this framework, which makes this aspect crucial for this research. The sixth and last aspect, Criteria identification, deals with the listing and substantiating the requirements of the government, contractor and end-user as well as certain

implications that either building system would offer or cause, if it were implemented, that would directly affect one of the role players.

The second objective, study surveys, involves the composition and conduction of the interviews and questionnaires. The interviews and questionnaires are the aspects that directly perform the survey. They involve the formulation of the questions which is based on the developed analysis framework. The surveys also involve the performing and gathering of the surveys.

The third objective, data analysis, involves the processing and the analysis of the data collected. This objective is comprised of three aspects, the application of the analysis framework and the commentary and analysis of the results. The first, applying the analysis framework, involves the processing the data collected from the interviews and questionnaires and formulating a result. These results are used to analysed the feasibility between industrialised and conventional building systems. This is the quantitative analysis of the research as it directly compares the numerical results and portrays its findings. The third objective, commentary and analysis and results, is the qualitative analysis as the results are reasoned and substantiated.

2.3 Research Process

To investigate the feasibility of industrialised building systems as an approach for housing the poor in South Africa the above objectives are used as a guide for this research process. The research process is a systematic guide to what this research entails, it involves obtaining findings, data collection, developing the analysis and to formulate a conclusion. The objectives and the tasks within each objective are shown in diagram 2.1 above. The objectives follow on from each other so that each objective is dependent on the next; this is also the case for the tasks within the objectives.

2.3.1 Definition of Research

Academically, research is defined as a systematic process of enquiry aimed at increasing the sum of human knowledge. To explain this definition it must be separated and each section explained on its own. The enquiry is posing a question for research and setting the aim and objective of the research. The systematic process in which the research is conducted is implementing the research plan which its purpose is to attain the aim.

The common objective that all research has is to increase the sum of human knowledge. The Research Process defines what stages and tasks the research involves. The aim of this research

explains what type of research this is. The aim is the investigation of the feasibility of industrialised building systems for housing the poor in South Africa. The question this research poses is how feasible is industrialised building systems for housing the poor in South Africa. Both industrialised building systems and government subsidised housing in South Africa are well researched topics. This research joins the two together and places them into a South African context which makes this research original as it has not been done extensively before.

This research requires an extensive literature review since the aspects of this research need to be well defined and understood so that the outcome can be well applied. This research does not explore new issues or explain why something happens, instead it adapts a current issue to a potential situation. The results of this research can be analysed qualitatively and quantitatively. Therefore, this research is clearly a descriptive research. This research is an applied research as it deals with a relevant problem, thus the social housing situation, and investigates a potential solution towards this problem. However, this research also entails qualities of a basic research as it also advances the theory of industrialised building systems for its use in social housing in developing countries. Yet as the title or aim of this research suggests it provides a feasibility investigation for an alternative for the housing problem in South Africa and is therefore mainly focused on an applied approach.

2.3.2 Research Procedure

The research process adopts the following step by step guide, as determined by the objectives.

Figure 2.1 below shows an outline of the objectives and the tasks. The top row shows the three objectives: Literature Review, Study Surveys and Data Analysis. Below these are the respective tasks of the study. This diagram illustrates summary of the process of the study in one glance.

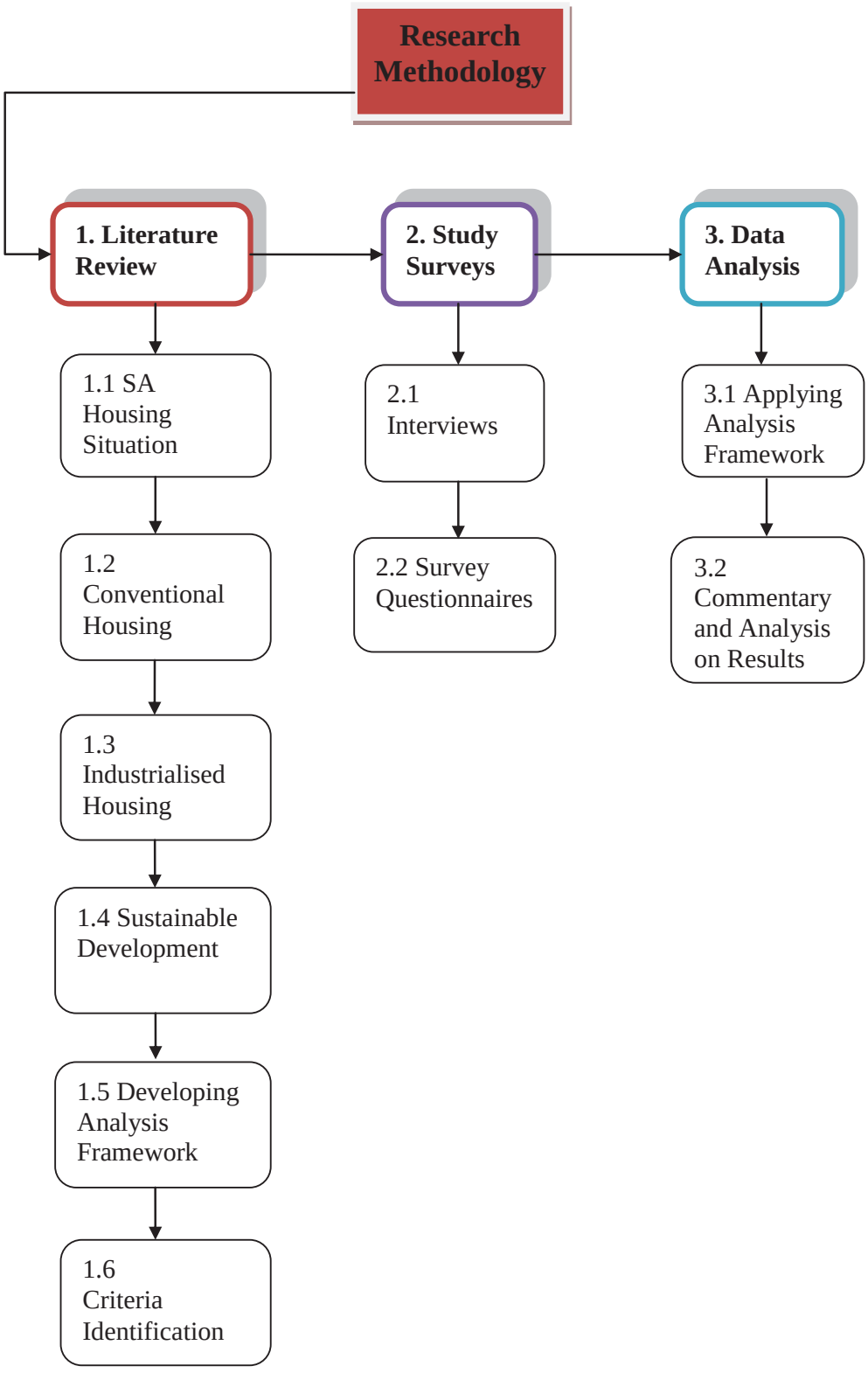


Figure 2.1 Research Methodology

The research methodology is comprised of three main objectives. The first one involves six aspects, the second objective involves two aspects and third objective involves two aspects. These can be referred to the diagram above as the numbering in the text below correlates to figure 2.1 above. These are explained and defined as follows.

1. Firstly, literature will be used to review of the certain aspects that form the basis of the research. The review will include the following aspects;
   1.1 The current housing situation and identifying its problems, this entails; a background on social housing, private and public involvement, future housing plans, housing delivery and housing standards set by government.
   1.2 The conventional building systems used for low income housing: a local background of the implementation and development, the advantages and disadvantages of this system, and the performance in its application for social housing in South Africa.
   1.3 The industrialised building systems: a background of the concept of this building system, it theory and application to low income housing, the potential advantages and disadvantages it can offer in the context of South African social housing.
   1.4 Sustainable development for low income housing; the environmental impact, social sustainability implications and economic sustainability through job creation and other socio-economic implications.
   1.5 The Development of the analysis framework is a crucial component of this research. At this stage sufficient background knowledge has been gathered to understand what type of analysis tool is needed. Applicable decision making tools are reviewed and a suitable one is developed so that it serves the aim of this study.
   1.6 Identifying the criteria used for the analysis by listing and substantiating the requirements of each role player involved in social housing. The criteria identified is for each role player in government subsidised housing in South Africa and is selected in terms of their requirements and the implications IBS would have on their role in government subsidised housing in South Africa.

2. The formulating of the questions for the interviews and the questionnaires are based on the framework so that the surveys will collect data for the analysis framework. This objective deals with the formulating and executing of the surveys. The interviews and questionnaires each play a different role for this study.
   2.1 The interviews and the questionnaires each perform a different task and thus collect different data. The purpose of the interviews is to weight the importance of the various

factors within the criteria identified. These interviews are aimed the three different role players involved in government subsidised housing industry, namely the government officials (developers and initiators), the contractors (service provider) and the end user (resident or home owner). All three of these groups have a different involvement, perspective, purpose and motive for low income housing development which is why each group is interviewed separately with respect to their particular criteria.

2.2 The questionnaires are used to rate the performance of each factor of the criteria for both conventional and industrialised building systems. The questionnaires are sent to contractors who are involved or have a background in both industrialised and conventional building systems. The results of the questionnaires and the interviews are combined in the analysis framework, so that an overall analysis regarding the importance and the performance of the criteria can be achieved.

3. The process of the data analysis takes the following steps:

3.1 The results of the questionnaires which rate the performance of the criteria provide two aspects of the analysis. The first is the level of performance for each factor can be measured and compared against the other factors of the criteria. The second is that the difference in performance between industrialised and conventional can be measured and analysed. Graphing the results of the questionnaire on a bar graph is the most suitable way of illustrating the results. The results of the interviews which weight the importance of the criteria for each role player identify the importance of each factor of the criteria. The data collected from the interviews is processed by first converting the raw values to proportional norms and then calculating the weighted averages of each factor, this process derives relative proportional values. These results are analysed by the criteria of each role player on their own. The degree of the importance of each factor is compared and reasoned.

3.2 The values collected from the interviews and questionnaires are applied to the developed analysis tool which is known as the Multi Criteria Comparative Feasibility Matrix (MCCFM). This tool combines the values that reflect the importance (interviews) of each factor and the values that reflect the performance (questionnaires) of each factor. The working of the MCCFM is explained in chapter 4. The results that are produced by the MCCFM are graphed on a bar graph. These results are analysed in terms of the level of the value for each factor and the difference in the result between industrialised and conventional, this is the quantitative aspect of the analysis. The analysis further involves

substantiating and reasoning for the level and difference of each factors results, this is the qualitative analysis.

2.4 Research Methodology and Methods

Table 2.1 below shows the relationship between the research methods and the objectives. The objectives are defined in section 2.2 above and the research methods are defined in section 2.3 above.

Table 2.1 –The Relationship of Research Methods and Objectives

Research Methods		Research Objectives		
		1	**2**	**3**
Data Collection Methods	Literature Review	x		
	Questionnaires		x	x
	Interviews		x	x
Data Analysis Methods	Quantitative: MCCFM			x
	Qualitative: Commentary and Reasoning of Results			x

2.5 Surveys and Sampling Methodology

This section deals with the interviews and questionnaires and explains the following:

1. The objectives and purpose of the survey
2. The reasoning for the type of survey
3. Selecting the survey sample
4. Reliability and validity

The first three components above are explained for the interviews and then the questionnaires each on their own, the fourth is explained for both interviews and questionnaires together. A copy of both the questionnaires and the interviews are attached in the Appendix section as *Appendix – Questionnaire* and *Appendix – Interview.*

2.5.1 Interviews

- **Definition of Interviews**

Interviews are defined as a piece of social interaction with one person asking another a number of questions and the other person providing direct answers. An interview can be structured or unstructured it doesn't, it can be planned or be impromptu, no matter how it is conducted, what matters is that it is a process of gathering data through direct interaction of the information bearer.

- **Purpose and Objectives of the Interviews**

The interviews are based on the MCCFM analysis framework. This framework requires the allocating a level of importance to each of the factors within the developed criteria. Since there are three criteria, one for each role player, three separate interviews are required. An interview directed towards the government, another for the contractor and for the end-user, each with their respective criteria. Each of these three types of interviews asked the interviewees to weight each factor of their criteria from 10 to 50 in terms of their importance. This is important for the analysis as the importance of each factor of the criteria needed to be included in the analysis so that a true reflection could be obtained. A copy of the interviews for the government, contractor and end-user is inserted in the appendix.

- **Reasoning for Interviews**

Interview as the type of survey was selected because of the following reasons:

  - All the necessary sample population were based within close proximity to allow easy access.
  - The criteria needed to be discussed and explained to the interviewees so to ensure an understanding and thus true response.
  - Reasoning for the weighting of importance could be beneficial to the study as well as implied terms.
  - Timeous and guaranteed responses were helpful especially for the interviews as they involved a calculation process.
  - Meeting people within the government subsidised housing industry was interesting and could be beneficial if this research would be implemented.

- **Selecting the Interview Sample**

Three types of interviews were required, thus one for every perspective group or role player. Initially it was planned to conduct five interviews per group which is a total of 15 interviews, however, finding reliable and helpful sources proved to be difficult and consequently only a sample

of four interviewees per group was conducted a total of 12 interviews. The sample for the government sector was comprised of government housing officials from the eThekwini housing department, of which two were project managers and two were civil engineers. The sample of the contractor was comprised of contractors who specialised in government subsidised housing projects, of which three were higher grade contractors and one was middle grade. The sample of the end user was comprised of community housing officials who act as representatives for the residents of the houses. These community housing officials were selected as their duty was to issue houses to the owners, facilitate applications for the houses, process complaints and perform quality checks of the built houses. Furthermore these officials were literate and had an understanding for construction and managerial method for housing.

2.5.2 Questionnaires

- **Definition of a Questionnaire**

'A questionnaire is defined as a set of written questions for respondents to complete themselves. It is a data gathering device that elicits from a respondent the answers or reactions to (pre-arranged) printed questions presented in a specific order.'

One of the real methodological differences between the use of questionnaire and interview is the interaction, which takes place between the researcher and the interviewee.

- **Purpose and Objectives of Questionnaires**

The questionnaires are based on the MCCFM analysis framework. This framework requires that the two options analysed, thus industrialised and conventional building system, must be allocated a level of performance for each relative factor of the criteria. Therefore the questionnaire requests to rate the performance of each factor for industrialised and conventional from 10 to 100. The questionnaire is regardless of the three role players as their function does not involve the performance of conventional and industrialised. The questionnaire obtains these values of performance which are directly inserted into the MCCFM framework, since each value rated is relevant on its own it does not need to be proportioned or weighted. All the results of the questionnaire are averaged before they are applied to the framework. A copy of the questionnaire is inserted in the appendix section.

- **Reasoning for Questionnaires**

Questionnaire as the type of survey was selected because of the following:

  - The sample was spread all over the country which would make it difficult to meet for interviews. The sample locally was not big enough to form a valid sample size.

- Questionnaires required less time and allowed a larger sample size.
- The questionnaire was relatively simple and easy to perform.
- It is certain that the sample was fully literate.
- Email made sending and receiving the questionnaire a simple task.

- **Selecting the Questionnaires Sample**

The questionnaires are directed at contractors who are either involved or have sufficient background of industrialised and conventional building systems for housing. The sample was identified and selected from the South African Yellow Pages under prefabricated building (Yellow Pages South Africa, 2008). The identified sample was investigated by reviewing their websites and or phoning to ensure applicability. The sample was limited to South Africa as foreign countries could not be expected to have knowledge of the conventionally built government subsidised houses of South Africa. A total of 12 samples were selected of which only 5 had responded.

2.5.3 Reliability and Validity

The validity and reliability is of importance to this research. In order to increase the validity and reliability of research methods and findings, ranking and rating questions in both the questionnaires and interviews helped minimise the risk of potential subjectiveness and biasness towards the factors analysed and a particular building system. Furthermore, meeting people who are directly related to the research problem (i.e. government housing officials, housing contractors and community resident officials) helped increase the reliability and validity of collected data and research findings.

2.6 Conclusion

The aim of this research is to investigate the feasibility of industrialised building systems for housing the poor in South Africa. There are three objectives that fall from this aim, these are: reviewing literature in the aspects of the research, survey studies, and data analysis. This research is defined as descriptive and applied, because it adapts a current issue to a potential situation. The research procedure follows the order of the objectives. The first objective entails the review of literature of the following aspects: (i) the housing situation in South Africa, (ii) conventional building systems, (iii) industrialised building systems, (iv) sustainable development, (v) developing an analysis tool, (vi) and lastly the identifying the relevant criteria. The second objective entails the formulating and executing of the surveys. This research uses questionnaires and interviews of which each has a different purpose. The interviews are used to weight the importance of each factor of the criteria. The questionnaires are used to rate the performance of IBS and CBS for each factor of the criteria. The third objective is adapting the values of the questionnaire and the interview to the

developed analysis framework. The analysis framework derives results from the values of the surveys which are then analysed quantitatively and qualitatively.

The surveys used, as mentioned above, were questionnaires and interviews, each for a different purpose. The interviews were used to weight the importance of each factor of the identified criteria and are directed at the role players of government subsidised housing, these are the government department of housing, the contractors involved in government subsidised housing and the end-user or residents of these government subsidised houses. The questionnaires were used to rate the performance of the criteria for each building system analysed (IBS and CBS). The questionnaires were directed at contractors who are involved in both IBS and CBS and who have an understanding for government subsidised housing.

CHAPTER 3

LITERATURE REVIEW

3.1 Introduction

This chapter presents an extensive background on the relevant aspects of this research. The information provided in this chapter is collected from existing literature as mentioned in the bibliography and references. The subsections are:

- General Background
- Housing the Poor
- Building Systems Approach
- Sustainable Development
- Discussion
- Criteria for Comparing Between IBS and CBS

3.2 General Background

The state of housing is directly linked to the social-economic condition of the country. Housing is a basic need that is integral in developing basic social structures in our society. The lack of basic needs in urban third world countries hinders social development and therefore reinforces poverty. It is clear that external intervention is required to break away from this poverty cycle. For an underdeveloped country, its ability to provide adequate housing in urban areas is a vital prerequisite for successful industrialisation (Chao, 1970).

South Africa is struggling to meet its own housing needs because the supply of housing is less than the housing demand. Exceeding the demand is a challenge facing the South African government. This is not a challenge that is overcome by a single lesson or a set recipe, it is overcome by the a strategy that encompasses the relevant lessons learnt by similar countries and by intelligent measures that will mitigate the problems that are particular to the situation. A ground breaking industrialist said: “Searching for the answers to the dilemma in a world of potential abundance, a crack in the rear view mirror” (Henry Ford). Not all new problems can be solved with conventional ways. Each solution is tailor made to the problem.

This research proposes industrialised building systems as an approach for housing the poor in South Africa. This country faces a giant housing backlog which, despite the government efforts, has increased. The rate of supply is too slow and the demand needs to be managed in order to meet the backlog. Controlling the demand is a difficult subject as it involves demoting urbanisation,

decreasing population growth and overall poverty reduction, but this is a subject on its own. Thus, rather, for the purpose of this research paper, the main issue of focus will be the supply of housing.

An industrialised building system (IBS) for low cost housing has proved successful in overcoming housing shortages in certain developed countries. However, there is a lack of literature directly linking IBS with public low income housing in developing countries. Therefore, this literature review will separate the housing shortage in South Africa from IBS. It will suggest that further research is directed towards investigating the applicability of IBS for low income housing in developing countries as this is a gap in literature which is relevant to a major global issue (Badir et al, 2002).

IBS is manufacturing orientated construction which increases the building efficiency and therefore increases of the production rate and quality of construction. In contrast, conventional building system (CBS) is the service orientated construction method, which is currently used for low income housing in South Africa (Thanoon et al., 2003). This research topic poses the question: Would IBS be a better solution than CBS as an approach for low income housing in South Africa?

3.3 Housing the Poor

3.3.1 The Lack of Housing for the Poor

Housing the poor is one of the greatest challenges facing the governments around the world, especially for the developing countries. Due to the lack of housing the establishment of slums are gaining momentum. Slums are intolerable human dwellings which can take the shape of make shift of shacks constructed by materials found on rubbish dumps. These slums are inadequate and unsafe building structures which lack basic services, especially water and sanitation, insecurity of tenure, overcrowding and located on hazardous land (UN Habitat, 2003). A house is important for the human being, it is a basic necessity for survival as food and oxygen are, yet it is not only a physical need but is also vital for the social and physiological health of a human being. A house is a place to live our lives, to interact with other humans, to rest, to nurture and feed ourselves, therefore, adequate houses are necessary for our well being. However, slums have a slight positive implication to the development of humanity. Studies have shown that slums are places in which vibrant mixing of different cultures frequently results in new forms of artistic expression. Out of unhealthy, crowded and often dangerous environments can emerge cultural movements and levels of solidarity unknown in the suburbs of the rich (Neuwirth. 2006). In 2001, 924 million people, which are 31.6% of the world's total urban population, lived in slums. This is mainly due to the developing

countries of which 43% of the urban population live in slums, where in contrast only 6% are slum dwellers in the developed countries. The sub-Saharan African region has the largest slum proportion of 73.2%, however Asia has the largest slum population of 554 million (UN Habitat, 2003).

Slums occur from mass urbanisation of the poor rural people, who come to the cities to find better employment opportunities only to find themselves worse off and homeless. Slums or squatter camps form on the outskirts and vacant lands around the city and in some developing countries form majority of actual city. Urbanisation has a detrimental effect on urban population growth and is the direct problem of the housing shortage. The UN-Habitat studies (2003) estimated that around 70 million people moved from rural areas to the city annually. This means that by 2030 we can expect about 2 billion squatters in the world, a third of today's population. The UN suggests that 35 million adequate homes need to be built every year to overcome the slum problem by 2030. This means that 66 houses need to be built every minute, the UN admits that this may be impossible and focus their efforts on poverty alleviation and rural up-liftment (Neuwirth, 2006).

Does this mean that efforts towards supplying houses to eradicate slums is futile or just a matter of utilising the better means? Even if the rate of low cost housing delivery is below the demand, it will still change the lives of a substantial fraction of the homeless. This research proposes a pro-active theoretical approach to maximise the public housing output.

3.3.2 The Housing Situation in South Africa

In 1994, the new South African government made a commitment to reduce the housing shortage, it was promised that 1 million houses were to be built annually. However, consistency fell short of its commitment, by July 2001 approximately 1.43 million houses were built as opposed to the aim of 3million (Radikeledi, 2005). Despite the government housing supply achievements, there remain issues for concern. Many South Africans are still homeless, settlements are located far from job opportunities, shelter performance is poor, layouts are monotonous and services are inadequate (Department of Housing SA, 2002).

Housing under Apartheid

Apartheid's Group Areas Act was a law of segregation allocated areas according to race groups. Blacks could not live in white areas and were forced to move to townships, which were located on the outskirts of the cities. The apartheid regime built very few houses for the Blacks such that in 1994 it was estimated that only 1 formal brick house was built for

every 43 Blacks, this was less than 10% of what was needed. The urban housing shortage that was inherited by the ANC led government and was estimated at 1.3 million houses (Knight, 2001). The ANC realised that lifting the apartheids segregation laws would burst the flood gates of urbanisation, exploding population growth rates and in turn creating substantial housing problems. Action needed to be taken immediately.

Housing the New South Africa

In 1994, the ANC led government has adopted two development programmes: the Reconstruction and Development Programme (RDP) and the Growth Employment and Redistribution (GEAR) programme. Both programmes are integrated socio-economic policy frameworks that co-ordinate governments development efforts into a holistic and common vision of social upliftment (Dept of Housing SA, 1998). The RDP sets out a clear vision for housing, based on its four programmes of: (a) meeting basic needs, (b) developing human resources, (c) building the economy, (d) democratising the state and society. In terms of the housing programme, which is defined by the RDP, 'meeting basic needs' is the dominant programme while the other three have a indirect bearing, on the housing programme objectives.

GEAR is the macro-economic strategy framework to strengthen economic growth from 1996 until 2000. Poverty relief and social development have been recognised as high priority policies in the GEAR framework. It also places a strong emphasis on a systematic reduction of the budget deficit and eliminating government dis-savings. The GEAR frameworks broad parameters within which a stronger economy and sound fiscal structure is formed and supports the attainment of the RDP goals (Dept of Housing SA, 1998).

In 1994 the Department of Housing formulated a White Paper entitled: A new housing policy and strategy for South Africa. This was in response to the RDP framework as it is a policy that aims to contribute to the social-centred development. It marks the nature of the housing environment from a socio-economic perspective, labels the issues and defines the problems of housing the nation. The white paper contains the principle of the housing policy and is enforced by the Housing Act of 1997 and the Urban Development Framework Act of 1997. The following excerpt, taken from the White Paper, defines the holistic motive for social housing: 'Success in meeting the housing challenge will be one of the cornerstones of rebuilding our social structures and regenerating the economy' (Dept of Housing SA, 1994).

Housing as a Basic Human Right

Section 26 (1) of the South African constitution (1996) deals with housing and states that everyone has the right to have access to adequate housing. The term 'adequate', in the context of housing, is the sufficient supply of houses that meet the standards in terms of structural quality, access to services and sanitation, acceptable size per resident and secured legal tenure (Dept of Housing SA, 1998). This sets out the specific right which requires a social public duty which only the government can perform. Section 26 (2) of the constitution provides that the state must take reasonable legislative and other measures, within its available resources, to achieve the progressive realisation of this right. In response to this, the Housing Act 107 of 1997 was passed which provides for the responsibilities across all tiers of government and states that the minister must set out broad national housing delivery goals. In support of these national goals, the minister must also facilitate the setting of provincial and, where appropriate, local government housing delivery goals. The government set their sights on a national housing delivery goal of a peak level of 350,000 units per annum until the housing backlog is overcome with a resource allocation for housing of 1.3% share of the total state budget (Dept of Housing SA, 1998).

The Sustainable Human Settlement Plan

In 2004 the Sustainable Human Settlement Plan – or also known as the Breaking New Ground (BNG) – was approved. As the name may suggest, it is a new framework to plan for sustainable orientated housing delivery service. The Comprehensive Housing Plan for the Development of Integrated Sustainable Human Settlements is a new housing policy to implement the BNG plan. The key aim is ensuring the delivery of affordable housing in sustainable and habitable settlements. The prime target is to eradicate or upgrade all informal settlements by 2014/15. (Dept of Housing SA, 2005, 2007). The BNG utilises housing to achieve a number of socio-economic goals as it directly links housing with economic development and social upliftment (Charlton and Kihato, 2006). This plan includes aspects that the previous policies had lacked, in terms of incremental housing, private partnerships, quality of housing, stabilising the housing market, sustainability and rapid housing delivery plans.

Public Housing in Developing Countries

During the 1960's and 1970's the developing countries attempted public housing initiatives to overcome the housing problem. Inspired by the success of the first world public housing projects during the 1950's to 1970's, the developing world followed suit. However, this

quickly stalled as the developing world realised that it would not provide a 100th of what was needed. The first world public housing programmes were in response to the ruins left by the 2nd World War. This meant that, although the same problem was shared, the first world after the war had a developed background and were still rich in human resources, skills and business opportunities. Having a strong economic foundation made rapid development possible and public housing programmes were generously supported. Thus, it was deemed that the first world public housing solution could only work for first world countries and the developing world focused on self-help or private housing. Considering the public housing background between first and third world countries begs the question if public housing is a futile effort for the developing world. However, there are success stories of public housing programmes that have been undertaken by developing countries which have since transformed into developed nations. Singapore has implemented sturdy public housing programmes that have eradicated the housing shortage. Their housing policies and institutions advance systematically and comprehensively with economic growth. Today about 82% of Singapore's housing stock has been built through their housing development board (UN-Habitat, 2003). Countries like Singapore and Hong Kong have shown that public housing programmes for developing countries are not futile and if well managed are more promising than self-helped or private approaches.

3.3.3 Housing Delivery

In 1994, the housing delivery targets were set at a maximum of 350,000 units per annum or a minimum of 1 million units over 5 years. By 2001, seven years on 1.1 million houses were built, a far miss from the set target (Knight, 2001). Are the government delivery targets set too high or are the policies, plans, procedures and implementation thereof not efficient enough? The 1994 delivery target, according to the National Housing policy, was calculated as follows:

- The housing backlog in 1994 was estimated at 1.5 million units, the goal was set to build 150,000 houses a year to overcome this backlog over a period of 10 years.
- New housing formation, in terms of population growth and urbanisation, required an additional delivery rate of 150,000 houses a year so that the backlog would not increase.
- The target was set to build 300,000 to 350,000 units per annum.

This gives reason for the stated delivery targets yet its reality was uncertain at the time (Dept of Housing SA, 1998). In 2001, the housing backlog was estimated to be 2.5 million houses, this is a 66% increase from the initial backlog. This could have been predicted as the housing delivery rates were half of what was planned as only 1.1 million houses were built instead of 2.1 million (7 years

x 300,000 units). Figure 3.2 shows the housing delivery, in 1998 as 295,811 units were built and in 1999 248,391 units, this proves that the target of 300,000 units is possible. However, 1998 was the highest delivery so far and the housing delivery averaged 208,856 where most years delivered less than 200,000 units. This shows that the target could not be sustained and may after all be difficult to provide.

Table 3.1 Housing Statistics

Housing	Delivery p.a.	Delivery Total	Delivery Rate y/y	Housing Backlog	Demand Rate y/y	Housing Demand	Expenditure p.a.	Expenditure Total
(March)	(Units)	(Units)	%	(Units)	%	(Units)	R,000million	R,000million
1994				1,450,000				
1995				1,555,000	7.78%		R 1,335.2	R 2,186.3
1996				$1,560,000_B$	7.22%	1,560,000	R 931.0	R 3,117.3
1997	$177,611_C$	177,611		$1,694,389_A$	8.61%	$1,990,200_D$	R 1,937.9	R 5,055.2
1998	295,811	473,422	66.55%	1,822,175	7.54%	2,295,597	R 3,135.0	R 8,190.2
1999	248,391	712,813	-16.03%	2,029,328	11.37%	2,742,141	R 3,024.5	R 11,214.7
2000	161,572	874,385	-34.95%	2,375,088	17.04%	3,249,473	R 2,720.6	R 13,935.3
2001	190,643	1,065,028	17.99%	2,550,000	7.36%	3,615,028	R 3,039.7	R 16,975.0
2002	143,281	1,208,309	-24.84%	2,585,219	1.38%	3,793,528	R 3,017.0	R 19,992.0
2003	203,588	1,489,510	42.09%	2,562,596	-0.88%	4,052,106	R 3,762.8	R 23,754.8
2004	193,615	1,611,078	-4.90%	2,497,111	-2.56%	4,108,189	R 4,706.9	R 28,461.7
2005	178,612	1,793,124	-7.75%	2,443,355	-2.15%	4,236,479	R 4,446.0	R 32,056.6
2006	252,834	2,081,694	41.55%	2,312,688	-5.35%	4,394,382	R 3,681.4	R 35,738.0
2007	274,219	2,355,913	8.46%	2,200,000	-4.87%	4,555,913		
2008	186,094	2,542,007						

The figures are from the end of March for their respective years according to the financial year of the housing department, except for 2008 which is taken from the 1 January. The formulation and source for these figures are explained as follows:

- Housing Delivery and Expenditure figures are directly sourced from the Department of Housing (2008).
- Housing Backlog figures are calculated estimates, the calculation procedure:
    - The red Housing Backlog figures (1996, 2001 and 2007) have been sourced from various publications: 1996 – 1,560,000 (Dept of Housing, 1998), 2001 – 2,550,000 (Knight, 2001), 2007 – 2,200,000 (Department of Housing, 2008).
    - These (Red) figures formed the base figures on which the other figure estimates could be calculated on, an example of the formula used is shown below, the figures are taken from 1996-1997:
        - Refer to superscript letters: $A = (Bx1.25^{*})-C$
        - * The 1.25 is a multiplier for demand increase, it is used for years 1997-2000, 1.10 for 2002 & 2003, 1.05 for 2004-2006. These figures are percentages

(thus 1.25 is 125% increase) calculated by taking the mean population growth rate and urbanisation rate for respective year categories. These rates are sourced form Statistics South Africa (1996, 2001 and 2007).

- The Housing Demand formula: D = A-C.
- It is important to note that these figures calculated by the formula are only estimates for the purpose of finding a relative trend line as data to form the graphs below.

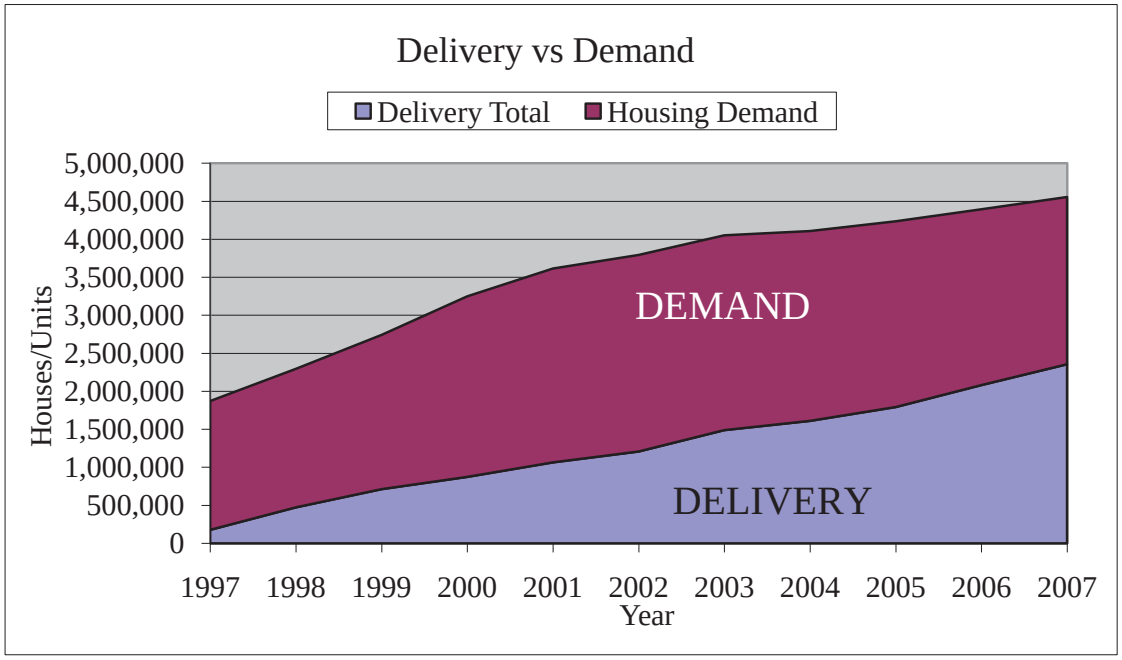


Figure 3.1 Housing Demand vs Total Delivery

The top curve (red area) shows the housing demand where the bottom curve (blue area) shows the housing delivery. The elimination of the housing backlog would be shown on this graph at the point where the supply (blue area) reaches the brim or intersects the housing demand (red area). The space between the housing demand curve and the supply curve is an indication of the housing backlog gap, this is also known as the supply gap. As it can be seen the supply gap in 1997 is smaller than in 2007 this shows that the backlog has grown. The gradients of the slopes are an indication of the rate of growth, therefore the delivery (blue) slope must have a steeper gradient than the demand (red) slope if the housing backlog needs to be overcome. Note that this is not the case in fact the gradient of the housing demand is substantially more than the delivery rate. Table 3.2 below shows the gradient or rate of delivery and demand. From 1997-2001 the demand rate was 184,353 houses per year higher than that of the supply, this has inflated the backlog, and is due to a number of reasons:

- The housing demand grew at a higher rate during this time as South Africa has recently seen the banishment of the apartheid segregation laws, which has led to extreme urbanisation, immigration and growth rates.
- The housing delivery was slow to start but still made substantial volumes.
- More accurate data as a national census was taken in 1996 and in 2001. All further data has been estimated.

From 2001-2004 a positive growth performance as the difference in growth rates stood 17,630 houses per annum. However, the net growth is still too slow to impact on the housing backlog. During the period of 2004-2007 the delivery rate has out-performed the demand rate by 99,037 houses per annum. Even though there is a substantial increase from the previous year, a significant backlog remains, which can be seen on figure 3.1 and is 1 million houses more than the initial backlog in 1996. It is therefore evident that the housing targets set and the performance measured must be according to the net growth in housing supply rather than gross supply volumes.

Table 3.2 – Delivery and Demand Rates

	Rate Houses p.a.		
	Delivery	**Demand**	**Difference**
1997/2001	221,854	406,207	-184,353
2001/2004	182,017	164,387	17,630
2004/2007	248,278	149,241	99,037

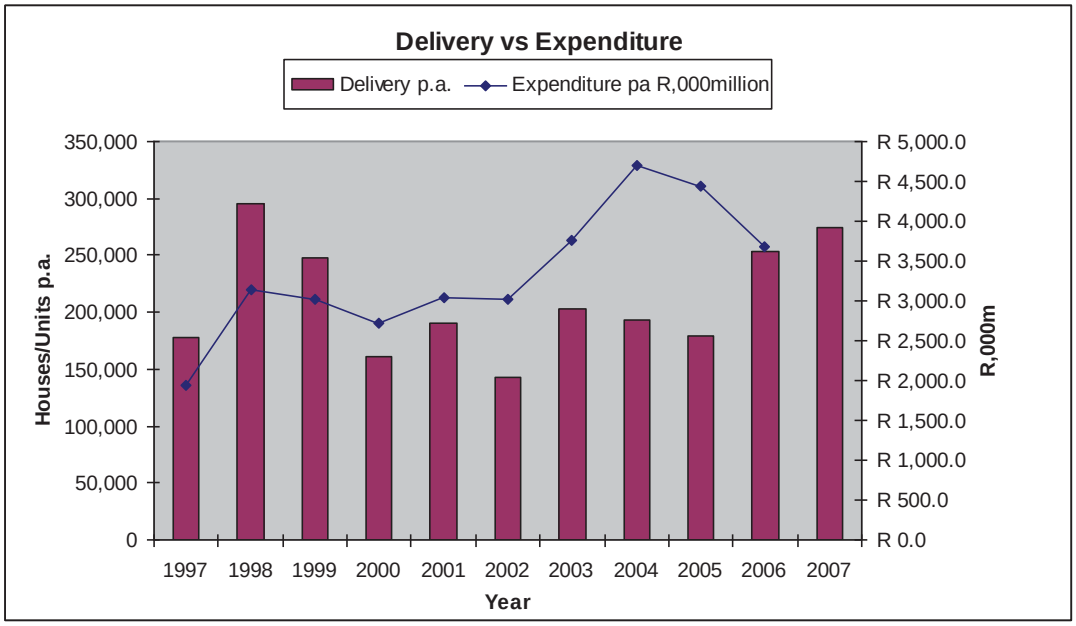


Figure 3.2 Housing Delivery & Expenditure

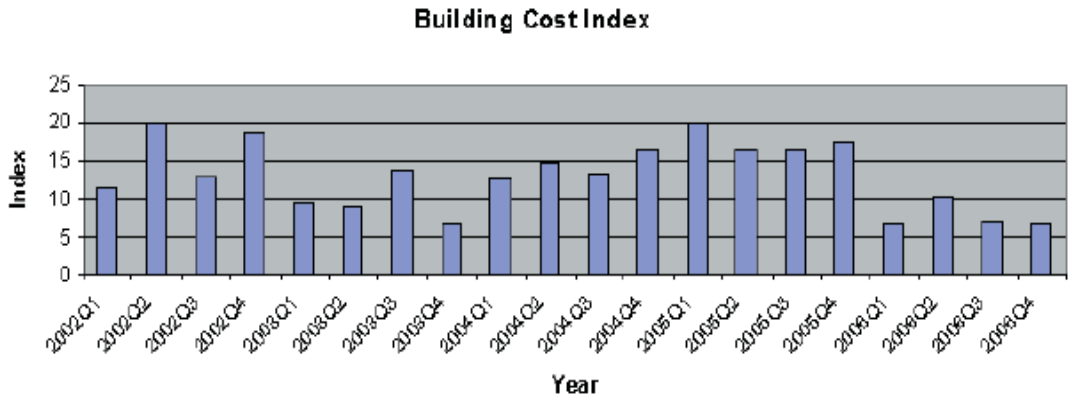


Figure 3.3 Building Cost Index (BER, 2007).

Figure 3.1 shows the delivery per year and the building expenditure for low-income public housing in South Africa. The delivery targets have been set at 300,000 – 350,000 units per year, so far no year has reached this target. Inflation is a potential hindrance to housing delivery as the housing budgets could deliver more houses if inflation were to be steady. Building material inflation, as in Figure 3.3, was particularly high during the booming years of 2004 and 2005. The inflation levels during 2002 have hovered between 13% and 20%, while end of 2004 and throughout 2005 have experienced levels from 16% to 20%. The building cost index in 2006 has become more buoyant with an average of 8.4%. These inflation rates differ from the Cost Price Indices (CPI) as the building cost index is derived from building material escalation and tender competition prices. When a construction boom is experienced the building costs escalate at a higher rate than the ordinary inflation rates.

Escalating prices increase the cost of delivering housing, thereby reducing the value of subsidies. This forces the department to adjust subsidies by a higher margin to ensure that the housing quality is not compromised. The individual housing subsidy has been increased from R23,100 in 2003 to R36,528 in 2006. Furthermore the inflation rates decrease the profit margins of the developers as the subsidies are only adjusted annually making the public housing market unattractive during inflationary times (Dept of Housing SA, 2008). Notice the relationship between the cost price index (Figure 3.3) and the Housing delivery per annum (Figure 3.2) for their respective years. There is an evident inverse relationship as the cost index increases delivery decreases. Years 2002 and 2005 have high cost index levels and subsequently the housing delivery for these years decrease, and thus the opposite for years 2003 and 2006. Furthermore, there is a direct relationship between the expenditure per annum (Figure 3.2) and the cost index.

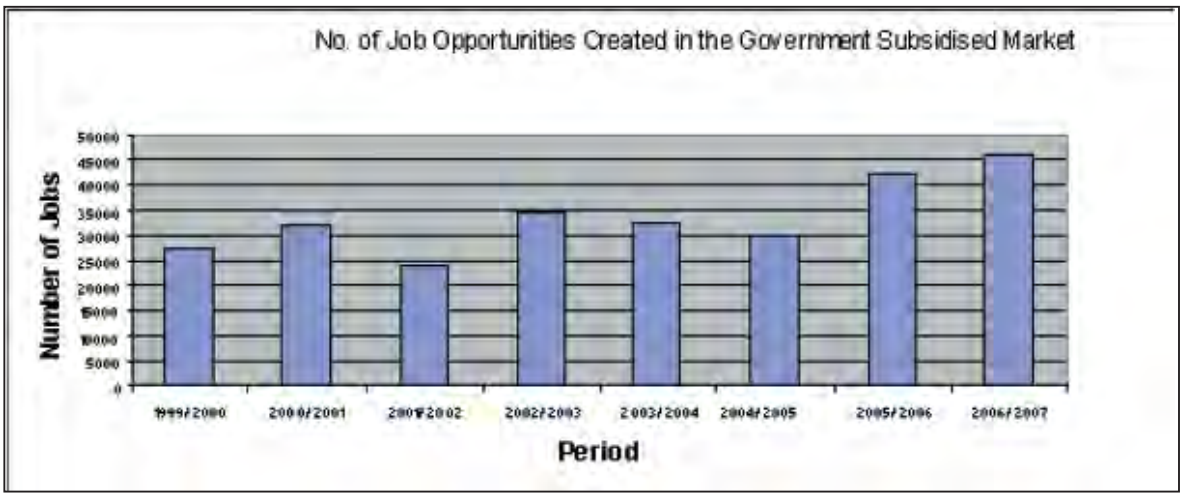


Figure 3.4 – Job Opportunities (Department of Housing, 2008)

The construction sector contributed 8% of the total employment of the country with 1,024,000 people in 2006. Referring to Figure 3.4, out of the total number of people employed in the construction sector 45,676 (4.5%) are job opportunities created by the government subsidised market during the period of 2006-2007. Within the job opportunities created 23,629 (52%) are direct jobs and 22,047 are indirect jobs. Direct jobs involve the actual building of the houses, where indirect jobs are involved with the suppliers who produce the materials and manufactured products utilised for the building process. The number of job opportunities has a direct correlation to the house delivery, as the volume of house construction requires an increase in human resources. This is evident as Figure 3.4 shows a similar pattern to Figure 3.2. In the period of 2006-2007 274,219 houses were produced and 45,676 job opportunities created. This is an average of 6 houses per job over 1 year which has been a consistent ratio between the 2000 and 2007. This is the productivity rate threshold, if this ratio of 6:1, increases then the productivity per employed has increased and will in turn provide better value per house built. If this ratio decreases then productivity and thus value per house would have decreased. One of the aims of the RDP and GEAR is for social upliftment and poverty eradication which supports labour intensive public projects, yet this might very well be a hindrance for performance. South African as labour in is mostly unskilled which in turn affects the productivity and quality of construction. Therefore a greater emphasis should be placed on skills training rather than job opportunities. A learned skill improves human resource and is more sustainable and self sufficient than mere unskilled job creation, which is a better road for socio-economic improvement.

The ambitious Sustainable Human Settlement Plan, also known as the BNG, aim to eradicate all informal settlements by 2014-2015. This requires meeting the housing backlog and covering the housing demand rate over seven years. Unless new and extreme procedures are adopted this goal is unlikely to be met, as the last 13 years has seen the housing backlog double. It is required that 272,356 houses are needed every year to meet the housing demand and 314,286 houses per annum are needed to meet the housing backlog in 7 years, so a total of 586,641 houses must be built every year. This is no small task, and according to the past years the highest delivery of houses in one year was not even half of the new goal. The new BNG includes better housing plans such as incremental housing, medium densities, better control and service. Still will these plans build 600,000 houses a year?

A +	B =	C
272,356	314,286	586,641

A – Is the average housing demand rate from 1996 to 2007.

B – Is the number of houses needed per year to overcome the housing backlog in 7 years.

C – Is the total number of houses that need to be delivered every year in order to meet the goals specified.

NB: these figures are calculated from the data in table 3.1, A = housing demand 2007 less 1996 divided by 11years. B = housing backlog divided by 7 years. C = A plus B. (Dept of Housing SA, 2008)

3.3.4 Housing Quality

The aim of the housing policy is to provide adequate housing for all, the emphasis is on adequacy which, as explained earlier, is the general quality of the building in terms of its structure, size, services, location and ownership rights. Yet the housing policy, before the BNG, focused on scale delivery and securing tenure rather than ensuring quality of the houses. The RDP houses are of substandard quality and in some cases have been unfavourable by the residents. Assessing quality of the housing takes two perspectives, one being the view of the resident, and the other are the technical aspects from research. The resident's view of quality is subjective and only what meets the eye, in terms of construction and structure quality. Therefore although, the resident's view of housing satisfaction is acknowledged, technical construction aspects have a stronger bearing for the purpose of this research. The issues of poor quality in terms of the technical aspects from researchers are as follows:

- Most houses lack internal finishes, bare concrete block walling is not aesthetically pleasing and simple internal finishes make all a big difference in terms of satisfaction and pride of the resident (Monkhi, 2007).
- The location of the houses is dominant in the township areas and, therefore, still seems to reinforce apartheid's geographies. This is due to change as the new BNG policy incorporates inclusionary housing, like the N2 Gateway project in Cape Town (Charlton and Kihato, 2006).
- The RDP houses lack thermal insulation. In research conducted by Makala, (2006), which compares RDP houses with traditional stone-clay houses, found that the traditional houses present better thermal conditions (up to 7°C) than the RDP units. The reason for this was found that the RDP houses used corrugated iron roof sheeting, the absence of ceilings and the use of thin concrete block walls which lacks thermal as well as sound insulation (Makala, 2006). Standard ceilings may be too expensive for the use of mass low-income housing, instead an effective alternative should be found that represents strong thermal insulation and is economical enough for low-cost housing.
- The building structure may in some cases be substandard as the construction of each house is inconsistent with effective construction supervision. This is apparent throughout the construction industry in South Africa. The main structural problems are sagging of foundations resulting in cracking walls, poor sealing between frames and walls and the use of poor materials. Radikeledi (2005) argues that the private sector who build the houses seem to use improper building techniques and standards to cut costs and time. This results in poor structural quality for the same cost of a quality structure (Mancheno-Gren, 2003).
- The RDP square single standing houses are $30m^2$ in size. An average of 4 people per house which is about $7.5m^2$ per person, this is inadequate for a family dwelling. It is from the cubic shape and miniature size that these houses have earned the nickname of 'matchbox houses' (Monkhi, 2007).

Residents of these housing projects are dissatisfied with their houses, displeased that the housing units are smaller than their previous informal structures, the houses are poorly built and have inadequate facilities and amenities. Consequently many occupants have sold their RDP houses and have returned to their informal settlements (Dept of Housing SA, 2007). A reason for this is that these social housing projects disregard the client's requirements and likes when planning the housing layout, design and position. However, government housing is expensive and in order to make it feasible a standardised mass housing approach is adopted making it difficult to deliver a

different type of house for each resident. It must be noted that social housing is providing a survival need and not a luxury, therefore the UN-Habitat (2003) has set the definition of adequate housing. Adequate housing acknowledges that the purpose of a house is not merely for shelter and privacy but also a dwelling which is a place to live, and therefore must have adequate facilities, size, quality and location. Deprived habitats and weak social family like structures have a strong negative influence on future social behaviour and is therefore an important socio-economic upliftment factor (Abdelatif and Othman, 2006).

The security of tenure as a core objective for a policy does not necessarily improve the lives of the poor; instead a systematic delivery of quality houses to the poor is more effective. The security of rights of property is a tool for poverty alleviation and is only helpful once a reasonable house is delivered as the property right is used for mortgage security or rental to generate income in various ways. This can only be effective if the house is of reasonable quality to strengthen market value. The market value of a house is determined by the location and its land use still it is a matter of supply vs demand. In terms of low income housing supply is dependant on the housing delivery and the demand is dependent on the backlog. If the government reaches its goal for eradicating informal housing such that no backlog exists, then the demand will drop along with its value, and as such will, therefore, be useless as a poverty alleviation tool (Buckley and Kalarickal, 2005). Mancheno-Gren (2003) states: ‘the dominant first impression one gets when passing along many of the newly planned low-income housing areas, is a depressing one, as one sees nothing but bare landscape covered by blankets of identical free-standing houses resembling square boxes’. Housing can promote social upliftment, provided, it produces a vibrant neighbourhood with houses of different character, encouraging pride. The BNG has recognised this as a problem and in response has implemented inclusionary housing policies, increased the housing density and improved sustainability.

Figure 3.5 Typical government houses (Solomon, 2005)

Figure 3.5 shows a typical government subsidised housing development. Notice the monotonous design, the poor township planning, no landscape and the sheer size of such a development. The houses have corrugated iron roofs, paintwork is showing the blocks of the houses also the size of the houses. Notice that there is plumbing on the walls.

Figure 3.6 More Pleasant Government Houses (Solomon, 2005)

Figure 3.6 shows the more pleasant view of a government subsidised house (GSH). This just shows that the residents can make a difference to their houses if the pride and effort is there. This lady in the picture had planted a garden around her house, put up a fence and seems to have mended most of the obvious faults. However, the structural quality is difficult, if not impossible, for her to make good on a tight budget. It shows how important it is to do job right the first time, so that people will not be scared of spending time and money on their houses because they know it will last.

3.3.5 Overview of the Housing Problem

This is a summary of the housing problem as explained in the text above. In 2001 there were 924 million slum dwellers in the world and the UN expects that by 2030 that this would increase to 2 billion. It is estimated that 35 million houses would need to be built every year to overcome this shortage by 2030, the UN do not believe this to be possible. Yet if this figure is divided between the most able countries then if 70 countries can build 500,000 houses a year then this goal could be achieved. Since 1994 the new government came into power and certain housing policies and programmes were implemented. The Reconstruction and Development Programme (RDP) and a white paper on the housing policy were produced in 1994, after which in 2004 a revised plan called the Sustainable Human Settlement Plan was introduced. South Africa faces a huge housing problem, in 1994 the estimated housing backlog was 1.3 million units and despite government efforts the backlog in 2007stood between 2.2 to 2.4 million houses. It is evident that the housing backlog is growing faster than what the government can supply.

The Constitution of 1996 states that everyone has a right to adequate housing, and that the government has a duty to supply this right. By 1997 only 177,611 houses were built, by 2001 1 million houses and by 2007 2.3 million houses were built. On average only 208,000 houses were built while the housing demand increases on a gross average rate of 300,000 houses per year and a net average rate of 130,000 (6%) every year. If the housing backlog needed to be overcome then it is important that the delivery rate needs to exceed the housing demand rate and build a further 220,000 houses per year to overcome the current backlog in 10 years.

Adequate housing implies that the housing meets human standards. The low cost houses are poor quality and in most cases substandard. It is not sustainable to produce houses that would need to be replaced in a short period of time. The reason for the poor quality houses is due to management, materials and the workers. The quality control is not consistent and specification checks are not well managed. The labourers are not skilled and produce poor work, inefficient and waste materials.

3.4 Building Systems Approach

3.4.1 Background and definition

Industrialised Building System (IBS) is difficult to define as it can apply to such a broad spectrum in construction and therefore a variety of definitions have arisen. Most definitions have created misconceptions over the years by either suggesting that industrialised building is not suitable as a local application or on the other hand claiming that industrialised building is one of the few panaceas left to solve construction problems. It is therefore necessary to establish a definition that is relevant to the particular study, some suitable definitions are stated:

- According to J. Kitchener (1979, cited by: Reddy, 1987) “IBS is carefully defined Technological and Managerial procedures for the repetitive manufacture and erection of buildings that are unique to and can be identified with particular building companies, i.e. they have, so to speak, ‘Brand Names’ attached to them.”.
- Esa and Nuruddin (1998, Cited by: Hong, 2006) defines IBS as “The continuum beginning from utilising craftsmen for every aspect of construction to a system that use manufacturing production in order to minimise resource wastage and enhance value for end users.” This definition regards the character of the manufacturing process rather than describing the actual classification, thus relating to the concept or the idea of industrialised building in respect of its purpose.
- A similar yet more comprehensive definition by Warswaki (1999, Cited by: Hong, 2006) stated that: “Industrialised process is an investment in equipment, facilities, and technology

with the objectives of maximising production output, minimising labour resources and improving quality while a building system is a set of interconnected elements that joint together to enable the designated performance of a building".

- A definition of the IBS concept that is accepted by the Malaysian construction industry is defined as a construction system in which components are manufactured in a factory, on or off site, positioned and assembled into structure with minimal additional site work (CIDB, 2003a, cited by: Hamid et al, 2007).
- Dietz (1971, cited by: Hamid et al, 2007) earlier defined IBS as a total integration of all subsystems and components into overall, process fully utilizing industrialised production, transportation and assembly techniques.
- Parid (1997, cited by: Hamid et al, 2007) defined IBS as a system which uses industrialised production technique either in the production of components or assembly of the building or both.
- Lessing et al (2005, cited by: Hamid et al, 2007) defined IBS as an integrated manufacturing and construction process with well planned organisation for efficient management, preparation and control over resources used, activities and results supported by the used of highly developed components.
- Trikha (1999, cited by: Hamid et al, 2007) defined as a system in which concrete components prefabricated at site or in factory are assembly to form the structure with minimum in situ construction.
- Reddy (1987) provides a suitable definition: "An Industrialised Building System is one in which the major components of a building are manufactured and erected by mass production technique."
- IBS can also be described as: prefabrication, systems building, modular building or panelised building.

These are but few definitions found for IBS. Defining IBS is a research topic on its own. A recommendation to researchers is to define the sub classifications of IBS in terms of its concept, its process, its character and its use rather than a single holistic definition. The definitions stated above are in context with their research topic. A suitable definition of IBS in light of this research topic is the system of mass production orientated construction with the purpose of optimising building efficiency. In addition to this definition, this research relates to industrialised housing as opposed to industrialised building of a larger context, as housing is a daily human need and an integral part of our social structure, furthermore it is an area where industrialised building can be most

advantageous (Culpin, 1970). For the purpose of this research the expression industrialised building has been used as if it was the same thing as adopting production and management principles developed and applied in the manufacturing industry (Unger, 2006). What has the construction industry learned from the philosophies of industrialisation? Has Henry Ford's mass production renaissance and the industrial revolution left housing behind? These are the questions that form this research.

The concept of mass production focuses on the economies of scale rather than scope. 'The economies of scale is about the benefits gained by the production of large volume of a product, while economies of scope is linked to benefits gained by producing a wide variety of products by efficiently utilising the same operations.' (Bar, 2004). Production has a relevant trade-off between mass production and product variety. Mass production of a standardised product can increase production efficiency but decrease the ability to change aspects of the product with ease as conventional building systems can offer. The theory of mass production technique in contrast with conventional or craftsmen production is that mass production requires a large initial capital outlay yet reaps the reward by an increasing output rate and a decreased cost per unit. The large initial outlay is required to establish the necessary setup for adoption of mass production and resulting in smaller profit margins in the short run yet an increasing profitability over time can find larger profit margins in the long run. This capital outlay is therefore an investment and not an unnecessary cost.

3.4.2 Industrialised Building Systems

IBS is perceived to comprise of three sub systems: Design and information management system, Automated manufacturing and Production system, and lastly Mechanical erection and Assembly system. The first sub system has been well developed, where the last two have been neglected and relatively unsuccessful (Ismial, 2006). This has become evident in the application of IBS around the world and therefore may have received unjust criticism of this concept when it is the improper implementation that had caused the negative effects. This should be kept in mind when reviewing this literature.

Before the 18th century, construction relied mostly on empirical experiences and the expertise of master builders, masons and carpenters. From the 1780's significant change was brought from the effects of the major industries. When coal was used to smelt iron, it brought a massive demand for coal, triggering a new and long line of further developments. The call for the steam engine to transport the coal, found the need to further develop the steam engine to serve its purpose more efficiently. In turn this increased the demand for iron from the rail tracks to the production of the

steam engine itself, and at the same time supported the coal industry. The industrial revolution brought great changes to society, farmers became urban factory workers and horses were replaced with locomotives (Unger, 2006). Iron and steel replaced wood and stone as structural material, and steel frame structures were born. The demand for factory buildings saw the need for the prefabricated steel beam construction, which played an integral role in the industrial revolution.

Industrialisation in building is not a new thing it has been a subject of a growing process over many years, mostly slow-growing but moving at an accelerated pace when political and economic circumstances applied the thrust (Culpin, 1970). A long time ago in the history of the art of building, prefabrication was used in the construction of Egyptian temples and Roman edifices (Hong, 2006). In 1066 when William the Conqueror invaded Britain from Normandy, he brought with him prefabricated forts. The first panelised wood house was shipped from England in 1624 to provide temporary housing for fishing fleets (Culpin, 1970). John Manning, an Englishman from the 1830s, manufactured 'Portable Colonial Cottages' for the West coast area of Australia (Herbert, 1984). In the USA around the 1920s and the 1950s what was known as the Packaged House companies like 'Lustron' and 'The General Panel Corporation' produced 'factory made' steel singular houses, despite the investments interest and promised success it proved to be a dismal failure as only half the houses produced were sold (Herbert, 1984).

The wake of the Second World War left ruins, not only of buildings, but also of thriving economies which was followed by a period of dire need for social housing and economic upliftment (Gelman, 1988). Europe and Japan had seen the worst from the war and needed to rebuild from the ruins left by the bombing, whole cities like Hiroshima and Nagasaki were destroyed. Bearing a massive housing shortage, in response socio-economic rebuilding and public housing became the primary objectives of these governments. This emergency situation left the homeless willing to accept any type of shelter that provided privacy and warmth. Housing became a priority over employment and debt servicing. The idea of industrialised building systems for mass housing became favourable as it posed a strong fiscal tool, rapid production and minimal scaled cost (Culpin, 1970). Large blocks of flats or 'Prefabs' were built using reinforced precast concrete panels, with a high degree of prefabrication. Most of these prefabricated houses were designed to last for 10 years yet they have lasted longer and some still stand today. This is the prime example of industrialised building systems for mass housing (Herbert, 1984).

3.4.3 Application of IBS

After the Second World War the immense housing shortage needed to be overcome. At this time construction methods were to a great extent craft production, which forced governments and housing producers to search for more efficient and faster methods to be able to cope with the situation. As many European countries lacked labour as well as building materials which strained the building capability. Industrialised mass production as a new construction approach offered a way to increase productivity utilising relatively minimal resources and thus seen as a viable solution to meet the enormous housing shortage (Unger, 2006). The history of prefabrication has been described as a record of successful response to the challenge of recurring crises, when local demand exceeds the local capacity to supply (Herbert, 1984). Europe, Japan, America and the former Soviet Union built high rise panel buildings, mostly for housing, schools and administration offices. From a reviewing the background of IBS in housing it is noted that mass production and prefabrication was an important ingredient at certain times. In a different light it could also be stated that the developments in the construction industry have taken place parallel to developments in society and other industries in general, thus when the situation was in need.

Despite actual development, the construction industry is often accused of being stiff and conservative when it comes to adopting new and improved production techniques, management philosophies etc. (Brochner 1997 cited by Unger 2006). Unger (2006) points out two views on the development of the construction industry. The first view claims that the construction development is gradual and that this development turns construction into a modern industry. On the other hand it is claimed that the pace of development is slower in construction than in other industries and so the construction process and its management processes are claimed to have changed little compared to corresponding processes in other industries. The development of industrialised building supported three views: standardisation, prefabrication and system building (Gann, 1996). Standardisation is a prerequisite for mass production. As mass production is the process of manufacturing by forging smaller components at a time by identical repetitive work therefore producing identical products at large volumes. Standardisation and prefabrication involves the coordinating the design of the final product with the manufacturing design. The design of the final product determines the applicability and the use of the product, this is seen as the purpose of the product. Where the design of manufacturing the product determines the economies and the method of manufacturing the product, this is the element of standardisation. Therefore combining final purpose of use with the constraints of the manufacturing technique to determine the overall design objective. System building is the process of assembling or constructing the standard prefabricated components together to form a building.

Europe

In Europe after the Second World War mass precast concrete panel high rise residential blocks were extensively built across Europe. In England, as the rest of Europe, the national economic expansion in the late fifties and early sixties once more revealed a social housing programme that was well beyond the capacity of the building industry to provide them by traditional building methods. Statistics showed that the industry needed to increase its capacity by 55% in ten years in order to supply the demand. However this was unlikely as the labour costs were on the increase and the capacity margins were too small for such an increase. In response industrialised building methods were utilised, as off-site construction would decrease the need for labour and increase the construction pace. During1964 and 1969 at the height of this housing drive, one third of all houses built by the public sector (Lawrence, 1970). England may have had less industrialised building activity than France, Germany, Netherlands and Sweden. The reason for this is that the English had a fear of utilising this building system and therefore never fully committed to industrialised building, which in turn affected the quality and practicality (Glass, 2001). The number of houses completed in the United Kingdom between 1960 and 1968 ranged between 300,000 and 425,000 per annum. Yet only a third are industrialised housing. In the early sixties investors of industrialised building calculated that each factory would require an output 2,000 houses per year per neighbourhood in order to work competitively and economically, this is to justify that the additional capital required for the factory and the production of heavy concrete requirements. In order to make industrialised building feasible each contract must require more than 100 houses as opposed to the average of 50 houses (Lawrence, 1970). The infamous Ronan Point incident, a precast panel high rise apartment block in London partly collapsed due to a gas explosion on the 16th May 1968. This sparked a negative perception about the use of prefabrication although its fault towards industrialised building is arguable (Rodin, 1970).

Figure 3.7 Construction of a Precast Concrete Panel House (World Press Photos, 1965)

Figure 3.7 shows the construction of a typical precast concrete panel house in London. Notice the simple assembly of components and panels.

Scandinavia

In Scandinavia, prefabricated methods for housing construction have a very large share of the market. In Finland, concrete is used in 54% of all new housing; 42% of new homes are constructed using precast concrete (Gann, 1999). Danish company Baderkabiner have been making precast concrete bathroom pods since the 1960's (Glass, 2001).

Former Soviet Union

The former Soviet Union embraced precast concrete panel high rise apartment blocks at massive scales. In 1999 about 170 million people resided in over 70 million apartments of panel buildings throughout central and Eastern Europe and Russia (what used to be the Soviet countries). In 1985, Budapest had 246,213 apartments in 105 panel housing developments, of which some developments had over 15,000 apartments. Around a third of the Czech population lived in a concrete panel block or 'panelák' as it is known in Czech. Bulgaria's Cities have over 1 million panel apartment units (Csagoly, 1999). One of the reasons why prefab high rise apartment blocks became unpopular was because it seemed to reinforce the socialist philosophies of supreme equality and mass standardisation with no sense of individualism. Prefabs had been accepted by people across the world, until in 1989 when the soviet union ceased and the extent of prefabs were shown to the western world, it immediately drew a negative stigma along with the socialist poor. Figure 3.8 shows the housing developments of the panelised apartment blocks extensively built in the Soviet Union and Europe.

Figure 3.8 Panelised Apartment Block (Csagoly, 1999)

Singapore

The fully prefabricated system in Singapore provided a labour saving of 46.5% as compared to conventional system. The "Bayshore Condomium" in Singapore indicated that the construction cycle time for each floor using conventional method was 22 days, which is 14 days more than using prefabricated methods (Cheong, 1996 cited by Thanoon et al, 2002).

Japan

Japanese companies like Toyota and Mitsubishi are known for house building as they are for cars in Japan. Industrialised housing is popular and successful in the Japanese market. Sekisui, a large prefab housing company, builds over 100,000 houses every year and has produced 1.25 million houses since the 1950s. The Japanese market builds eight times more houses than the UK per annum, although the population is twice the UK's. Housing is designed and made to the buyer's requirements and tends to make maximum use of land available for development. Housing itself is thought of as a consumer product, and has a design life of 20 - 40 years only. Thus, prefabricated industrialised housing is perceived as a bespoke, high quality product and customers are also shown evidence of the manufacturing processes involved (Glass, 2001).

Malaysia

Most of the IBS in Malaysia have been established in the early 90s, this is due to Malaysia's ambitious Seventh 5 year housing Plan (Badir et al, 2002). Badir et al (2002) recommends that the raw materials used for construction are made locally without exports, because the IBS industries in Malaysia are facing material shortages due to the sudden rapid construction.

Hong Kong

Prefabrication together with the extensive use of standardisation and modularisation became essential principles in the design and construction of high rise residential towers in Hong Kong

during the 21st century (Yeung et al, 2002). This public housing has made a significant influence on the social and economic development of Hong Kong. It is claimed that this housing programme is one of the outstanding achievements throughout its history. The last 50 years has seen the Hong Kong government commit itself to the sufficient provision of affordable public residential flats to meet the planed housing demand. In order to cope with such an extensive public housing project a 'construction process re-engineering' approach had been adopted, with aims to improve the productivity, cost, quality and overall efficiency. Chan (1998) states: 'This introduction of innovative design initiatives and construction technologies is identified as very influential in enhancing overall construction productivity and the quality of the finished product.' The public housing sector in Hong Kong is an exhibit of the profound success the utilisation of industrialised and semi-industrialised building (*Yeung et al, 2002*).

Israel

In 1984, found that IBS brought a considerable saving in labour up to 70% while the total construction costs saving was 5-8% compared to the conventional construction (Warszawski, 1999 cited by Thanoon, 2002).

USA

In the USA, 30% of all housing is prefabricated. Although the potential benefits of quality, less labour costs and reduced site time prefabrication can offer, buyers had been discouraged by the plain appearance of the panels, risk of water penetration and difficulties of installing insulation. However, in a series of interviews with US house builders, it was found that up to 70% chose industrialised house building on the basis of cost/value alone. The idea of prefabrication is gaining value in the US house building market (Glass, 2001).

Pakistan

During the 1970s low cost prefabricated housing was introduced to Pakistan, however the quality and safety of these units were viewed as inferior. In the 1980s, during an economic boom, large quantities of low cost prefabricated housing units were built. However the quality was unacceptable and the prefab projects proved unsuccessful in turn causing huge financial losses. There had even been a case of a prefab apartment block collapsing, though the reason was attributed to theft of material and poor construction quality. After the devastating earthquake in Kashmir, many houses, schools and clinics had been destroyed. The housing demand was huge and has highlighted the fact that globally there is a massive shortage of

artisans mostly bricklayers. Because of this dilemma more focus is given to systems and semi-industrialised building for low cost housing in Pakistan (Associated Press of Pakistan, 2007).

Venezuela

In Venezuela a new social housing programme has introduced fully industrialised building systems for low cost housing production. These IBS houses called "Petro Casas" are developed by *Pequiven* the state owned oil company. These houses are made from PVC, since Venezuela has large oil reserves PVC is cheap and easy to manufacture. Some 60,000 houses have been produced as it takes 10 days to build. Hise (2007) states: "The residents seem very pleased with their Petro Casas" (Hise, 2007).

Figure 3.9 PVC Development Houses (Hise, 2007)

Figure 3.9 shows the 'Petro Casas' Development of PVC houses. Notice the size of the development.

Egypt

Keivani and Werna (2002) claim the massive initial costs of investment, shortages of skilled labour, materials and foreign exchange for the efficient running of prefabrication factories and importation costs led to much higher costs than alternative techniques. Egypt has shown that the fully industrial and semi-industrial systems are 30 and 10 per cent respectively more expensive than the traditional system (Okpala, 1992, cited by Keivani and Werna, 2001).

South Africa

South Africa has not embraced IBS for housing as much as other countries have. There are cases of classrooms, site offices and other similar buildings, even garden sheds that are prefabricated, yet in light of the mass housing efforts little prefab systems have been considered for mass low cost housing. This is possibly due to certain factors:

- Cheap labour
- Negative public perception

- Only identified with high-rise buildings
- Less job opportunities
- Need for industrialisation
- Substantial investment and high uncertainty for success

Recently the South African department of Housing has provided for 'Fold-away house' as emergency housing. This fold away house is 24cm high when folded and can be erected by a handful of people in less than 5 minutes. The Housing Department (2006) stated that it could also be used as a decent temporary housing while permanent structures were being built (Moodley, 2006). This reveals that South Africa could have the means to be able to produce industrialised low income housing.

Precast concrete panels have been and still are the main use of IBS globally. The highly publicised Ronan Point incident and 'social engineering' of the 1960s has resulted in an unfortunate, but in many instances, unnecessary stigma being attached to industrialised building (Glass, 2001). However, recently, in the light of green building techniques, a revival in the interest of prefabrication for house building is peeking through the clouds.

3.4.4 The Characteristics and Qualities of IBS

In order to evaluate the advantages or disadvantages of a particular item it is necessary to compare it against another similar item or a relative standard or norm. Industrialised building systems can simply be evaluated against conventional construction which is the standard construction practice in South Africa. It must be noted that construction is a heavily interdependent process which makes certain possible theory fallible in reality. Meaning; text books don't necessarily predict the outcomes in reality, especially in construction. Therefore qualities that seem beneficial may be a hindrance in reality. Industrialised Building Systems are most advantageous to the housing sector (Culpin, 1970). There are various types of industrialised building systems, from plastics, steel, wood and concrete to different designs, manufacturing processes, assembly techniques and intention. Each type of IBS has its unique character in terms of cost, insulation, structure, weight and aesthetic appeal (Badir et al, 2002). However, industrialised building has general qualities that apply to all types of IBS, regardless of the material or design. In terms of this research it is the benefits and drawbacks emanating from adopting the concept of industrialised building technique in contrast with the conventional system. The main emphasis on the qualities of IBS is the speed of construction, quality, cost savings and building efficiency (Badir et al, 2002).

Employment

Labour represents a substantial portion of the building costs, up to 40 percent in some countries. Although, South Africa has cheap labour and therefore the portion of labour is less between 10-20%. Not only is the labour expensive but also health and safety requirements, facilities and the administration for labour. IBS requires less labour as most of the work is performed in the factory and therefore the process is mechanised. This labour saving is dependant on the type of industrialisation and the degree of onsite/offsite work (Monsted and Percinel, 1982). More importantly is not the quantity of labour but the quality: less skilled labour is required than for conventional construction. Monsted and Percinel (1982) estimate that up to 80% of labour can be unskilled because much of the work is repetitive and the workers need not to have any previous experience in construction as it is a different process to conventional. On average about 70% of the labour consumption is in the factory, 30% for transportation and on the building site.

Table 3.3 – Labour Efficiency (Monsted and Percinel, 1982)

Labor Efficiency in Precast Construction			
Productivity Area	1958	1969	1979
New buildings (in 1,000 square meters)	3,030	9,045	9,562
Total investment (10^9 D.Kr. [1975])	9 81	27.40	26.70
Investment index (1958)	100	279	272
Total labor force (for new buildings)	45,000	81,950	54,500
Labor index (1958)	100	182	121
Productivity (inv. index/labor index)	100	153	225

Table 3.3 above shows the labour efficiency based on statistics from Denmark for the years 1958-1979. The reason these particular years have been selected is:

- 1958 is the base year in that conventional construction was used, it is for comparison hence the indices are at 100.
- 1969 experienced a construction boom and conventional construction method was used, note the investment index increased by 179%, labour force increased by 82% and as a result 9045 new buildings were built. However, in the light of this substantial investment the labour productivity only increased by 53% which is less than the increase in labour employed of 82%.
- 1979 industrialised building systems became the dominant method of building. In comparison with 1969 which is the conventional construction year the following is noted:

- Real investment index increased by 172%, 7% less than in 1969 this is negligible, the investment injection was about the same.
- Labour employed increased by 21% from 1958, where in 1969 the increase was 82%. This is substantially less than the (61 index points) and shows evidence of the change in the building method.
- The number of new buildings produced was 9562 for 1978, 517 more than what 1969 had produced, yet this is only a 5.7% increase, which is not substantial.
- The labour productivity 125% in 1978 compared to only 53% in 1969. Bearing in mind that the investment was the same, number employed decreased 33.62% (61 index points) and the building production increased by 5.7%. This is a substantial increase in productivity.

It is evident from the table above that industrialised building systems offer higher productivity per labourer with the same amount invested. The point is that industrialised building systems can produce the same volume with fewer resources, and if the amount of resources used in conventional construction were applied to industrialised building then the production would be higher. The onsite production is substantially less than conventional and the factory workers are generally more productive per house produced, this is the reason why the productivity levels are so high.

Management and Professionals

Industrialised building requires less managers and professionals per project, because:

- Plans and drawings are reused
- The building process is well rehearsed and familiar to the staff
- Less labour is employed which requires less employee management and facilities.
- Inspections and quality control can be better implemented as the product is checked as it comes out of the factory.

However, industrialised building uses complex machinery to manufacture the buildings, the maintenance and management of this is vital and is costly, furthermore an industrial specialist may be needed to properly manage the machinery which comes at a substantial price (Gelman, 1988).

- **Costs**

Table 3.4 – Precast vs Traditional (Monsted and Percinel, 1982)

Table 2: Comparison of Costs between Precast and Traditional Construction
(based on March 1980 figures and a 3-story, 14,000 m² scheme)

	Precast		Traditional		Price difference
	Kr/m²	percent	kr/m²	percent	percent
House shell	683	32	761	33	11.4
Exterior doors & windows	88		121		
Wall finish	20	17	59	18	18.0
Other finishes	254		247		
Installations & Fixtures	311	14	314	14	1.0
Normal stories	1,356	63	1,502	65	11.0
Roof & basement	798	37	811	35	1.6
Total building construction	2,154	100	2,313	100	7 4
Site & mobilization costs	173	8	219	9	26.6
Unforeseen contingencies, value-added tax, etc.	1,034	48	1,156	50	11.8
Total Construction costs	3,361	156	3,688	159	9.7

Table 3.4 above is a cost comparison made, in Denmark, of selected items. This is based on a three storey house with an area of 14,000 square meters using March 1980 prices. Prefabrication is 9.7% cheaper than traditional overall, this is substantial when considering the amount of funds involved. The largest cost difference is site and mobilization costs of 26.6% which can be expected, however this should be weighted with the total amount to attain a true reflection. The site and mobilization costs are 5.1% of its total building costs for prefabrication and 5.9% for traditional, a 0.8% difference. An interesting point is building contingencies, an 11.8% difference, this is due to planning and management, industrialised building systems need to be well planned and managed and cannot overlap design and construction which is not the case for conventional. This results in a later construction start date however the production is then quicker for IBS and results in less rework and better managed projects. One issue is that IBS requires a factory where the panels are produced, this is costly and is not reflected in this cost statement. This cost would show as a repayment on a loan or dividends to shareholders, overhead costs, delivery costs, etc. The question is if 9.7% difference would cover this cost (Monsted and Percinel, 1982).

Industrialised building offers savings for finishes compared to conventional building as the concrete panels are cast well cast on a good surface in a factory. This is an advantage as costs are saved by eliminating the need for further touch ups and finishing. This is dependant on the method of industrialised building system and the degree of industrialisation, some general advantages in terms of finishes are listed below (Monsted and Percinel, 1982):

- Screeded or power-floated floors are not needed as the floor slabs are precast in a factory with high quality moulds.
- The mounting of windows and doors are easier and less time consuming as the dimensions are standard so the doors don't need to be planed to size, the frames are easily installed if not pre installed. This saves time, money and ensures better quality in the fitting of the frames.
- Conduits and plumbing lines are cast into the slabs eliminating the need for chasing and saving time for electrical installations.

In the third world, the timber consumption is about 2-3 cubic meters per apartment of 100 square meters making it an expensive item, where industrialised system would not need timber at all. Waste for materials in industrialised building is about half that of traditional building. Better health and safety and quality control. Finishes are not needed as the slabs are cast on a flat surface (Monsted and Percinel, 1982).

Thermonex, a Swedish prefabrication basement company, claim a traditional basement for a detached house would costs about, £50,000, where their basement would cost £28,000 and £15,000 for a semidetached houses (Glass, 2001).

Large initial Capital outlay

In order to implement industrialised building system for large scale housing projects a large initial capital outlay is required to finance a factory and its pricy manufacturing machinery, tools and to train or import specialists that will run the factory. Not only the factory but also transportation the prefab panels is needed, thus trucks and cranes are also needed. Funding this tremendous capital is the main problem for adopting this approach (Badir et al, 2002). However, if funding can be received by joint private and public enterprises then enough capital could be collected, making this approach more feasible.

Material Price Hikes

During the project duration certain material prices will escalate and will increase the contract value. Industrialised building systems can pre order materials which can lessen the impact of material price hikes on the cost of the buildings (Gelman, 1988). Furthermore, the use of standard precast concrete panels allows stocking up for expected price hikes, thus bearing less effect on cement shortages and price hikes. Where conventional requires unmixed cement which has a short shelf life and can therefore not be stocked for long term future use.

Rapid Production and Onsite periods

The builder can take more contracts at a time with less plant, labour and equipment than conventional construction. This is because the rapid production utilises less resources per building and less on site erection periods which makes plant, labour and equipment more available (Thanoon et al, 2003).

Weather delays

Industrialised construction is less weather dependant than conventional construction, as most of the building is built in a factory and less time is spent on site where conventional would spend more time on site thus more reliant on good weather. This is a contingency cost and building duration advantage (Thanoon et al, 2003). Sweden mostly build with industrialised systems as their winter weather is generally unfavourable for casting and curing of concrete (Glass, 2001).

Standardisation

Mass production requires the standardisation of the product, with no exception to industrialised buildings. In order to maximise production efficiency elements of the building product need to be standardised, so machinery and worker's training can be best absorbed to the characteristics of the product (Thanoon et al, 2003). However, conventionally constructed current low income houses are completely standardised, one RDP block house is nearly identical to the next. Industrialised building systems can incorporate a variety without decreasing production efficiency. Different finishes, textures, paint colours, tiling etc. (Monsted and Percinel, 1982). As variety, especially for houses, brings a sense of individualism and prides the resident, which is socially beneficial and important for personal morale.

Lean Construction

Lean production is the philosophy of maximising production efficiency through eliminating waste and streamlining work flows, it also emphasises the need to maximise the efficiency for

both the value adding activities and non-value adding activities. Lean production philosophies can be better applied to industrialised construction as opposed to conventional. This is because industrialised building system is more manufacturing orientated than service orientated (Howell and Ballard, 1999). The materials are standardised and supply deliveries are easier to manage, wastage is minimised and production is more efficient. Just in Time inventory policies and Total quality management can be adopted, this saves costs with no effect to the product. Conventional construction is service orientated therefore making it lean production less applicable (Gann, 1996).

Stigma

People dislike industrialised or prefabricated buildings, it is uncertain what has caused this stigma (Csagoly, 1999). As explained in the introduction to this section that theory is not necessarily reality. Some reasons for this stigma is that industrialised buildings are:

- Not trusted – cases of industrialised buildings collapsing may have scared people.
- Grey image – Identical mass buildings are displeasing to the community, with possible socialist connotation, although an unfair claim.
- Fear – people fear what they do not know. People are used to the idea of having a building built onsite.

Resell Value

Industrialised building systems mass produce houses which floods the market with a large supply of similar houses and in turn could decrease the value of the building substantially. The standardisation and poor stigma attached to industrialised buildings decrease the value. This has been evident in the former soviet nations as the price for the old panel buildings are low yet are not all occupied where newly conventionally built houses of the same standard are more popular (Csagoly, 1999). In terms of public low income housing this may not be a problem, however if housing is aimed at poverty alleviation through increasing credit worth, then this may strike as a disadvantage.

Overview of characteristics

Table 3.5 IBS –CBS Comparison

Comparing Industrialised Building System with Conventional System (Badir et al, 2002)

	Answering percentage of respondents (with reference to conventional system)		
Factors	More (%)	Less (%)	Same (%)
Cost of construction	5	86	9
Cost of transportation	20	50	30
Speed of construction	77	23	—
Save in raw material	55	27	18
Total number of laborers	5	86	9
Unskilled	41	50	9
Skilled	14	86	—
Expert	14	63	23
Initial capital investment	57	10	33
Flexibility of design	59	9	32
Heavy equipment	24	48	28
Ease of erection	68	32	—
Quality of building	95	—	5

Table 3.5 above shows the views, of a selected sample of the Malaysian construction industry, towards IBS in comparison to conventional construction.

The points that are worth noting are:

- Construction costs show substantially less
- High rates of rapid construction
- Less employment of labour
- Less skilled employment
- More capital outlay required
- Very high levels of building quality

This study investigates the feasibility of industrialised building systems as an alternative for low income housing in South Africa. As explained in the introduction, the term Industrialised Building Systems applies to the method of construction whereby the majority is a fragmented manufacturing orientated practice rather than conventional service orientated. There are countless ways or procedures of prefabrication and industrialisation of the building process and each as their own characteristics. Some industrialised systems can offer higher employment rates than others or less capital outlay. This overview illustrates the general characteristics as an average of all these systems combined and examines the implications of this prefabricated building concept on a theoretical level. Ultimately this

shows what this system can offer and how it would differ from conventional construction. The actual application of this system would require a Taylor made industrialised building system to achieve the ultimate benefits according to the requirements, purpose and available resources.

3.5 Sustainable Development

3.5.1 Definition and Background

Glass (2001) defines the term sustainability 'as the need to undertake to change our current ways of working to conserve resources in such a way that the quality of life for future generations is not jeopardised.' This has a direct influence on the way buildings are produced. Sustainability has become an important issue and is beginning to appear in both corporate and legislative documents relating to construction (Glass, 2001). The Sustainable Human Settlement Plan of 2004 is the new South African housing framework which is more orientated towards sustainability than the previous framework (Department of Housing, 2004). It is likely that in the next few years more emphasis will be placed on sustainability and would possibly change the way of construction as we know it (Glass, 2001).

As sustainability in construction, including low cost housing, has become an important issue and requires innovative building technologies that can offer greener solutions for the design and construction process of buildings. 'Sustainability is achieved when a building maintains qualities such as its being: delivered on time, cost effective in both short and long runs, high quality, good indoor environment, durable, cheaper to maintain, and user friendly.' This is seen as a requirement for sustainable construction, and should be included in the building design and construction process. Not only must the establishment of the building, but also its purpose and its use in the long run, meet sustainable requirements (Abdellatif and Othman, 2006). Sustainable development involves different categories, those applicable to low income housing is the Social, Economic and Environmental sustainability, as each is discussed below.

3.5.2 Environmental Sustainability

Construction is major contributor to climate change, resource depletion and pollution (Abdellatif and Othman, 2006). There is a lot of wastage that is caused through building rework, this is not only the material wasted but also the equipment and trucks that need to demolish, clear rubble and the rebuilding. This is highly inefficient and unsustainable. It is because of this that new construction methods are needed to improve efficiency and reduce wastage. Cast in situ work or wet trades have a greater environmental impact than precast construction. This is mainly due to the on site durations

of which the environmental implications are: airborne dust form mobile vehicles, erosion form stripped land, ground pollution of cement spillage, oil, litter etc. (Lo and Lee, 2001).

Materials such as cement are non-renewable resources and therefore its use must be responsible and well managed. IBS consumes fewer resources, as the study above shows, and is more sustainable over conventional systems. Some industrialised or prefabricated panel housing systems allow the whole building to be recycled as the building can be taken apart and rebuilt in a another area. Where conventional construction would need to demolish a building and rebuild it on another site, this is a tremendous waste of energy and resources and is not sustainable (Glass, 2000). Factory production of IBS consumes less energy than conventional construction for similar building size, yet this would depend on the type of IBS. The assembly process of IBS consumes less energy than conventional production (Lo and Lee, 2001). The RDP houses in South Africa have been criticised for poor insulation level and during winter the residents heat their houses by stove, fire or electric heater (Makala, 2006). This is an unnecessary consumption of energy, it would have worked out cheaper to insulate the houses rather than to heat them. IBS would produce standard insulated wall panels thus saving on heating costs.

Veit Dennert, a German prefabricated housing company, can erect their 104m^2 prefabricated house in just 5 days (Kromer, 1999 cited by Glass, 2001). This house only consumes 58 kWh/m^2/pa, which is lower than current energy efficiency standards in Germany. The cost is 25% lower than a similarly sized home built using conventional method.

3.5.3 Social Sustainability

Social sustainability aims to enhance the quality of life, form communities, social cohesiveness, flexibility to future changes and a capable self sufficient environment. The state of housing is a determinant of the society and crucial for community development (Glass, 2001). The RDP housing in South Africa had little regard for the social requirements of its residents and resulted in housing dissatisfaction. There have been cases of people selling their state subsidised house to return to their informal settlement because the quality was better and their informal house was better suited for their needs (Dept of Housing SA, 2007). Fortunately, the housing department have recognised this and in response have implemented a more socially requirement orientated housing policy. A personal social requirement is the need for flexibility so that residents could extend their houses, add different finishes and suit their house for their own needs. Anything that has or will be built has an effect on the local community and therefore society must be considered in planning construction projects (Abdellatif and Othman, 2006).

Industrialised building systems for low income housing can be beneficial to the community as this system can offer more flexibility in extensions and location. A prefabricated house can be taken down and re-assembled in another location (*Glass, 2000*). This is more sustainable as it offers flexibility in neighbourhood or even town layout. Moving areas does not necessarily mean moving houses. IBS, due to its rapid construction, could provide adequate housing in a community in a short space of time. However, as mentioned in the building systems section the prefabricated concrete panel housing left its residents dissatisfied with their houses. This developed into a negative stigma for prefabricated housing (Csagoly, 1999). Yet satisfaction levels are subjective and don't necessarily reflect the actual state of the building. In terms of sustainability it is important that the resident is willing to live in the house so that its occupation is sustained. The standard of quality of the house is important for the human health, community morale and pride. IBS implement more quality management than conventional construction, as in South Africa the current government subsidised houses are of substandard quality, which affects the community and renders those houses as undesirable. This is providing value to the end-user and the community, and thus practicing sustainability on all three levels.

3.5.4 Economic Sustainability

The economic dimension of sustainable construction has two views. The one is the growth in construction industry stimulated by sustainable practices. The other increases the client's profit and increase investment on return. The first point is a long term benefit as increases the GDP by sustainable employment and further wealth distribution (Abdellatif and Othman, 2006). IBS may not create as many employment opportunities as conventional but the employment offered by IBS is permanent and produces a skill, which is more sustainable. Conventional construction in South Africa mostly employs casual labour which is not sustainable. In fact it is a hindrance to productivity and quality. A reason for this is that not much morale and pride can be expected form a temporary job as their efforts are as temporary as the employment time. The productivity and quality is sometimes purposely underperformed as the longer they can delay the completion of their job the longer their employment is intact. This is a problem that is caused by cheap labour and prominent temporary employment, a fiddle that is played by most developing countries. This relates to the first view as explained at the beginning of this section (Hamid et al, 2007).

The second view was return on investment which is applicable to IBS. This is because a large capital outlay is required to establish the equipment and building needed to start production of prefab panels. This is investing funds into a process that could yield higher returns which could be reinvested. Economic strength is important for market sustainability. Sustainable employment,

continuous reinvestment and production efficiency are factors that strengthen the economy and make it more resilient against recessions. This is sustainability towards economic growth and the construction industry at a whole (Hamid et al, 2007).

Providing adequate housing that benefits the residents will increase their morale and thus their productivity which is beneficial to the construction industry. Housing is a building that could also be used to run a small business, as premises thus mortgage or rental is the main hindrance to business success. Entrepreneurship is sustainable economic development which adequate housing could provide. Otherwise a house can be utilised as collateral for a mortgage or a rental income yielding asset. Housing is thus seen as an integral element in poverty alleviation and economic growth.

3.6 Discussion

This research aims to investigate the feasibility of IBS as an approach for low income housing in South Africa. IBS must offer quicker production, more value, better quality and higher degree of sustainability than conventional building in order to make it more feasible. The literature presented above only explains the concept of IBS and therefore the qualities that IBS can offer are taken from a holistic theoretical approach, rather than a particular Industrialised housing process. This grants the research flexibility to its application, as different types of industrialised building can offer different qualities and may be more applicable to different situations and countries depending on the requirements. The conventional building system is evaluated by what it had presented in the low income housing sector of South Africa over the past 13 years, however only the factors that are directly linked to the construction of the houses are regarded. This determines the problems that conventional construction present in its application to public low income housing and identifies the problems that industrialised building would need to overcome as a feasible solution.

The housing policies were also evaluated to determine if the problems presented were in fact due to conventional construction or the policies, furthermore it identifies the requirements for public low income housing which need to be fulfilled by IBS. These requirements are: sustainable development, rapid production, inclusionary housing, adequate housing, security of tenure, allocated budget limits and affordability.

These main requirements, the general application of the construction practices and whether IBS could offer better means than conventional are discussed below. The housing delivery, job creation, quality assurance, value for money and sustainability are the topics that will be discussed below.

3.6.1 Housing Delivery

- The housing delivery is at an average of 200,000 houses a year (1997-2007), which is substantial, but is not sufficient to even cover the housing demand rate not to mention the current backlog. At 2007 2.2 million houses were still needed, which is 60% more than the initial backlog in 1996 of 1.3 million houses. In the light of the new housing policy the aim of eradicating the housing backlog by 2014-2015 requires delivery rate of a minimum of 600,000 houses a year. This is three times as much as the average housing delivery. Unless new procedures and progressive plans are adopted this housing goal is unlikely to be met.

- The Industrialised Building System (IBS) is known for its rapid construction, management control and value.
    - The "Bayshore Condomium" in Singapore indicated that the construction cycle time for each floor using conventional method was 22 days, which is 14 days more than using prefabricated methods (Cheong, 1996 cited by Thanoon et al, 2002).
    - The use of industrialised and semi-industrialised building in public housing sector was a profound success in Hong Kong (Yeung et al, 2002).
    - During the early 1960s Europe faced a lack of housing, it required an increase of 55% in the construction capacity in order to meet the demand. By the 1970s the housing problem was overcome. These houses are apartment blocks which is different to singular housing as in South Africa. Medium to high density construction is more economical per house than singular houses and allows for more rapid construction. Furthermore, high-rise apartments are more sustainable in urban areas as they utilise less space and can therefore be positioned in better employment areas. However, apartments are untraditional to the poor people and are thus seen to be unfavourable.
    - A German prefab housing company can build a $104m^2$ singular house in five days, where conventional construction would take months.

- To date no information is available that could directly compare how many houses could be built, however it is clear that IBS can offer more rapid delivery than conventional.

- In order to meet the housing backlog industrialised building could meet the 600,000 units' p.a. level where this target is unlikely to be met through conventional building systems. IBS is seen as an investment towards more rapid production as the initial outlay is higher the possibility of replacing informal housing with adequate houses is more likely. Where the investment placed in the IBS will reap the benefits for generations to come.

3.6.2 Job Creation

- A study in Denmark (1958-1979) reveals that the labour productivity increased by 125% from conventional with no extra cost or decrease in delivery (Monsted and Percinel, 1982). This study showed that IBS employs 33% less labour than conventional. IBS requires less skilled and unskilled labour. Another study (Badir et al, 2002) showed that between IBS and conventional that the degree of skilled labour required was less than for unskilled. However, housing is a great fiscal tool for wealth distribution, job creation and community upliftment. South Africa, as a developing country of high unemployment rates and few skills is ideal for conventional housing. The South African housing department embrace this fact and require that the contractors employ people from the community of the housing project for the construction of these houses. Job creation is a major requirement of the government and the housing schemes. Yet this might be the cause of a few problems. The employment of the unskilled community members hinder the quality of construction and delay the building process.

- As the studies the have shown, IBS does offer less employment than conventional, which in this case is a disadvantage to IBS. However, the people employed through IBS factories learn a valuable skill that will mostly be required in the future and will be more sustainable than the short term employment offered by the conventional housing job creation scheme.

- The aim of social housing scheme is to provide houses to the poor citizens of this country, who are also temporarily employed to provide them. The philosophy to help people to help themselves is true for poverty alleviation, but has backfired with the self help housing process. The people earn money from their jobs to provide necessities for themselves and their families. Yet the houses that they build are for themselves anyway.

- The new BNG or Sustainable Human Settlement Plan housing policy aim to eradicate all informal housing by 2014 which, judging by the current performance, is unlikely. If this

target is to be met then a more emphasis needs to be shifted to accelerated production and quality control and maybe less on job creation.

- Previous housing targets had not been met but have been celebrated by the government as 'a remarkable achievement' for the number of houses produced. The confusion sets in when the terms *failure to achieve target* and *remarkable achievement* are used for describing the same thing. It is no myth that social low income housing has a strong voter influence and is a brilliant tool for political promotion. It is possible that the housing goals set by the government are motivated by promoting a particular political party rather than actual intention of delivering the stated amount of houses. Job creation is a noble aspiration unlike public deception and hollow promises.

3.6.3 Quality Assurance

- The RDP houses in South Africa are known to be of poor quality, this is the fault of the private and public sector. As the unskilled labour affects the building quality as well as the contractor cutting corners to meet deadlines also has a negative effect on the building quality. The public sector lacks the supervision and management needed to insure the quality of the buildings. Yet this is a problem across all building sectors in South Africa and is attributable to the nature of construction. It is difficult to supervise and manage a large site with varying activities. This is where IBS can offer a beneficial alternative, the components in a factory can be better supervised and the products leaving the factory are checked, therefore better quality assurance. The products are assembled together on site and since the work is a simple standard procedure, which leaves the workers little room for error. IBS requires a smaller workforce than conventional construction, and will therefore be less affected by the skills shortage. However, high standard of skills, though not as many as conventional, are required for IBS as an error caused in the factory can have detrimental effects on the building.

- Not only is the structure of the current low cost houses inadequate but also the absence of finishings, thermal comfort is low and water leakages. Pride is the best fiscal policy, a person that can pride himself, his work, his possessions even though small, can still affect the community around him and will encourage a good morale. A personal spirit is contagious. If good quality houses are delivered, the people residing in them will be more likely to pride and care for their houses. The current RDP houses are delivered without internal plaster and sometimes external plaster in order to save costs. The window and door

joints are not sealed and leak rain. The houses have no ceilings and the roofs until recently have been corrugated iron. As a result the thermal comfort levels of these houses are simply inadequate. The lack of insulation, ceilings and roofing is seen as cost savings, but have should be seen as a necessity to providing adequate homes.

- IBS can build buildings for less due to the efficient and streamlined building production. This cost saving can be used for better quality materials, insulation and finishings. Since IBS could cast slabs on quality factory surfaces and produce well finished slab and panels which would not need to be plastered. The painting of theses slabs and panels can be done for cheaper in a factory. The wall panels can be insulated in the factory and thus save costs. An innovative way to make ceilings cheap and effective is needed for their application to low income housing.

3.6.4 Value for Money

- The less the house costs the more can be produced. IBS can produce houses at a much cheaper rate than conventional construction this is because of production efficiency. However IBS requires production facilities which conventional construction doesn't need. This means that a factory needs to be built, thus a large initial outlay is required before any type of production can be started. Funding this initial capital outlay is a hindrance for the application of IBS.

- In 2006 on average R14,560.00 had been expended on housing subsidies, this does not cover the full cost of the house. The rest would be financed by the owner. The government spends on average R 3 billion on housing. This is 2.5% of the states budget, South Africa is one of the countries with the highest expenditure on housing.
- A cost comparison study, undertaken in Denmark, of selected items showed that prefabrication is 9.7% cheaper than traditional this is substantial when considering the amount of funds involved. The housing sector receives R3 billion of which R300 million would be saved. It is uncertain if this study included the expenses on the initial capital financing. Nevertheless, the end-user can obtain a building at lower costs. Otherwise, the government can afford to build more houses every year from the subsidies.
- Adopting an IBS approach does not mean that the government expends less but that the allocated money can go much further. The subsidies per house would become less but more houses could be built as more are afforded.

3.6.5 Sustainable Development

- **Environmental Sustainability**

  The reductions in waste, pollution, carbon emission, etc are the main factors that need to be considered for environmental sustainability. Industrialised Building is more efficient and greener than conventional. Construction consumes large volumes of cement which is a non-renewable resource therefore it is important that its consumption is minimised and wastage is reduced. Prefabricated panel construction can be recycled, instead of demolition and rebuilding. IBS is generally greener than the conventional. Recently, in the light of climate change, there has been more emphasis on sustainable production, especially for a government backed project this is a good advantage. The new Sustainable Human Settlement Plan or BNG lists sustainable development as one of their top priorities.

- **Social and Economic Sustainability**

  Housing is a tool for social and economic upliftment, as Hong Kong and Singapore Remark that their housing was an integral component to their success. If enough housing is delivered that is of good standard then it will benefit their morale and thus their workplace and the economy. Employment is an important factor when comparing IBS with conventional. The government has always supported labour intensiveness, the contractors enjoy cheap labour but have been discouraged by the administration, poor skills, low productivity and legal parameters of intense labour. The construction industry mostly employs casual labour which affects the labour productivity through job uncertainty. There are many benefits of that IBS can offer in terms of sustainability over conventional construction.

3.7 Criteria for Comparing Between IBS and CBS

The factors that are selected for this study are taken from the literature review through previous case studies, housing reports and various relevant research articles. Since this study aims to critically compare the two systems the factors thus selected are not merely general housing requirements but requirements that relate to the current housing problems in South Africa, the potential application of industrialised building systems and the issues facing conventional systems separately regarding the role of each perspective group. The factors that have been selected for this study are relevant to the social housing process, respective to each perspective group. These factors separately reflect what the housing requirements are for each group. The sources of the criteria are given in table 3.6 at the

end of this section. This table shows the corresponding references to each of the factors. The identification and substantiation is discussed in criteria identification below.

The Government requirements are taken from the Housing reports, policies and commentaries on these policies. There are three major aims of the government: housing delivery, job creation and financial implications, each of these aims have are comprised of smaller requirements and are reflected as factors in this study, each is explained below:

1. The provision of adequate housing – This aim requires a housing supply of a reasonable standard. In the housing reports housing delivery goals are set against a time frame. Their latest aim is to eradicate all informal settlements by 2014 which requires a delivery rate of about 600,000 units per annum (Department of Housing, 2007). This requirement is the delivery rate factor. The provision of adequate housing is not only the delivery rate but also the quality of the houses produced. It is pointless to provide houses that are unfit for human occupation. The term 'adequate', in the context of housing, is the sufficient provision of reasonable houses. This requires that houses must meet certain standards such as: sound structure, service provision (light and water), warmth, shelter, etc. This requirement is reflected in various factors for housing quality, durability and service provision (Department of Housing, 2004).

2. Job Creation and Socio-Economic progression – This aim is broad and is shared with a few tasks, housing being one of them. Housing is a great fiscal tool for socio economic progression. As housing can create a high volume of jobs for unskilled labour and distributes wealth over a large portion of the population. This is a major requirement for the present government as its economic benefits are substantial. The recent housing report shows the total number jobs created, it showed that only 2.5% of the jobs created in the construction industry are direct jobs for government subsidised housing. This is a a small portion. There was no sign of future goals for job creation statistics, this is surprising as job creation is a major requirement for the government housing (Department of Housing, 2007).

3. Financial Implications of housing – The cost of housing subsidies are expensive and currently consumes 5% of the annual budget (Department of Housing, 2007). Decreasing the cost of the construction of houses means that the government can afford to build more houses every year.

The Contractor's requirements are those which make it feasible for private contractors to enter into the government subsidised housing market. Their prime objective is profitability which can be influenced by smaller requirements. These factors are divided into two groups thus what the current housing situation can offer and what IBS could offer. The factors or requirements that relate to what the current housing situation offers is taken from housing policy commentaries, housing reports and case studies. The factors which IBS could offer the government subsidised housing contractors are explained below as these factors also relate to the government and end-user alike.

The End-User's requirements are the necessities for shelter as explained by the definition of 'adequate housing'. Thus, sound structural quality of houses, thermal insulation, durability, space, services and security of tenure. These are recognised by the government and have been are part of the adequate housing requirement. The other requirements the end-user has for housing is the service delivery such as: the delivery waiting period, sanitation, maintainability of the houses, the cost of maintainability, the cost of upgrading (for example: installing a ceiling or plastering walls) and a home for the next generation. These factors have been mainly taken from various case studies on the housing situation and their residents. Other sources include policy commentaries, housing reports etc. Other factors are that have been included in this study are the implication that IBS could have on the end-user, these are explained in the next paragraph.

The purpose of this study is to investigate the feasibility of IBS in Housing in South Africa. It is thus, important to include the relevant implications of adopting IBS as housing system and reflect these as factors in this study. These factors are as follows: sustainability in construction, green practices, resource efficiency, building reuse, Initial capital outlay, manageability, design and construction complexity and maintainability.

Table 3.6 Criteria Identification

GOVERNMENT	Housing Provision	1 Delivery Rate	Department of Housing, 2004
		2 Adequacy & Housing Quality	Department of Housing, 2004
		3 Durability & Structural Quality	Department of Housing, 2004
	Affordability Job Creation	4 Cost per House	Department of Housing, 2007
		5 Initial Capital	Monsted and Percinel, 1982
		6 Job Creation	Department of Housing, 2004
	Sustainable Development	7 Socio-economic Growth	Radikeledi, 2005
		8 Building Reuse & Adaptability	Department of Housing, 2002
		9 Green & Resource Efficiency	Keivani and Werna, 2001
CONTRACTOR	Production	10 Production Cost	Thanoon et al., 2003
		11 Initial Capital Outlay	Monsted and Percinel, 1982
		12 Production Rate	Thanoon et al., 2003
		13 Product Quality	Monsted and Percinel, 1982
	Management	14 Manageability	Hashim et al., 2002
		15 Production Control	Thanoon et al., 2003
		16 Quality Control	Monsted and Percinel, 1982
		17 Skills Dependency	Badir et al, 2002
		18 Labour Intensity	Gibb, 2001
	Physical Implications & Sustainability	19 Design Flexibility	Unger, 2006
		20 Construction Complexity	Badir et al, 2002
		21 Carbon Footprint	Glass, 2001
		22 Resource Efficiency	Huovila1 & Koskela, 1998
END-USER	Time & Future Value	23 Delivery & Waiting Period	Hemson & O'Donovan, 2006
		24 Adaptability & Alteration	Buckley & Kalarickal, 2005
		25 House Value	Keivani and Werna, 2001
	Cost	26 Affordability	Radikeledi, 2005
		27 Maintainability	Radikeledi, 2005
		28 Life Cycle Period	Buckley and Kalarickal, 2005
	Quality	29 Diverse Design & Aesthetic	Mancheno-Gren, 2003
		30 General Quality of House	Charlton and Kihato, 2006
		31 Adequate Service Provision	Radikeledi, 2005

3.8 Conclusion

It is not certain if IBS would succeed in South Africa as there are many types of IBS with varying characteristics. The shortage of research on the use of IBS for housing in developing countries has made it difficult to predict the fate of IBS for housing in South Africa. Still the performance of conventional construction is evident and indeed it hiders the housing delivery capacity then it could only be beneficial to investigate an alternative approach.

The government policies have changed every ten years with new ways and short term goals only for the next ten years without seeing the need for a long term plan, yet the problem has not diminished. Solving a long term problem with a short term solution is futile. The housing problem is a worldwide issue and its solution should be systematic and progressive.

IBS has proven to be very successful in the first world countries yet there are very few cases of IBS housing in the developing countries. Some have shown failures in the past, although more recently success has been claimed in Venezuela. From this literature it is clear that IBS can offer many advantages more than disadvantages when compared with conventional. Yet as mentioned in the introduction: theory is not reality. It is not certain if IBS would succeed in South Africa. The shortage of research on the use of IBS for housing in developing countries has made it difficult to predict the fate of IBS for housing in South Africa Still the performance of conventional construction is evident and indeed it hiders the housing delivery capacity then it could only be beneficial to investigate an alternative approach. After all industrialised construction has been developed for housing.

It is important that the resources spent on housing provide sustainable returns that will benefit the community of South Africa and its generations to come than what monetary value can offer. Housing the poor is a social responsibility and a human need and not a mere requirement.

This study views IBS as the more beneficial building system, especially if the housing shortage is to be overcome. This study focuses on the concept of industrialised housing, however there are varying degrees of industrialised building thus also varying characteristics. This study would propose to develop a particular building system that offers a more rapid production without compromising job creation, quality or durability. The system must still be manageable and must directly benefit the surrounding community. The dream of a factory made house is motivated by its dire need and its potential social benefits. This has led to the imagination of a portable panelling factory which is machined by systematic human labour and in the process providing a specific skill which would then promote entrepreneurship and overall social benefit.

CHAPTER 4

MULTI CRITERIA COMPARATIVE FEASIBILITY MATRIX

4.1 Introduction

This chapter presents the Multi Criteria Comparative Feasibility Matrix developed by the authors to investigate the feasibility of utilising industrialised building systems for housing the poor in South Africa. This chapter includes:

- Development of the MCCFM Analysis Frameworks
- Mechanism of the MCCFM Analysis Tool
- Source of Criteria
- The Analysis of the MCCFM
- Conclusion

4.2 Development of the MCCFM Analysis Frameworks

There are four different decision making tools investigated, these are as follows:

1. Paired Comparison Analysis – This tool is used for directly comparing various options with one another. it compares each option with the one at a time then with each comparison selecting which option is better and by how much, thus on a scale of 1 to 3. Then the values of all the options are added up and the option with the highest value is selected. This tool, however, lacks some of the criteria listed above. Although it directly compares options it doesn't involve analysing each factor. It is less effective for only two options, is not detailed enough and the quantification is too inaccurate for this study. (Mind Tools, 2008)

2. Decision Trees – This tool analyses the course of action of each option. It starts with a decision to take either option then works out all the advantages and disadvantages of following this option. This tool is particularly good for analysing the risks and the options involved with a particular course of action. This tool is not appropriate for this study as it lacks analysing various factors between two options and is difficult to analyse subjective factors. (Mind Tools, 2008).

3. Cost Benefit Analysis (CBA) – This tool, as the name suggests, analyses financial costs and benefits for each option. The analysis is done over a time period where it reflects the costs incurred and the incomes generated over a particular time period. This analysis tool results in a payback period of a particular option. It is possible to quantify a qualitative factor and include compare it to a cost in this analysis however it makes it difficult to form an accurate

analysis. Furthermore, applying a time frame to adopting industrialised or conventional is difficult unless a case study is done, which then confines the study to a particular type of system rather than investigating a concept. A case study is difficult to perform as South Africa has not yet seen mass industrialised housing thus making it difficult to collect specific information. This is a possible tool to use however it is too direct and requires specific information which is difficult to obtain. (Shutt, 1988).

4. Simple Multi Attributable Rating Technique (SMART) – This tool quantitatively evaluates a number of options against various factors. This is done by valuing the importance of each factor and by rating the performance of each option against each factor thus forming a scoring system. The highest precipitated score is deemed the most appropriate option. The systematic and fragmented evaluation makes it possible to analyse the various options in greater detail. This is an appropriate tool for this study as it analyses options against various weighted factors through detailed quantification. It is also applicable to a broad study as it can incorporate a large number of factors and options. It is a detailed and applied enough to from a valid conclusion. (CIRIA, 1996).

The SMART was selected as it compares proposals against a number of factors furthermore it calculates weighted averages for each factor making it accurate when analysing a wide range of factors of different importance.

Social housing in South Africa involves three major role players; these are government, contractor and end-user. Each role player has different requirements for low income housing, therefore it can be said that each role player has a different perspective. It is important to evaluate each role player or perspective separately yet in a manner that is directly comparable between each group so that an overall result can be obtained.

This study requires the analysis of the criteria of each of the three role players or perspective groups separately, therefore it is necessary to develop an analysis framework that will be suitable for this type of analysis. Since a new analysis framework for the purpose of this study is developed it could not be referred to as the SMART analysis but rather a name that is directed to this type of analysis. This new analysis framework is called the Multi Criteria Comparative Feasibility Matrix (MCCFM). This name describes the purpose and the character of this analysis framework. ‘Multi Criteria’ suggests that the analysis framework allows the direct analysis of a multitude of different criteria, which is suited to this study as it analyses the criteria of the each perspective group, of

which each criteria is comprised of a series of primary and secondary factors. 'Comparative Feasibility' suggests that this analysis framework evaluates the feasibility by comparing between the available options. Which is suitable as this study investigates the feasibility between the industrialised building system and the conventional building system. Lastly the term 'Matrix' suggests that the analysis is performed through a matrix. Using a matrix as a layout of the analysis is suitable since the options compared are rated against the criteria. The MCCFM is essentially based on the SMART technique but differs as it encompasses the analysis of the three different perspective groups and formulates a final matrix bring the results of the analysis together so that an overall evaluation can be made. The MCCFM is comprised of four tables one for each of the three perspective groups each with their respective requirements as criteria and a final matrix which summarises the results of the other three tables.

The Government is seen as the project initiator for the low income housing projects. As they implement and fund the housing projects. The requirements for the government are more towards the socio economic progression through job creation and adequacy of housing. Cost is another important factor as the government fund the housing projects, so the cheaper the houses are the more can be built.

The Contractor is seen as the project facilitator as they deal with the actual building of the houses. Contractors are profit orientated organisations and therefore their requirements are towards cost, production and efficiency. The government department of housing requires the contractors to hire labourers from the community of the project. The purpose of this is to maximise job creation. Therefore job creation or labour intensity has become an important factor for the contractors although it reduces potential profitability and product quality.

The End-user is the resident of the houses and is directly affected by its design, quality and layout. The end users requirements are linked to the basic necessities in terms of shelter as the idea for social housing is providing adequate homes for the poor. A home is a place where people can live their lives it must provide security, warmth and shelter. The resident must be able to cook meals, rest and have enough space to live with a family. These are the basic requirements for the residents of low income housing.

The MCCFM works by valuing each factor on a hierarchy basis this is done through the interviews with representatives of each group. The interviewees rate only the primary factors on their own from 10 to 50. Then the interviewees rate the secondary factors within their respective categories

from 10 to 50. The rating is done during the interviews as to avoid any confusion, miss interpretation and provide further clarification.

Conventional and Industrialised Housing are then valued separately in terms of their performance respective to each factor. The valued proposed building systems are then multiplied by the weighted factors to derive a score for each factor. These scores are then all added up and the score with the highest value is deemed the better option, as can be seen in the Total column of each table. A summary matrix provides a final score of each group. This demonstrates that the overall score accounts for the relative importance of each factor and the performance of the building systems respective to the given factor.

4.3 Mechanism of the MCCFM Analysis Tool

Table 4.1 - MCCFM Example

MCCFM	**Primary Factor 1**				
	Secondary Factor 1	Secondary Factor 2	Secondary Factor 3	Secondary Factor n	**Total**
Weighing	W1	W2	W3	Wn	
Conventional	R(c)1	R(c)2	R(c)3	R(c)n	
Score	S(c)1	S(c)2	S(c)3	S(c)n	∑S(c)
Industrialised	R(i)1	R(i)2	R(i)3	R(i)n	
Score	S(i)1	S(i)2	S(i)3	S(i)n	∑S(i)

The working of the MCCFM is fairly simple. This process comprises of 5 steps.

Step 1 – Firstly the factors need to be established this is done by identifying the requirements of each perspective group, thus government, contractor and end-user. These requirements become the factors of the analysis table. The 'primary factor' comprises of related secondary factors, the purpose of the primary factor is to categorise the factors so that they can be weighted within a comparable category. For example one of the Governments primary factors is 'Housing Provision' within this are three secondary factors 'Deliver Rate', 'Adequate Housing' and 'Durability'.

Step 2 – Once all the factors have been established within their primary factor categories the weighting of these factors begins. First the Primary Factors are weighted by importance amongst the other primary factors from 10 to 50 (10 being least and 50 being most). Once the primary factors have been weighted then the secondary factors are weighted within their category in the same way as the primary factors. After the interviewees have weighted the values in terms of their importance their participation is then no longer needed. The values are then converted to relative norms, this is done by dividing the smallest value in the category by a tenth of its own value so that it becomes ten. The proportion of the smallest value to ten, thus the value it was divided by, that same value is then divided by the other factor values in its category to derive a proportional relative norm. For example in diagram 1 below: PF1 is rated 30 and PF2 is rated at 45, PF1 is the smallest thus is divided by 3 (a tenth of its value) so that PF1 becomes 10, PF2 is then divided by 3 so that it becomes 15. The purpose of this is to eliminate any distortion caused by over optimistic or pessimistic valuing by the interviewees. After all the raw data of the interviews have been converted to relative norms, then all the relative values of all the interviewees are averaged to derive one figure for each factor. Then value of each factor is divided by the sum of the values in its respective category this is known as the 1st Weighting. This is done for each category of the secondary factors and for the primary factors. After this the values of the secondary factor are divided by their respective primary factor values to derive a value in the analysis (the bold underlined value in diagram 1 below) this is known as the 2nd Weighting. These values are reflected in the MCCFM table above in the weighting row as W1-4 for each factor. A worked example is shown in Diagram 1 below.

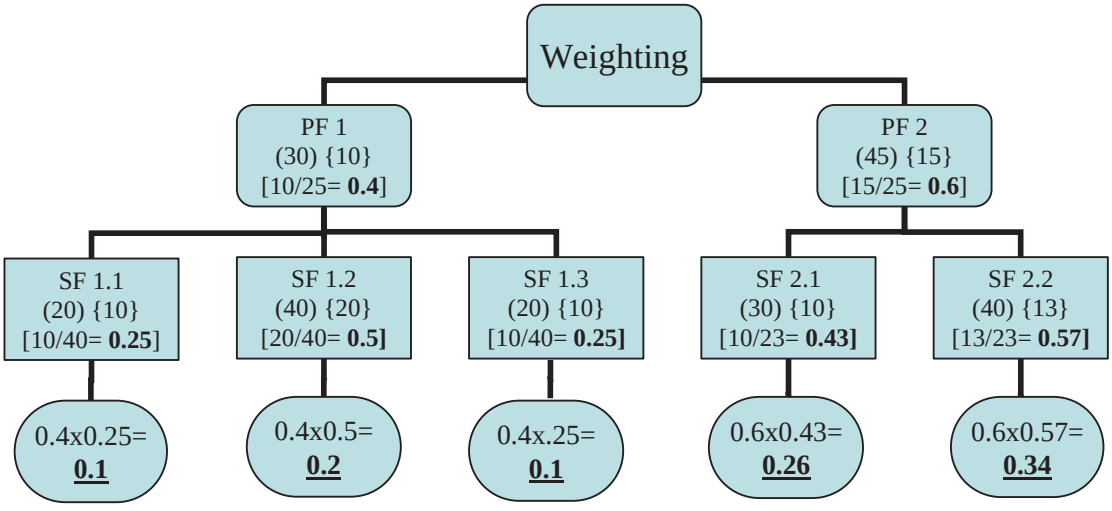


Figure 4.1 – MCCFM Weighting

Referring to the figure above: PF are the Primary Factors and SF are the Secondary Factors. The figures in the round ( ) brackets are the weighted values of importance which are determined by the interviews. The figures in the { } brackets are the relative norm figures. The bold figures in the square [ ] brackets are the calculated weighted averages. The rounded balloons at the bottom level of the diagram are the final weighted values these are shown as underlined and in bold. The final weighted values are calculated by multiplying the PF bold values by the SF bold values. The final weighted values add up to 1 this shows that these final figures are evenly proportioned.

Step 3 – The next step is to rate the compared building types against each factor that has been weighted as explained above. Questionnaires have been sent to a sample of contractors involved in industrialised and conventional housing in South Africa to rate the performance of industrialised and conventional building systems. The rating values each factor from 10 to 100 (10 being least and 100 being most) according to the performance. These values are then inserted in to the MCCFM table under the Conventional building rows and the Industrialised building rows which are shown as R(c) 1-n or R(i) 1-n in the MCCFM example respectively.

Step 4 – Once the performance of each building type has been provided then the values are scored. The weighted values of each factor from step 2 are multiplied by the rated values of the building systems from step 3 to obtain a score for each factor. Referring to the MCCFM Example W1 is multiplied by R(c)1 to obtain a score for S(c)1 and W1 is multiplied by R(i)1 to obtain a score for S(i)1. This is done for all the factors. Once all factors have been scored then all the scores are added together to obtain an overall score for each building system, thus for conventional = S(c)$\sum$ and industrialised = S(i)$\sum$. The values of these two scores are compared and the higher one is the more feasible option.

Step 5 – The above four steps are done for each role player group, thus for Government, Contractor and End-user. Once all three of these tables have derived a final score for the two building types, they are then placed in a fourth and final Summary Table which reflects the score for Government, Contractor and End-user for the two building systems. The values are added together to derive a final score that would decide which building system is the more feasible option.

4.4 Source of Criteria

The criteria is identified through the review of certain relevant literature. Documents such as the housing reports, policies and commentaries provide a clear understanding of what the relevant criteria may be for each perspective groups. Yet the criteria is not only determined by the requirements of each role player but also the implications of adopting either building systems. These implications are important to consider as part of this criteria as it is currently not considered by the role players but if a particular building system were to be implemented then it may cause implications that would affect the role players and should therefore be included in the criteria.

4.5 The Analysis of the MCCFM

The MCCFM are comprised of four tables, one for each perspective group and another for the final matrix. Each perspective group has their own because each group has a different criteria. The analysis must be within their own criteria as the different criteria's do not allow direct comparison. Furthermore, each perspective group is analysed on their own so that an analysis can be taken for each group on their own so that the feasibility can be evaluated for each group. The final matrix takes the scores of each perspective group so that it can be analysed and compared so to obtain an overall evaluation.

The analysis of the MCCFM is comprised of five stages. Each of these stages builds on to the next, it is possible to jump to the last stage and still make a reasonable analysis, however this will not provide a strong and progressive analysis. These stages are explained as follows:

1. The results of the questionnaire is analysed as it provides the study with data that reflects the performance of both industrialised and conventional building systems for each factor of the criteria. This data can be shown in bar graphs which will illustrate the level of performance for each factor and the difference in the performance levels between industrialised and conventional. The analysis of this data will illustrate the performance of the two systems and thus their advantages and disadvantages.

2. The results of the interviews is analysed as it provides the study with data that reflects the importance of each factor of the criteria analysed. This data is illustrated in a table and in bar graphs which will show what factors are regarded the more important ones. This analysis does not regard either building system but purely focuses on the criteria. The importance of

the factors must be read in conjunction with step 1 the performance of the building systems for each factor.

3. The final scores for each factor of the MCCFM analysis combines the data of performance and the data of importance. This step analysis the combination of the analysis of stage 1 and 2 for each factor. This analysis is the most informative as the scores show the importance and performance of the factor against both building systems. While the stage 1 and 2 would only regard the performance or the importance separately this analysis would highlight, for each building system, the advantages and disadvantages that are important for social housing in South Africa. The data of the final scores of the MCCFM are shown in bar graphs for each factor. At this stage each perspective group must still be analysed separately as their criteria is relation to their perspective. This is why three separate bar graphs, one for each group, would be analysed separately.

4. The fourth table of the MCCFM is the Final Matrix, this places the sum of the final scores for each factor of the perspective group. The final matrix shows the scores for the government, the contractor and the end-user. This matrix analyses and compares the value of the scores between the different perspective groups. More so it would analyse and compare the difference margin of the two building systems for each perspective group. This analysis would evaluate the suitability of either building system for each perspective group.

5. The Final Matrix, not only analyses the final outcome of each perspective group but also a final value for the study as a whole. The values for each perspective group are added together to derive a final value for industrialised and a final value for conventional. This analysis is evaluated purely through the difference in the score between industrialised and conventional. The final score summarises the whole analysis into two figures, as each of the stages analyse values that are accounted for in the final value.

4.6 Conclusion

The MCCFM is a tailored analysis framework tool that suits the requirements of this study. It is able to analyse each perspective group separately yet is also able to draw a direct comparison between each perspective group so that a final conclusion can be made. Furthermore, the MCCFM combines the performance of each building system with the importance of each factor.

The workings of the MCCFM are comprised of five steps. The first is the identification of the criteria, the second is weighting the importance of each factor, thirdly is rating the performance of industrialised and conventional for each factor, fourthly is scoring the values in the MCCFM tables for each factor and lastly is the formulation of the Final Matrix.

The method of analysing the MCCFM is comprised of five stages. The first stage is the analysis of the results of the questionnaire, the second stage is the results of the interview, thirdly is the analysis of the scores in the MCCFM tables, fourthly is the overall analysis of each perspective group and lastly is the final analysis of the whole study.

The MCCFM has ultimately formed this study as it determined what type of information was to be collected, the development of the criteria to be analysed, the layout and structure of this report and the method of the data analysis. Since such a framework determines the development and outcome of the study, then the development thereof must be strongly considered.

CHAPTER 5

DATA ANALYSIS

5.1 Introduction

This chapter analyses the data collected from the survey questionnaires and interviews conducted to test the Multi Criteria Comparative Feasibility Matrix (MCCFM). It includes: response rate, analysis of the data gained from government officials, contractors and end-users, summary of findings and finally, conclusion.

5.2 Response Rate

The data used for the MCCFM analysis is collected from questionnaires and interviews. The survey questionnaire was sent to 12 contractors of which 5 have responded this is a 42% response rate. 15 Interviews have been planned where 12 have been conducted.

Table 5.1 Response Rate

	Planned	Response	% Diff	Within 1st Month	Within 2nd Month	Within 3rd Month
Questionnaire	12	5	46%	2	1	2
Interviews	15	12	80%	5	7	

From table 5.1 Questionnaires: For the questionnaires only 46% of the sample responded with a valid response 2 others responded with a blank claiming that they couldn't be of any help. Within the first month of sending the questionnaires 2 had responded, in the second month only 1 had responded and in the third month 2 more had responded. Four respondents replied via email while one replied via fax. Twelve of the fifteen interviews intended were actually conducted which is an 80% margin. Two potential interviewees failed to arrange an interview date within the time needed and contact was lost the one. Five of the twelve interviews were conducted within the first month of arrangement and seven of the twelve were conducted within the second month of arrangement.

5.3 Government Analysis

5.3.1 Analysis of Government Questionnaires

The results of the questionnaire are shown in table 5.2 below.

Table 5.2 Questionnaire Government

Sec	Primary Factor	No.	Secondary Factor	CBS	IBS
GOVERNMENT	Housing Provision	1	Delivery Rate	46	76
		2	Adequacy & Housing Quality	58	78
		3	Durability & Structural Quality	54	76
	Affordability & Job Creation	4	Cost per House	60	68
		5	Initial Capital	58	52
		6	Job Creation	70	48
	Sustainable Development	7	Socio-economic Growth	53	29
		8	Building Reuse & Adaptability	44	54
		9	Green & Resource Efficiency	47	70

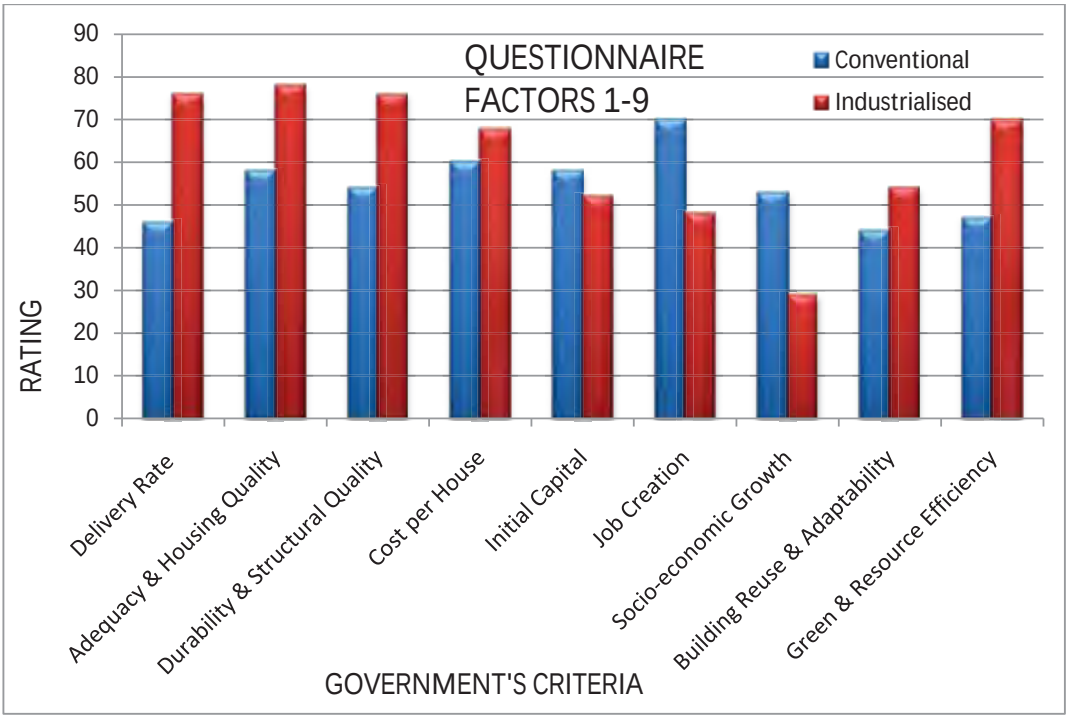


Figure 5.1 Questionnaire Government

This bar graph shows the rating of the factors from the questionnaire. These factors are taken from the government criteria. Each factor is analysed as follows:

- Delivery Rate – Industrialised building systems is a manufacturing orientated construction process and therefore offers the advantage a rapid production process. Conventional construction is only as fast as the blocks and mortar allow. IBS makes use of assembly line production process where rapid production is one of the main advantages. It was expected

that delivery rate would be the highest scored out of these 9 factors, surprisingly adequacy and housing quality has received slightly higher score.

- Adequacy & Housing Quality – The highest scored factor was not expected to be this factor. Both systems could offer similar standard of finishes, services and layout designs, the difference is that industrialised can offer better quality control of meeting standards where conventional has less on site control of such standards. Furthermore, industrialised can fix its conduits and plumbing lines into the walls before the assembly or construction of the house which secures the standard without delay.
- Durability & Structural Quality – This factor should not be confused with the previous factor Adequacy and Housing Quality. As the previous one deals with finishes, services and layout, Durability and Structural Quality deals with the structural standard and the durability. As can be seen in the graph industrialised has achieved a higher performance than conventional. This is due to the quality control measures and production process of industrialised building systems. Conventional is more dependent on the skill of the labourers, the materials used and the quality control measures. Judging by the current housing process the labourers have no experience and the quality control measures are poor.
- Cost per House – The government subsidises the cost of the houses and in most municipalities the full cost is subsidised. Therefore the cheaper the cost of the house the further the subsidy can cover the more can be built. Industrialised has scored higher but only at a smaller margin. Industrialised can offer cost savings through resource efficiency and mass production. Conventional may be cheaper depending on the wage rate and material prices.
- Initial Capital – A main difference between industrialised building systems and conventional building systems is that industrialised requires a considerable amount of capital to establish the process needed for production, thus a factory, equipment and machinery. This is factor is rated inversely to the amount of capital needed as initial capital is a barrier of entry in the housing market. Conventional is rated higher for than industrialised because conventional requires less of a capital outlay.
- Job Creation – Government requires that the contractors employ a certain number of labourers from the community where the project is taking place. Conventional is able to provide considerably more jobs per house built than industrialised. This is because industrialised utilises mechanised production therefore less labour. Conventional is more labour orientated process and therefore offers more jobs.

- Socio-Economic Growth – As these factors are criteria of the government Socio economic growth is an important factor as a fiscal tool for social housing. The performance is relatively low for both building systems this is because housing can only offer houses and short term employment. Conventional has a considerably higher performance than industrialised mostly due to the job creation both direct and indirect. Industrialised building systems could implement certain ways which would add more social benefit.
- Building Reuse & Adaptability – The ability for a house to change and adapt to a different use. Industrialised has a better performance than conventional but only by a small margin. Since IBS constructs houses from larger components and panels the extensions are quicker. In some cases industrialised can recycle their buildings, it can be built in place, taken apart and be rebuilt in another place, similar to a tent. Conventional building system is more able and flexible towards extensions due to the block and mortar type of building.
- Green & Resource Efficiency – The government must consider the environmental impact of housing, even though it is for a dire need. Industrialised has performed considerably better than conventional. This is mainly due to the nature of industrialised building. As IBS is a manufacturing orientated construction it offers better resource efficiency, less wastage and less impact on the building site. The performance is relatively high for industrialised where for conventional it is fairly low. Conventional is dominantly on site and therefore has bigger impact on the environment of the site. Furthermore the greater consumption of cement and the wastage thereof also has a considerable impact on the environment.

5.3.2 Analysis of Government Interviews

Table 5.3 Interviews Government

Sec	Primary Factor	No.	Secondary Factor	Data
GOVERNMENT	Housing Provision	1	Delivery Rate	**0.125**
		2	Adequacy & Housing Quality	**0.125**
		3	Durability & Structural Quality	**0.14**
	Affordability & Job Creation	4	Cost per House	**0.118**
		5	Initial Capital	**0.095**
		6	Job Creation	**0.129**
	Sustainable Development	7	Socio-economic Growth	**0.114**
		8	Building Reuse & Adaptability	**0.073**
		9	Green & Resource Efficiency	**0.08**

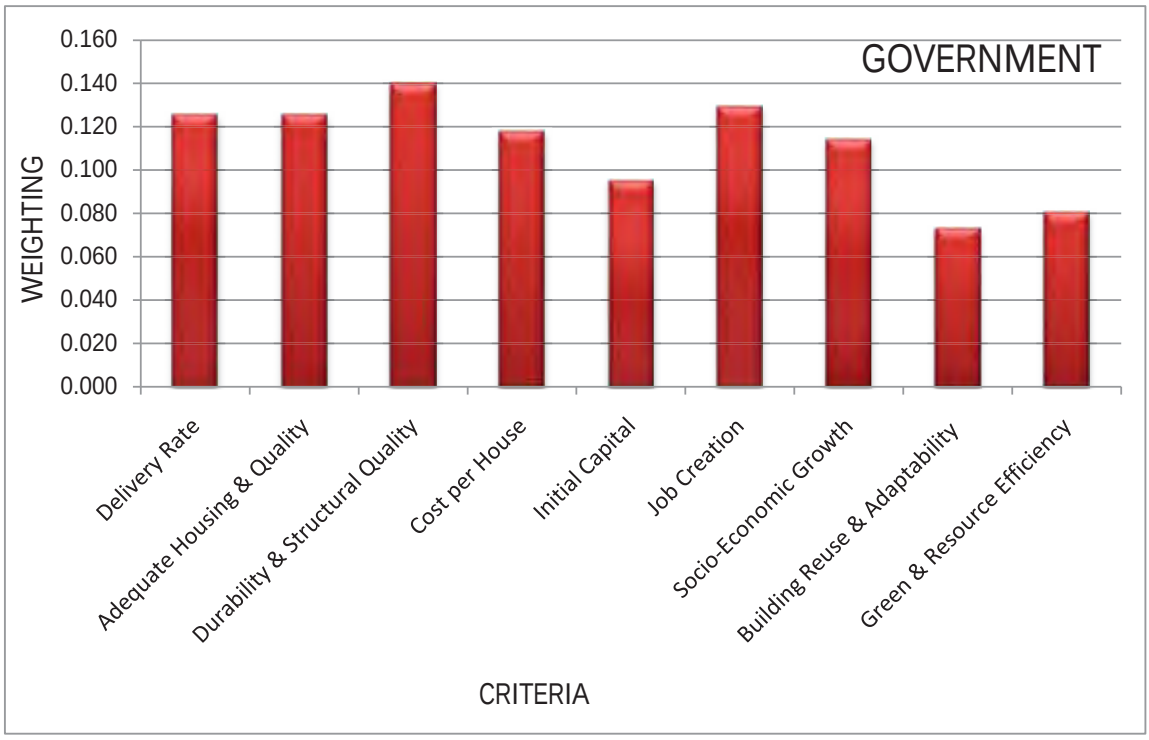


Figure 5.2 Interview Government

This graph shows the weighting of the importance of each factor of the government's criteria based on the data in table 5.3. Only the important factors will be analysed as the lowly weighted factors are unimportant. All the factors that have weighting above 0.100 will be analysed.

- Delivery Rate – The government intends to eradicate all informal settlements, and thus the housing backlog, by 2015. Therefore the delivery rate of the houses is an important factor. In order to reach this aim by 2015 the current delivery rate must increase by 200%.
- Adequate Housing & Quality – The houses that are delivered must be of adequate standard otherwise the houses would be as good as a shack. Adequate housing must include lights, running water and must offer decent living conditions. Therefore this factor is rated as the fourth most important for government housing.
- Durability & Structural Quality – This factor is the most important for government. This is because the buildings should last as long as possible and must still be useable for the next generation. There would be little point in building houses that would not last long enough, so when the housing demand has finally been supplied then the government will have to start replacing their previous houses.

- Cost per House – This is financial aspect of the housing process, and is thus considered an important factor for the government. This is because the government subsidises the houses that it builds therefore the cheaper the house the houses can be subsidised and thus built.
- Job Creation – This is the second most important factor of the government. These houses must also provide jobs for the communities where the houses are built. Therefore the government requires the contractors to employ a certain number of labourers from the community where the houses are being built. The aim of this is to create a wider spread of wealth and to share the advantages of this government subsidised housing.
- Socio-Economic Growth – This is how the houses can influence help the community, by providing a better quality of life and create economic opportunities. This is a noble aspiration of the government, but is a difficult to implement. Low income housing is a good fiscal tool as it directly benefits the poor, which is a large portion of the South African population, and is well spread throughout the country. Furthermore it helps create communities and the alleviation of poverty.

5.3.3 Analysis of Government MCCFM

Tables 5.4 MCCFM Government

Government	Housing Provision			Affordability & Job Creation			Sustainable Development			Total
Factors	Delivery Rate	Adequacy & Housing Quality	Durability & Structural Quality	Cost per House	Initial Capital	Job Creation	Socio-Economic Growth	Building Reuse & Adaptability	Green & Resource Efficiency	
Weighing	0.125	0.125	0.140	0.118	0.095	0.129	0.114	0.073	0.080	
Conventional	46	58	54	60	58	70	70	44	48	1.000
Score	5.760	7.262	7.557	7.073	5.514	9.051	7.989	3.206	3.858	508
Industrialised	76	78	76	68	52	48	48	54	70	57.271
Score	9.516	9.767	10.636	8.016	4.944	6.206	5.478	3.935	5.626	570

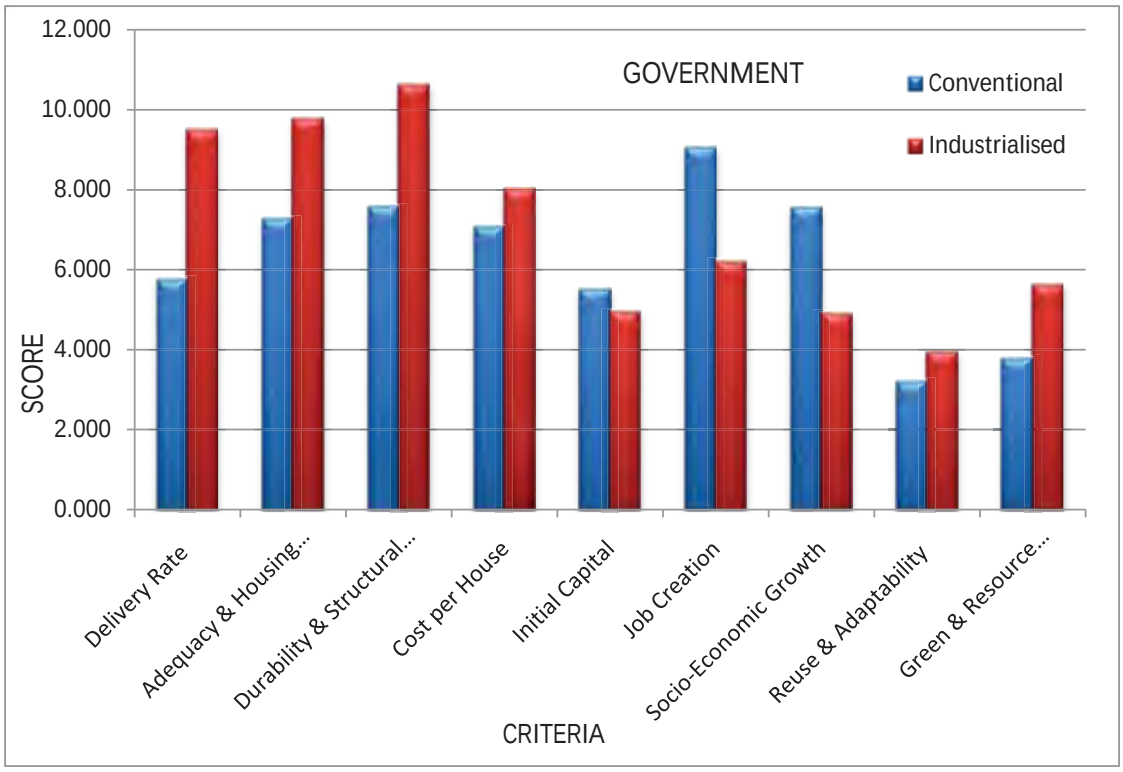


Figure 5.3 MCCFM Government

This graph illustrates the scoring difference between conventional and industrialised for the government sector based on the table 5.5. The following points are noted:

- Delivery Rate – This factor shows a substantial difference between Industrialised and conventional. Industrialised has the higher score as the construction of an industrialised house is quicker than that of a conventionally built house. In terms of mass low income housing delivery rate is an important factor to consider and is amongst the top three most important for government. Hence the high score.
- Adequacy & Housing Quality – This is an important factor for housing and shares the same level of importance as Delivery Rate. The difference between the two building systems is considerable. The standard of the house in terms of adequate finishes and services is of crucial importance. As these houses are built for the poor only adequacy and not luxury can be expected. However, this standard of services and finishes must still serve it functional use well enough to last a generation. The other issue is the time taken for the services to be installed and connected as this is currently a problem for government subsidised housing. IBS can offer installation of services before the assembly of the house, which optimises time and delivery of the services.

- Durability & Structural Quality – This is different to the previous factor as this involves the physical aspects of the building where Adequacy and Housing Quality regards matters such as finishes, lights, water and layout design. This factor has a considerable difference in favour of industrialised. The reason for this is that currently in South Africa conventional building system is used to construct the low income houses and since the use of poor materials and mostly unskilled labour which results in a poor product. Industrialised offers better quality control measures and requires less labour and skills, it uses standardised materials and is said to be more durable. This factor is the most important for government and is thus the highest scored.
- Cost Per House – This is an important financial requirement and is considerably important. Since the government subsidises the construction of the houses the cheaper the house the more houses they are able to build and subsidise. This is a relatively highly scored factor yet with marginal difference between the two building systems. Industrialised peaks over conventional by a small margin. In theory industrialised should produce cheaper buildings, however in the case of mass low income housing in South Africa the terms differ. This is because South Africa has cheap labour which is usually a saving for industrialised in high wage rate countries. The other point is that industrialised saves through less onsite costs which in the case for SA's low income housing is negligible. However industrialised can have considerable savings through mass production and resource efficiency.
- Initial Capital – This factor measures the extent of working capital needed to start construction of the houses. Industrialised needs considerably more than conventional. This is because industrialised requires machinery, equipment and factory premises to start the production which is more expensive than the equipment needed for conventional. However the running costs after the initial outlay is cheaper for industrialised. It is because of the extensive initial requirements of industrialised that conventional has received a higher score. This is important for government as implementing industrialised building for low income housing would require this capital outlay which is a barrier for entry. The extent of this factor is difficult to measure as there are certain degrees of capital required.
- Job Creation – This is an important requirement for government. The contractors who build government subsidised houses are required by government to employ a certain percentage of labourers from the community in which the houses are built. This is to increase job creation and to maximise wealth distribution. Conventional has outperformed industrialised by a considerable margin for this factor. This is seen as the as the strongest drawback for industrialised since job creation is rated one of the top requirements for housing. The reason

for this is that industrialised is a manufacturing orientated construction and through efficiency and mechanisation it decreases the need for employment which is in direct contrast with conventional.

- Socio-Economic Growth – It is important not to confuse this requirement with job creation as they are similar but essentially different. This factor regards how housing can benefit the community at large. This is has been scored in favour of conventional and at a substantial margin. The reason for this is that this is a difficult factor to measure and that industrialised is burdened by a negative stigma through mass identical housing in European countries although it is still extensively used. Conventional offers job creation and design flexibility which impacts on the community.
- Building Reuse & Adaptability – This is the extent to which a building can be recycled and its adaptability for other uses, thus, its ability to be modified and altered. Industrialised has scored higher than conventional although the score is relatively low. To measure this factor is dependent on the extent of the alteration. Conventional is better for smaller alteration where industrialised is better for larger alterations. Industrialised is more capable of physically recycling their buildings, it can be taken down and rebuilt somewhere else. Conventional, on the other hand, could more easily reuse their building for another use as smaller alterations are easier.
- Green & Resource Efficiency – This factor is currently unimportant for the government for low income housing, their reason is that, although that it is a considered factor, in the light of the desperate poor green methods and resource efficiency must be placed below other factors that directly deal with the housing problem. It is believed that this factor will become more pressing in the future. Industrialised is regarded a more greener and resource efficient building method due to its production process and shortened onsite periods. The fact that this factor has scored so low is to show that it is relatively unimportant.

5.4 Contractor Analysis

5.4.1 Analysis of Contractors Questionnaires

Table 5.5 Questionnaires Contractor

Sec	Primary Factor	No.	Secondary Factor	CBS	IBS
CONTRACTOR	Production	10	Production Cost	60	70
		11	Initial Capital Outlay	60	40
		12	Production Rate	46	76
		13	Product Quality	58	78
	Management	14	Manageability	46	68
		15	Production Control	44	79
		16	Quality Control	40	74
		17	Skills Dependency	68	56
		18	Labour Intensity	70	62
	Physical Implications & Sustainability	19	Design Flexibility	82	66
		20	Construction Complexity	54	52
		21	Carbon Footprint	62	66
		22	Resource Efficiency	48	70

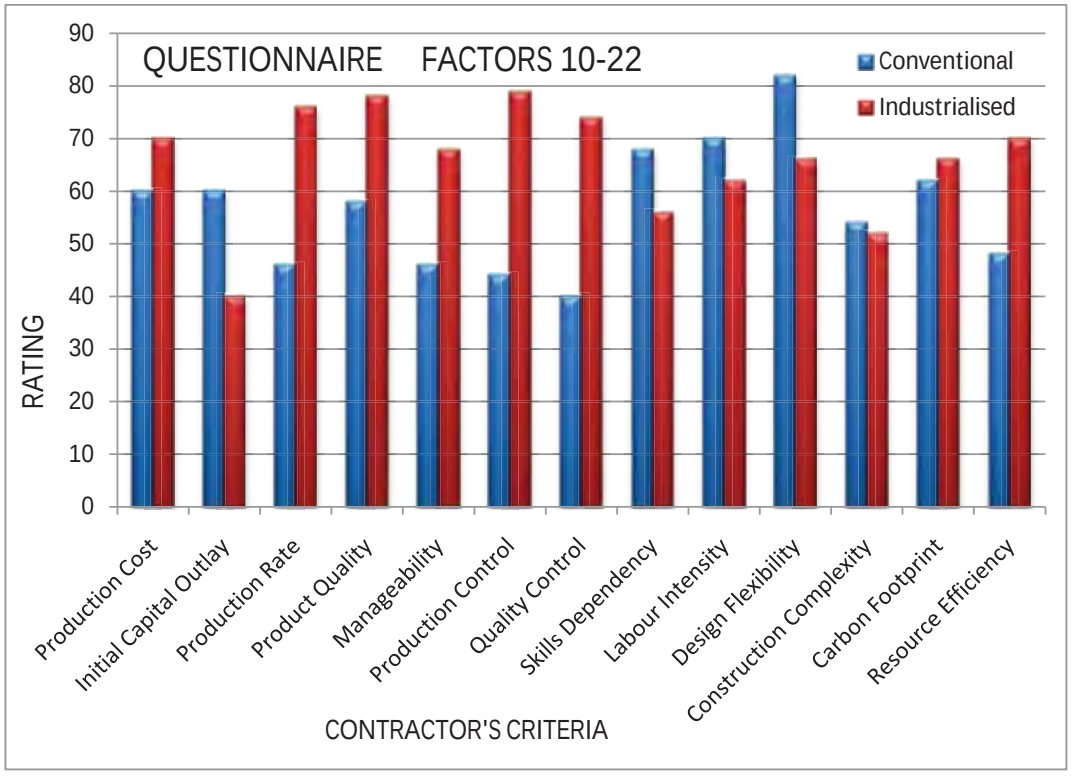


Figure 5.4 Questionnaire Contractor

This bar graph shows the rating of the factors from the questionnaire. These factors are taken from the contractors criteria. Each factor is analysed as follows:

- Production Cost – Industrialised can offer savings through their efficient production process and on labour. Since South Africa has relatively low wage rates the labour savings are not as much as it might be in other countries. Cost is an important factor for low cost housing, which is why both systems perform relatively well for production cost.
- Initial Capital Outlay – Establishing an industrialised building process requires a considerable amount of capital to fund the equipment, machinery and factory needed for production and construction. The performance is rated inversely to the amount of capital required. The graph shows that conventional needs much less capital than industrialised. Conventional is rated fairly highly for this factor which shows that its ability to establish such a business on little capital is possible.
- Production Rate – Industrialised, due to its assembly line production, is able to produce houses at faster rate than conventional. This is one of industrialised greatest advantages. Conventional has a fairly slow building process as each house is built on its own, one at a time, from foundation to roof. This is evident in the graph as industrialised is rated as one of the highest factors where conventional is fairly low.
- Product Quality – This factor is dependent on the quality control, the materials used and the standard of workmanship. Industrialised is rated at a high level which shows that it is capable of constructing good quality houses. This is because industrialised is less dependent on the skill of the general labourer and is able to systematically control the production of its product. Conventional is more dependent on the skill of their labourers which in South Africa is at a sub-standard level.
- Manageability – Construction, when compared to the manufacturing sector, is a difficult process to manage. This is because the variation of work and the wide spread of dependencies. Manufacturing is easier to manage because it standardises and systemises the work process which results in less dependencies and standardised routine checks. IBS is a manufacturing orientated construction and therefore it allows itself to be managed in a manufacturing way, which explains the high level of manageability as shown in the graph. Conventional is does not share such similarities with the manufacturing sector and is therefore confined to be managed as construction allows, which is why it lower level of manageability.

- Production Control – This factor is related to manageability, because the control of production is dependent on the management. Manageability involves two areas which are distinctly different in their process, this is the production control and the quality control. Industrialised has reached nearly highest level of performance for this factor, where conventional is at one of the lowest. This is because of the manageability and the assembly line production process offered by industrialised. This factor has the largest difference in performance between the two building systems which shows how much the production control process differs between the two systems.
- Quality Control – This factor is also related to manageability and product quality, because the quality control is dependent on the ability to implement quality checks and administering the use of the materials used in construction. Industrialised is rated at a considerably high level for this factor, which is due to the systematic production process as it allows an interval of quality control after each stage or component of production. Conventional, on the other hand, is more difficult to implement quality checks due to its onsite construction process. In terms of conventional as the building is built the quality checks can only occur on the parts of that are already cast in the building, and if it is of poor quality that work must be torn down and rebuilt, making it more costly, time consuming and less likely to remedy defective work.
- Skills Dependency – This factor expresses the level of skill and responsibility needed from the professionals in the industry. For industrialised the less professionals are required but because of this the dependency and the standard of the skill is higher than that of conventional. For conventional the more professionals are required but because of this the responsibility and standard is less. This is reflected in the graph as conventional is higher than industrialised at a substantial margin.
- Labour Intensity – Industrialised employs less labour than conventional and therefore requires less dependent on labour. Labour intensity can be a disadvantage due to health and safety regulations, administration, training etc. However, it must be considered that government subsidised housing requires the employment of a certain number of labourers from the community. Therefore the labour intensity is also an advantage in this regard. Conventional is rated at higher performance than that of industrialised. The performance of both systems is fairly high as construction does employ a large number of labourers.
- Design Flexibility – This factor is rated the highest of all the others, which is not expected. Conventional is rated substantially higher than industrialised because conventional is more able to adjust the building plans after construction has started, provided it does not change

work already done. Industrialised is less flexible as the production of wall panels or larger components make it difficult to change the plan of the building.

- Construction Complexity – Low cost housing is generally a very simple construction, hence its lower rating for both systems. There is little difference between the two building systems for this factor because low cost housing on its own is a simple process regardless of the type. The more complex the item is the less it is rated.
- Carbon Footprint – This factor is corporate initiative requirement. The lower the carbon footprint the higher the rating. Generally low income housing has low levels of carbon footprint and is therefore rated highly for both systems. Industrialised is rated slightly higher than conventional because of the resource efficiency.
- Resource Efficiency – The high material wastage levels of the conventional building system is due to the poor workmanship and thus the tearing down and rebuilding of defective work. This is why conventional is rated so low in terms of resource efficiency. Industrialised, due to its production process and component pre installation quality checks is more resource efficient, as the substantial rating shows on the graph.

5.4.2 Analysis of Contractor Interviews

Table 5.6 – Interviews Contractor

Sec	Primary Factor	No.	Secondary Factor	Data
CONTRACTOR	Production	10	Production Cost	0.118
		11	Initial Capital Outlay	0.096
		12	Production Rate	0.07
		13	Product Quality	0.101
	Management	14	Manageability	0.073
		15	Production Control	0.08
		16	Quality Control	0.08
		17	Skills Dependency	0.056
		18	Labour Intensity	0.061
	Physical Implications & Sustainability	19	Design Flexibility	0.058
		20	Construction Complexity	0.051
		21	Carbon Footprint	0.099
		22	Resource Efficiency	0.058

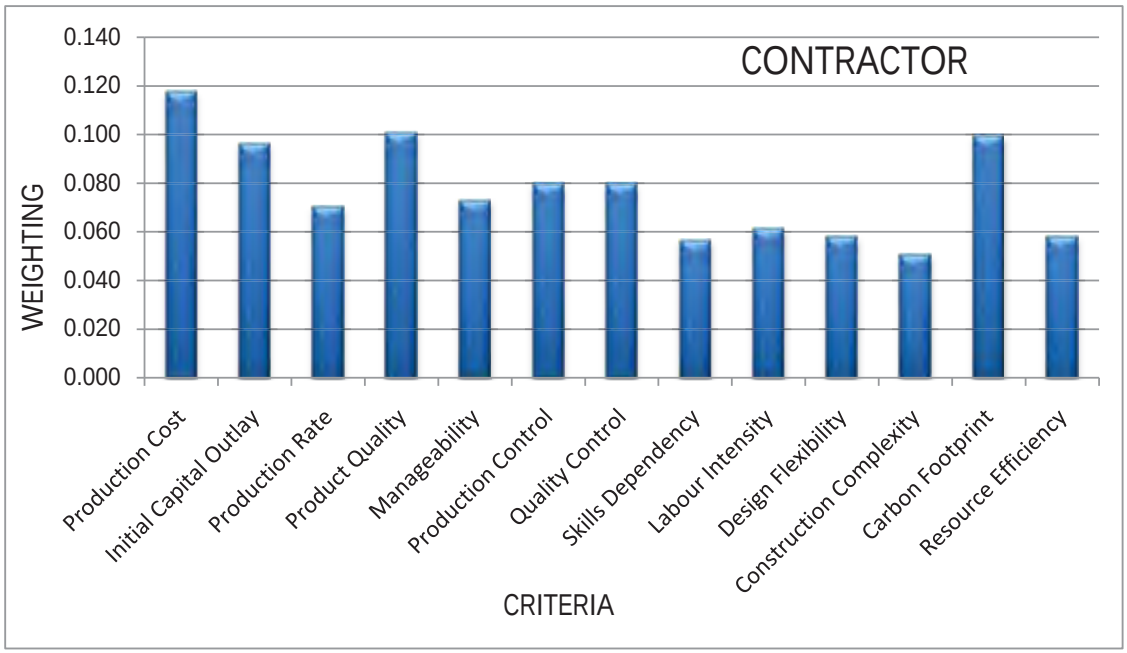


Figure 5.5 Interview Contractor

This graph shows the weighting of the importance of each factor of the contractor's criteria. Only the important factors will be analysed as the lowly weighted factors are unimportant. All the factors that have weighting above 0.080 will be analysed.

- Production Cost – The contractor's main aim is to make a profit from their projects. Therefore, the cost of construction or the production of the houses affects the profitability of the contractor. The lower the costs the higher the profit. As it can be shown in the graph, it is the most important factor for the contractor as has the highest weighting. Since this the construction of low income houses the profit margins are small and therefore the cost of production is a crucial element in the low income housing industry.
- Initial Capital Outlay – To establish any type of business a certain amount of capital is needed to purchase assets that will run the business. Industrialised is known for its expensive establishment costs, due to the extent of machinery, equipment and facilities needed to run such an assembly line production. The initial capital is an important factor for the contractor as it will affect the profitability and feasibility of the business. If a loan was acquired to fund the initial capital needed then interest on repayments would need to be made for some time which may inflate the production costs and therefore the price of the product or houses. Another way of funding the capital needed is through shareholdings, although the profits will be shared among the shareholders, no repayment nor interest on the capital is required. This factor is rated as the fourth most important factor for the contractor.

- Product Quality – The government will choose the contractor a particular housing project. Their choice will depend on the cost, quality and socio-political compliance. Therefore the quality of the product is important as it will help to win contracts from the government. Furthermore, if the quality proves to be below expectation then it is unlikely that the contractor will receive another contract. On the other hand if the quality is above expectations then it will be likely that the contractor will be awarded further contracts. Therefore, the product quality is an important factor for the contractor, and is thus shown in the graph as the second most important factor.
- Production Control – The contractor must ensure that it can deliver the number of houses within the time required, otherwise the contractor is liable to face penalties for late completion. The contractor must ensure that the production or construction of the houses is at a rate that will ensure timeous completion. Therefore, production control is an important factor for the government.
- Quality Control – The contractor must ensure that the houses are of reasonable standard. The earlier the defect is found the easier and cheaper it is to remedy. This requires continuous quality assessment to ensure defects are found and remedied as soon as possible. If the contractor delivers a substandard product then it is unlikely that the contractor will be awarded another contract. It is also possible that after the construction has been completed the defects would need to be remedied at the expense of the contractor. To remedy a defect after completion is more costly than to remedy it before completion, the extent of this cost would depend on the defect. Not only would the lack of quality control result in expensive costs in remedies but also expensive loss in time as the contract would only be completed after the final approval, thus once all defects have been remedied. This means that the contractor would need to pay penalties for late completion if the remedy extends past the completion date. This is why this factor is fairly important to the contractor.
- Carbon Footprint – This is a corporate incentive requirement. The general carbon emissions and usage of the contractors company is measured as a carbon footprint rating. Since these low income housing project are government funded this factor might become a stronger requirement in the future. As the graph shows this factor is weighted as the third most important.

5.4.3 Analysis of Contractor MCCFM

Table 5.7 MCCFM Contractors

Contractor	Production				Management					Physical Implications & Sustainability				Total
Factors	Production Cost	Initial Capital Outlay	Production Rate	Product Quality	Manageability	Production Control	Quality Control	Skills Dependency	Labour Intensity	Design Flexibility	Construction Complexity	Carbon Footprint	Resource Efficiency	
Weighing	**0.118**	**0.096**	**0.070**	**0.101**	**0.073**	**0.080**	**0.080**	**0.056**	**0.061**	**0.058**	**0.051**	**0.099**	**0.058**	**1.000**
Conventional	60	60	46	58	46	40	40	68	70	82	54	62	48	734
Rating	7.053	5.779	3.225	5.831	3.354	3.189	3.189	3.834	4.287	4.735	2.728	6.169	2.772	56.145
Industrialised	70	40	76	78	68	74	74	56	62	66	52	66	70	852
Rating	8.229	3.852	5.328	7.842	4.958	5.899	5.899	3.158	3.797	3.811	2.627	6.567	4.042	**66.010**

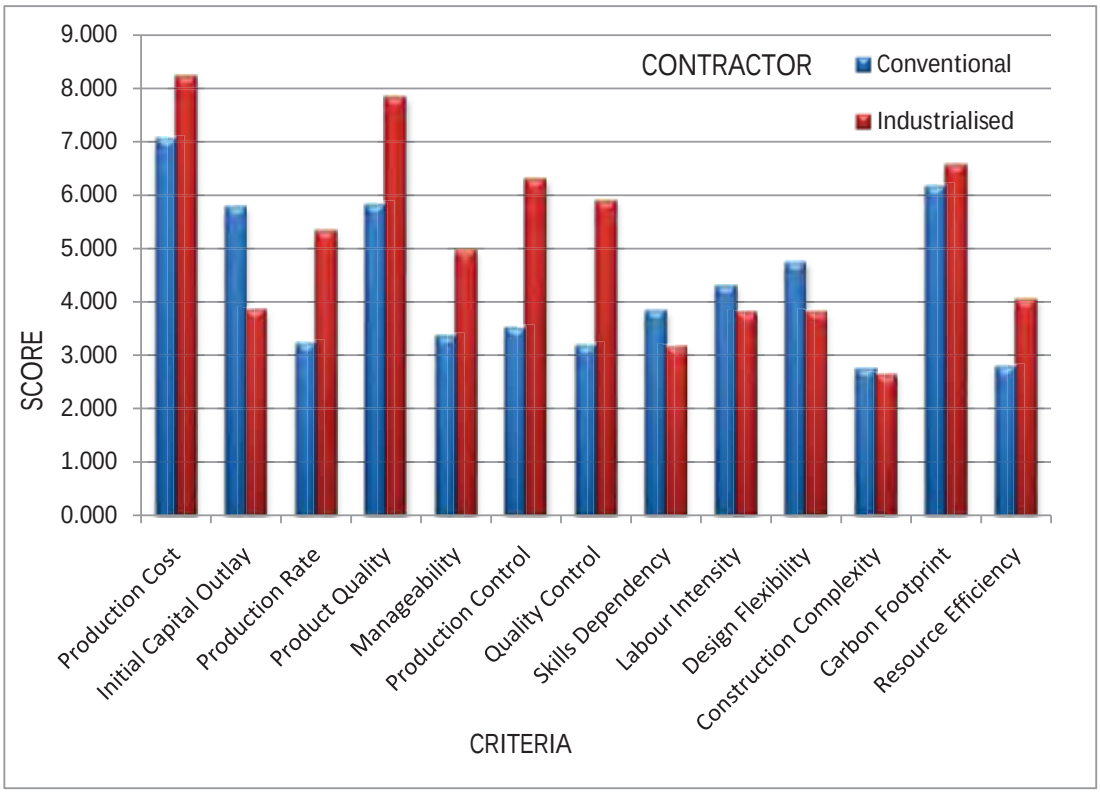


Figure 5.6 MCCFM Contractor

This graph illustrates the scoring difference between conventional and industrialised housing for the contractor sector. The following points are noted:

- Production Cost – This is an important factor to consider as the cost of producing houses needs to be within the government subsidy margin and must still make a profit. The cheaper the production cost the more profitable the production becomes. This factor is the most important for contractors; this is shown on the graph as it has the highest score. The difference, although only marginal, is in favour of industrialised. This is because industrialised offers a lower production cost per unit due to its high production capacity, production rate and efficiency. Conventional has a cheap production cost through utilising cheap materials, cheap labour and minimising the use of machinery.
- Initial Capital Outlay – This is the same factor as in the government section except that this is directed towards the contractor. One of the greatest differences between industrialised and conventional is the initial capital needed to establish production. Industrialised requires more capital than conventional, this is evident in the graph as conventional has a considerably higher score than industrialised.
- Production Rate – This is more important for government and end user than it is for contractors, as it can be seen by its low score. This is because the contractor is only

interested in producing as much as is required. Industrialised can offer higher production rates thus the substantial difference in the score.

- Product Quality – This factor measures the general quality of the product, form a contractor's perspective. This is an important factor as contractors aim to produce a product that would please their clients and ensure future contracts. Industrialised has a considerably higher score than conventional in this regard. This is mainly because industrialised produces standardised products which are, to a large extent, identical. Standardisation and less onsite construction provides greater quality assurance. On the other hand, conventional is largely onsite construction which leaves more room for error, although building plans and processes are standardised product quality outcome is more likely to vary. Conventional is more dependent on onsite labour quality, and since labour with no experience is employed the housing product quality reflects the standard of workmanship.
- Manageability – This is an interesting factor to consider as good management on a construction site results in better efficiency, quality and productivity. Manageability is essentially the extent of transparency within a particular system. This was rated a factor of medium importance as it is a general requirement. Industrialised performs better for this factor than conventional. This is because the production process of industrialised is more manufacturing orientated which offers a systematic, standardised and fragmented production line. Furthermore, it results in better supervision and quality checks the product can be checked at various stages of production. Conventional is more difficult to implement supervision and systematic management due to its nature of construction.
- Production Control – This factor continues from manageability but is directed towards the rate of production and its process. Ensuring good production control will lead to better efficiency and production capacity as well as the speed of production. The importance of this factor was rated as moderate. It is clear that industrialised considerably outperformed conventional in this respect. The reason for this is that industrialised is manufacturing orientated construction and the use of assembly line production increases efficiency, speed of production, transparency and controllability. Conventional is different in that its production process is onsite uniquely producing a building at a time.
- Quality Control – This factor falls part of manageability, it is the extent to which quality control measures can be soundly implemented into the production process. The importance of this factor is rated at moderate. Again, industrialised is scored considerably higher than conventional. This is due to the production process of industrialised building. Just like

production control, quality control can be similarly implemented. The assembly line process of industrialised building includes check points at the end of producing each component, then again at the final assembly stage. This fragmented and systematic production system lends itself to better quality control implementation. Conventional, on the other hand, is different in that it is one set process for each house and does not include assembly line production. Conventional is also considerably more sensitive towards the quality of labour and thus, the quality of the product depends on the workmanship of the labour employed. This is why quality control measures are more difficult to implement.

- Skills Dependency – This factor is easily confused with the skills required. This is not the case, Skills Dependency is the level of expertise and the responsibility of each professional employed and not the amount professionals needed. In fact there is a direct opposite relationship between the number of professionals hired and the responsibility of the each professional, although it depends on the type of building. Conventional performs marginally better than industrialised in this regard. The reason for this is that industrialised would employ less professional staff per house produced than conventional, because of the production method. Although less professionals are employed for industrialised the responsibility for each professional is a lot more. This is why industrialised has a low rating for skills dependency as the responsibility is a negative aspect considering the quality of the skills and its shortage. However, conventional does not score much higher as it requires a greater number of professionals but with a smaller responsibility.
- Labour Intensity – This factor measures the importance and extent of the amount of labourers employed. Conventional employs more labour than industrialised which why the score is in favour of conventional. This is a moderately important factor for contractors as labour is costly and requires management. With aspects such as health and safety, labour unions, transport issues and strikes, labour intensive processes are becoming more unattractive for profit orientated organisations. However, the amount of labour employed entails job creation which is a government housing requirement and it must be considered that labour might still be cheaper than machinery.
- Design Flexibility – This factor measures the ability of changing the building plans at any given time. The importance of this factor to contractors is considerable but in terms of mass housing it becomes less important. Conventional has scored higher than industrialised for this factor. Since conventional constructs each house on their own the ability to change the layout or plans of these houses is fairly simple and can be done even after construction has started. Industrialised is different in this regard as it requires

standardised elements of the housing product and is therefore limited to what can be assembled from their components. Their plans or designs are easily changeable. In terms of mass low income housing, each house is standardised and the chance of changing the plans or design for one particular house is unlikely. This is why the difference is small.

- Construction Complexity – The complex nature and process of the construction of the houses. In terms of low cost housing is not at all complicated, since it is such a simple structure, which is why this factor is rated as of the lowest importance. The graph shows very little difference between the two building systems. This is probably because it is in terms of low cost housing and is also difficult factor to measure. The reason why this factor was included in this study is because it would be interesting to see what factor would be considered as the more complex one. It was expected that industrialised would be more complex and thus receive a lower score, as complexity is a disadvantage.
- Carbon Footprint – This is factor is a corporate requirement and is chosen in the light of environmental issues. This is a factor that is rated as the third most important, which shows that it is considered for low income housing. The graph shows this by its high rating. Industrialised has been scored higher than conventional for this factor. This is because industrialised is generally more resource efficient and has less of an impact on the building site. Industrialised also includes a factory which produces the components which impacts on the carbon footprint of this system. Conventional, on the other hand, doesn't have a factory but has a greater impact on the environment of the building site and is more wasteful.
- Resource Efficiency – This factor measures the extent to which either system uses its resources effectively and allows less wastage. This factor was expected to receive more importance because it is a pressing issue for environmental reasons and the cost of resources. However, in construction the higher the cost the greater the profit margin, therefore the more resources that are wasted legitimately the higher the project cost. Industrialised has a higher score than conventional for this factor. This is because the production process of industrialised is considerably more efficient and allows less wastage. Conventional is more wasteful as it uses general components (eg: bricks or blocks and in-situ concrete) to construct a building. It can be expected that this factor will become more important in the future as it saves on resource cost and is more considerate on environmental issues.

5.5 End-User Analysis

5.5.1 Analysis of End-User Questionnaires

Table 5.8 Questionnaires End-User

Sec	Primary Factor	No.	Secondary Factor	CBS	IBS
END-USER	Time & Future Value	23	Delivery & Waiting Period	46	76
		24	Adaptability & Alteration	52	56
		25	House Value	60	40
	Cost	26	Affordability	60	68
		27	Maintainability	60	54
		28	Life Cycle Period	36	52
	Quality	29	Diverse Design & Aesthetic	82	66
		30	General Quality of House	54	76
		31	Adequate Service Provision	40	74

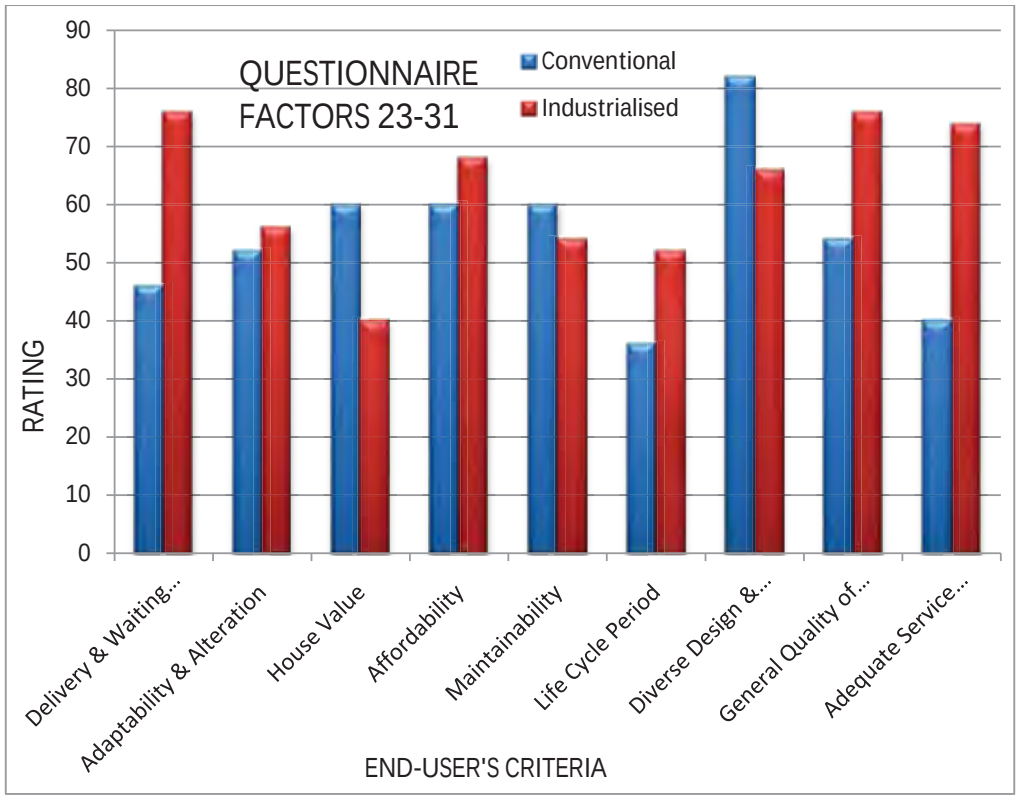


Figure 5.7 Questionnaire End-User

This bar graph shows the rating of the factors from the questionnaire. These factors are taken from the end user criteria. Each factor is analysed as follows:

- Delivery & Waiting Period – Industrialised is rated considerably higher than conventional and is one of the highest ratings compared to the others. This is due to the efficient production process of IBS, as it offers rapid housing delivery. The time it takes from ordering of the house to the actual delivery is what this factor rates. Thus industrialised can offer a faster delivery period. Conventional delivers over a slower period due to its nature of construction.
- Adaptability & Alteration – The ability for either building system to allow extensions and alterations to the house is what this factor measures. The rating of this factor is relatively average. The margin between the two systems is negligible. The reason why this factor was rated so close to each other is because both systems would have a similar performance in adaptability and alteration.
- House Value – The resell value for low income houses cannot be not expected to be much, however this factor rates the extent of it resell ability after a minimum of five years and the mortgage value. This is an interesting factor to consider as it may help with socio-economic growth and poverty alleviation. Since these houses are standardised and mass produced and are after all built for the poorest, resell value is not a factor that can be expected to be rated highly. Conventional is rated higher purely because the design variation and aesthetic appeal. Industrialised is rated fairly low which is because its negative stigma and it standardisation.
- Affordability – Industrialised is rated slightly higher than conventional, this is because of the cost of production and the cost of alterations and extensions. The reason why this factor is rated fairly highly is because low income housing must be affordable.
- Maintainability – The owner or resident of the house must be able to maintain their house, which considers the cost of maintaining, the extent of maintenance needed, the ease of maintaining and the frequency. Conventional is rated higher then industrialised for this factor because its ability to upgrade finishes and to alter or remedy other aspects in a building is better than industrialised. Since industrialised buildings are pre built and later assembled the fixtures and conduits etc are all cast into the wall panels making it difficult to remedy defects. However, industrialised is more durable and of a better quality standard than conventional and will need less maintenance.
- Life Cycle Period – This is the required life span of the houses. Essentially the required life span is forever but this is unreasonable because in most urban cases the houses would need to be removed to make space for a higher density type of housing. The houses aimed to last for the next generation which is about 30 to 40 years. Industrialised performs better for this

factor due to better durability, quality and recyclability. Conventional has a smaller life cycle because of it structural standard and its choice in materials such as corrugated iron roofs. This factor is rated as one lowest in performance for both factors because in actual fact the type of low income housing that is currently being built is unsustainable and takes too much space per person especially in the urban areas.

- Diverse Design & Aesthetic – It is not sure why this factor has been rated so highly, it doesn't make sense and was expected to be one of the least rated factors. Low income housing is standardised and aesthetics is a luxury and should not be highly considered for low income housing. Conventional performs considerably better for this factor because of its ability to alter designs and style for every house. Industrialised is more standardised and less flexible in this regard.
- General Quality of House – This factor has been rated as one of the highest for both buildings types. Industrialised outperforms conventional by a substantial margin. This is because of the quality control and delivery of the industrialised product. The general quality of the conventional building is, to a large extent, dependant on the standard of the workmanship of the houses.
- Adequate Service Provision – This factor measures the ability of either system to fix and install services into the houses, thus the electrical conduits and plumbing lines. Industrialised outperforms conventional by a margin larger than any other factor. This is because there is such a difference between these building systems in terms of installations. Industrialised casts its plumbing lines and conduits into the wall panels before it is assembled onsite, this speeds up the process and ensures the services are in place and ready to be used once the main connection is done. Conventional installs their service lines by chasing them into the walls after the walls have been built, this consumes time and therefore delays the provision of the services.

5.5.2 Analysis of End-User Interviews

Table 5.9 Interviews End-User

Sec	Primary Factor	No.	Secondary Factor	Data
END-USER	Time & Future Value	23	Delivery & Waiting Period	0.134
		24	Adaptability & Alteration	0.129
		25	House Value	0.082
	Cost	26	Affordability	0.129
		27	Maintainability	0.098
		28	Life Cycle Period	0.088
	Quality	29	Diverse Design & Aesthetic	0.099
		30	General Quality of House	0.103
		31	Adequate Service Provision	0.137

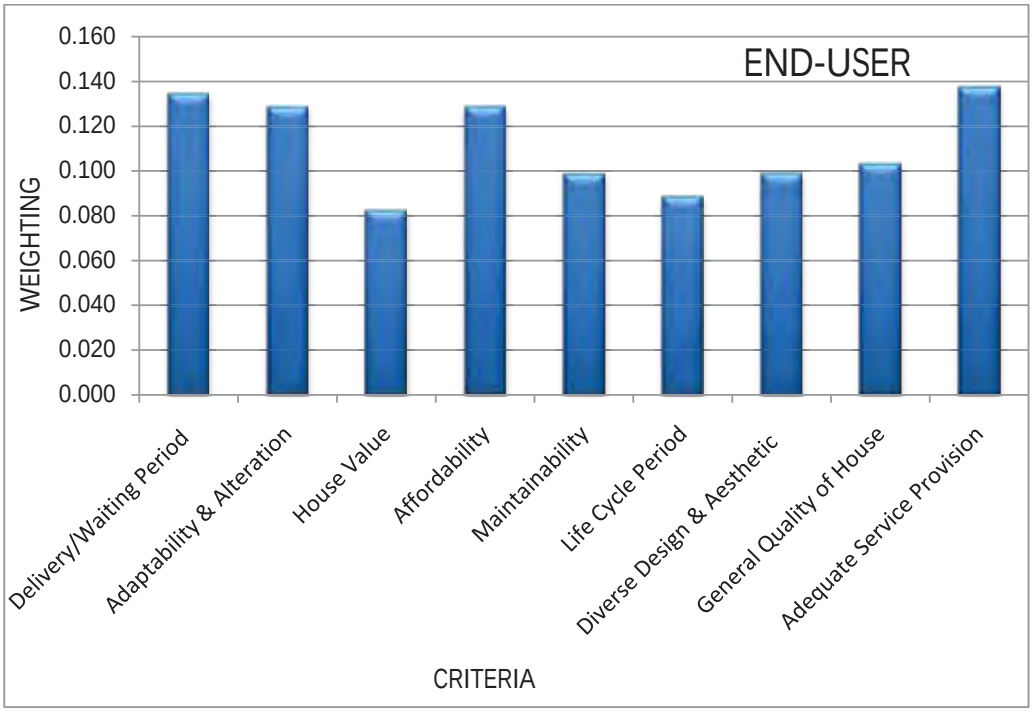


Figure 5.8 Interview End-User

This graph shows the weighting of the importance of each factor of the end-users criteria. Only the important factors will be analysed as the lowly weighted factors are unimportant. All the factors that have weighting above 0.100 will be analysed.

- Delivery/ Waiting Period – The end user registers for a house after which he must wait for period of time before the house is built and delivered. This waiting period can be years and is the second most important factor for the end user. For example, when a squatter camp is

transformed into formal housing the previous resident of one of these shacks must reside in transit house until his designated formal is built. The previous shack dweller dislikes the transit houses as they are small, uncomfortable and impersonal.

- Adaptability & Alteration – The resident (end-user) may require to extend an extra room on to the house or plaster and paint or even to change the roof. Since the houses are built with the intention that the end user can build extensions to the house then their adaptability and alteration ability is an important factor to consider. The ability for the house to accommodate alterations and extensions is dependent on the ease and the time it would take to build the extensions as well as the cost thereof. This is the third most important factor for the end user.
- Affordability – Since the houses are built for the poor who regard cost as an important factor. The government subsidises the cost of the houses, in most municipalities the cost of the house is fully subsidised. Therefore, in terms of the end-user, the affordability does not only apply to the initial cost of the houses but more so for maintenance, improvements and any other cost to the end-user. This factor is weighted at the same level as adaptability and alteration at a weighting of 0.129, and thus are both rated as the third most important factor.
- General Quality of the House – The quality expectation of the end-user is difficult to determine as it is largely a subjective matter. However, certain standards or elements of quality expectations are similar to all end-users, these are; the size of the house, its thermal qualities, its finishes and its services (lights and water). The end user also expects good structural and durability standard, although the quality these are immediately evident to the end user as well as the lack of knowledge about the structural ability of the house is not evident.
- Adequate Service Provision –The greatest difference between a shack and a formal house is the provision of electricity, lights and running water. This factor is weighted as the most important factor for the end-user, as this is their main expectation upon reception of a formal house. In order for a house to be deemed adequate and formal it must include the provision of such services. The aim of the government is to replace all informal housing with formal houses, therefore each house must include adequate services.

5.5.3 Analysis of End-User MCCFM

Table 5.10 MCCFM End-User

End-User	Time & Future Value			Cost			Quality			Total
Factors	Delivery/ Waiting Period	Adaptability & Alteration	House Value	Affordability	Maintainability	Life Cycle Period	Diverse Design & Aesthetic	General Quality of House	Adequate Service Provision (L&W)	
Weighing	0.134	0.129	0.082	0.129	0.098	0.088	0.099	0.103	0.137	1.000
Conventional	46	52	60	60	60	36	82	54	40	490
Rating	6.178	6.699	4.934	7.713	5.910	3.177	8.092	5.577	5.495	53.775
Industrialised	76	56	40	68	54	52	66	76	74	562
Rating	10.207	7.214	3.289	8.742	5.319	4.590	6.513	7.849	10.166	63.888

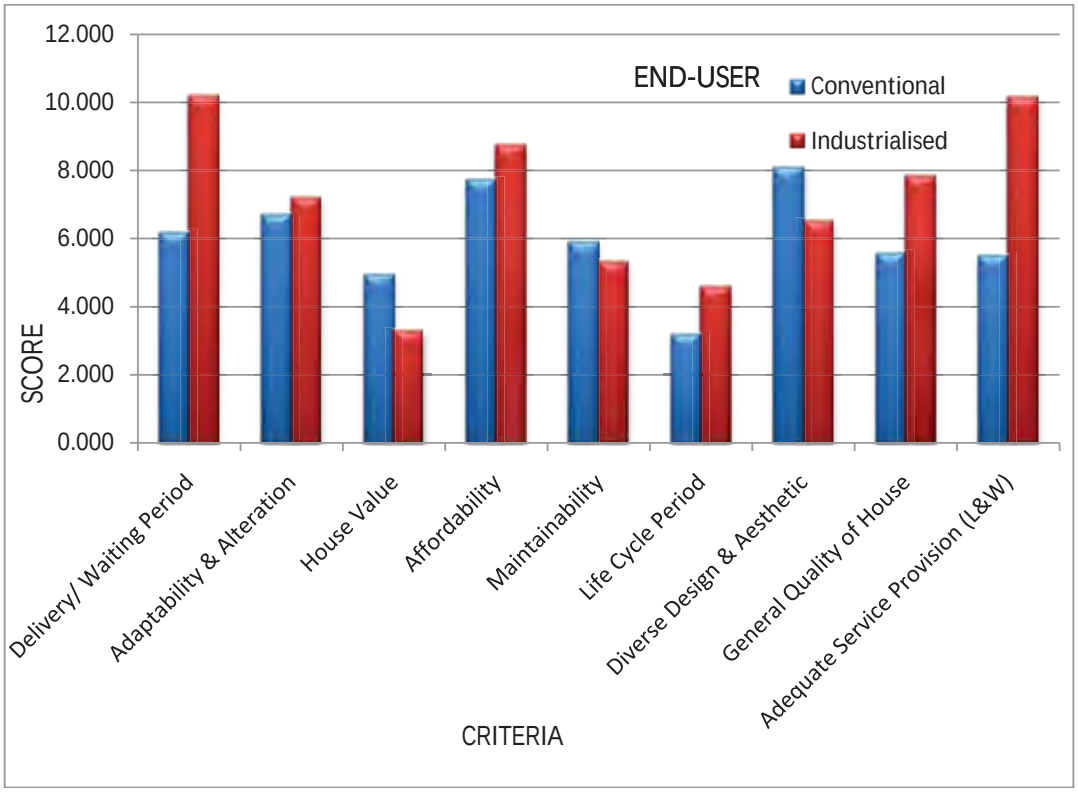


Figure 5.9 MCCFM End-User

This graph illustrates the scoring difference between conventional and industrialised housing for the End-User. The following points are noted:

- Delivery /Waiting Period – This is the average waiting period for the housing applicant to receive their government subsidised house. This factor is related with the production rate and delivery rate in the contractor and government sectors respectively. This factor is one the top three rated factors for the end user. Industrialised has scored considerably more than conventional. This is because industrialised is capable of a higher production rate, better manageability and transparency, making the process from production to delivery more efficient.
- Adaptability & Alteration – This measures the ability for the building to adapt to other uses and the extent to which it allows physical alteration. This is a considered factor for the end user as their house may require extensions to accommodate growing families or to provide space to run a small shop. It is evident that this factor is fairly important judging by its high score. Industrialised has scored higher than conventional but only on a small margin. This is because industrialised is more adaptable and allows larger expansions with ease.

Conventional, on the other hand, is more capable of allowing smaller scale expansions and alterations to the house. Each system performs equally for changing its use.

- House Value – This factor measures the resell value of the houses. This is an interesting factor as it may function towards poverty alleviation through mortgage security. However, this was scored as the lowest in terms of importance. The residents do not intend to sell their houses and are not familiar with debt security. The resident prefers to keep the house for the next generation to keep. Conventional has scored higher than industrialised. This is because conventional buildings are more trusted by the public perception. Industrialised would mass produce standard houses and in terms of supply and demand the supply would dilute the demand per unit.
- Affordability – This factor measures the cost aspect of not only the houses but also the cost of alterations and finishes. As the government subsidised houses are built with the intention that the residents will add their own improvements. This is a considerably important factor, because cost is the main concern for the end user. Industrialised has a higher score than conventional but only by a small margin. Industrialised can offer cheaper houses and cheaper extensions on an existing building. This cost advantage is achieved through larger building components and panel building. However, this cost advantage must be set against the initial capital required, this is why the difference in cost in smaller. Conventional houses are cheap but not as cheap as industrialised could offer. It must be kept in mind that the initial capital outlay for conventional is significantly less than industrialised, which would directly impact on the cost of the houses.
- Maintainability – This factor is measured by practicality and cost effectiveness by which the end-user or owner can maintain their low cost house. This is a factor of moderate importance as it durable building should require less maintenance. Conventional has fared better against industrialised because as conventional has smaller building components, the replacement or mending of a defect would be easier for conventional than industrialised. However, having larger building components, as industrialised offers, may be more practical but not as cost effective.
- Life Cycle Period – This is the average time of which a low cost house changes use or is demolished. This is an interesting factor to consider. The reason why this factor was chosen to evaluate how long the end user expects to reside in their particular house and for how it should stand as a house. The benefit of knowing the life cycle period of such houses can determine what the durability standard should be. The longer the life cycle period the higher the score. Industrialised has achieved a higher score than conventional, this is mainly

because industrialised buildings can certain extent be taken down and rebuilt somewhere else, as well as being more able to allow larger modifications.

- Diverse Design & Aesthetics – This factor measures the extent to which either system can offer aesthetic appeal and diversification in the housing design. Conventional has is obvious to have scored higher for this factor. However, the reason why this factor was chosen is because studies criticised the housing projects for mass identical housing and the government housing reports have provided for 'non-monotonous' developments as a requirement. Although industrialised had shared the same criticism for its use in social housing in Eastern Europe, conventional still has the higher score with reason. This is because conventional is more capable of diverse designs and aesthetics. Industrialised has come a long since the 1960s and can offer more aesthetics and a dynamic design and layout production as is currently being used in Japan.
- General Quality of House – This is a self explanatory factor it measures the standard of the houses in terms of what a house should provide for its resident. This factor entails the structural, finishes and any other general standard of the house. This factor is of high to moderate importance for the end user. Industrialised has fared much higher as it provides better quality assurance and performance. The current housing projects are evident to what the standard of conventional housing is.
- Adequate Services (Lights & Water) – The reason why this factor has been separated from the previous factor (General Quality of House) is because the services in the houses is an aspect which currently is not adequate enough. It on its own is an important factor for the end user, hence it has one of the highest scores. Industrialised has considerably out scored conventional. The main reason for this is because the conventional building method separates the construction of the houses with the provision of the services, which is why the conduits and plumbing lines have to be chased into the walls afterwards. This delays the process and is impractical for mass low income housing. Industrialised, on the other hand, can combine the construction (production) process with the installation of services. This is done by fitting the conduits and plumbing lines into the wall before it is cast or made. Fittings and lines are connected during the assembly process. This ensures that the services are in place, it is also cost effective, practical and shortens construction periods. Most of all it shifts the responsibility to one contractor who doesn't have to rely on subcontractors.

5.6 Summary of Findings

5.6.1 Findings from Questionnaires and Interviews

Out of 12 questionnaires only 5 have been completed and received. Out of 15 interviews planned to achieve, 12 have been conducted. Results of the questionnaires and interviews have been placed in the MCCFM analysis tables. Table 5.11 below shows the three most important factors for each group and the corresponding performance rating for these factors. The factors of importance are taken from the results of the interview and the rating values of performance are taken from the questionnaires.

Table 5.11 – Important Factors with Performance Rating

Group	Most Important Factors	Performance Rating	
		IBS	CBS
Government	1. Durability & Structural Quality	76	54
	2. Job Creation	48	70
	3. Delivery Rate	76	46
	4. Adequacy & Housing Quality	78	58
Contractor	1. Production Cost	70	60
	2. Product Quality	78	58
	3. Carbon Footprint	66	62
End-User	1. Adequate Service Provision	74	40
	2. Delivery/Waiting Period	76	46
	3. Affordability	68	60

The most important factors for the government are the four major requirements that the government aims to achieve through their housing process. The least important factors are those which are currently unimportant but may become more considered in the future. From governments most important factors Durability, Delivery and Adequacy on their own show to be more favourable towards IBS where Job Creation is favoured by CBS by a substantial margin. Since three of the four most important factors scored substantially higher for IBS than CBS it makes sense that IBS is the favourable option. The reason for the top three factors is as follows: 1. Durability and Structural Quality – The government maintains that houses should last long enough for the next generation. 2. Job Creation – The government is using the housing process to create jobs for socio-economic upliftment. 3. Delivery Rate – The houses must be developed fast enough to supply the need and

overcome the housing backlog. 4. Adequacy & Housing Quality – the houses that are built must be of reasonable standard and must be liveable.

The contractors' primary goal is to make a profit from their housing production. Therefore the product cost and product quality are the most important requirements. Production cost and product quality are both strongly favoured by IBS. Carbon Footprint is only slightly favoured by IBS which is a negligible difference. The fact that most of the important factors have performed higher for IBS is reason enough for IBS to be the favourable option for contractors. The reasoning of the top three factors is as follows: 1. Production Cost – the cheaper the contractor can construct houses the greater the profits. 2. Product Quality – the quality of the houses must be good enough to ensure future contracts. 3. Carbon Footprint – This is a factor that is a corporate incentive requirement to reduce carbon emissions.

The requirements of the end user are generally towards basic needs of a house as table 5.11 indicates that their most important factors are Adequate Services and Housing Delivery. Factors like House Value and Aesthetics are the least important for low income housing. All three of the end user's most important factors perform in favour of IBS. Adequate service provision and Delivery/Waiting period perform strongly in favour of IBS. Affordability is also favoured by IBS but only at a small margin. However, despite the performance ratings, the end user may dislike the idea of a factory made house as other studies have shown a negative stigma towards IBS housing. The reasoning of the top three factors is as follows: 1. Adequate Service Provision – Essentially the end user requires running water and electricity in their houses. 2. Delivery/Waiting Period – The waiting period sometimes takes a few years before the house is built, during which the community must be placed in transit housing while their shacks are replaced with formal houses. 3. Affordability – In some municipal areas the housing subsidy does not cover the full cost of the house, consequently the owner must pay the difference. Furthermore, the cost for upgrading and maintain their house is also an important implication.

Generally industrialised housing can offer more advantages than conventional housing, however the certain but few advantages that conventional construction can offer are important to government subsidised housing in South Africa such as labour intensity, job creation, and less skills dependency. Adopting either system is will have to compromise between the advantages offered by either building system. Therefore, without being able to escape a trade-off, the suitable building system must be selected by least trade-off cost in advantages and not only by what one system can offer.

5.6.2 Findings from MCCFM

Table 5.12 MCCFM Final Summary

Final Matrix	Government	Contractor	End-User	Total
Conventional CBS	508	734	490	1732
Rating	57.271	56.145	53.775	167.190
Industrialised IBS	570	852	562	1984
Rating	64.124	66.010	63.888	194.022

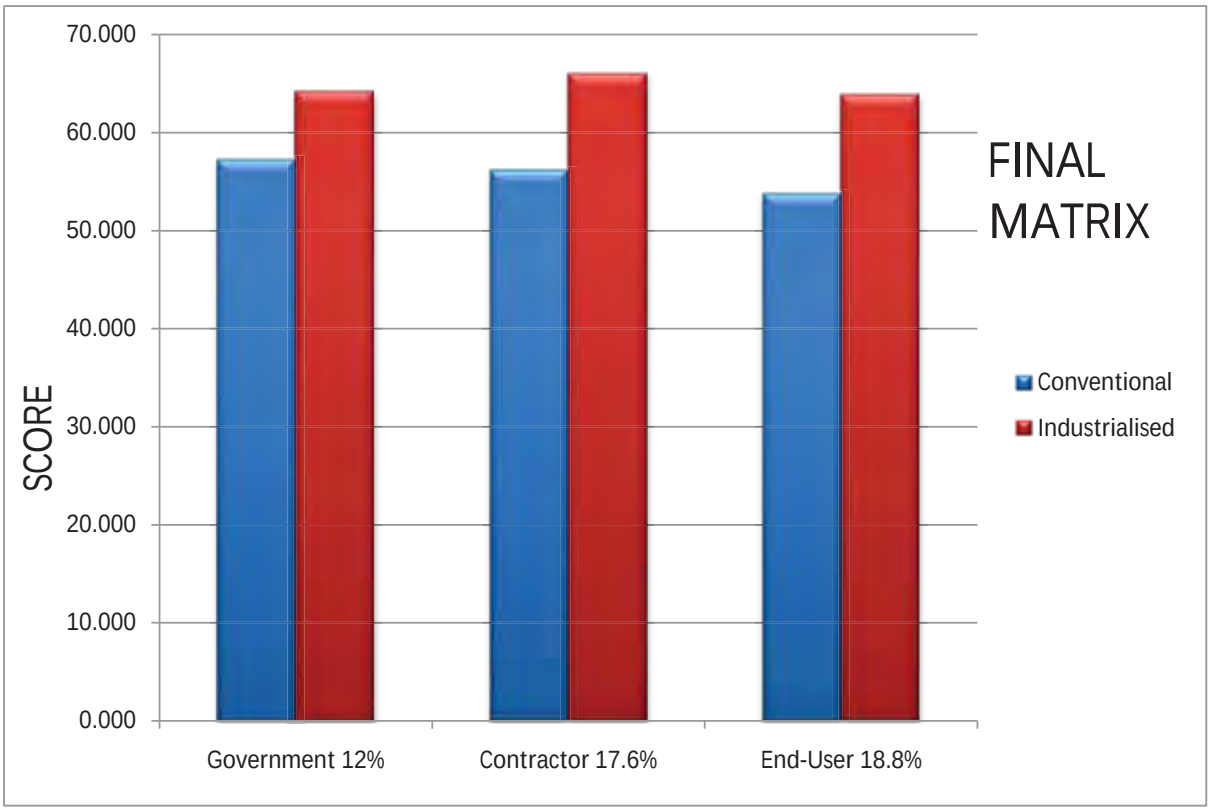


Figure 5.10 MCCFM Final Summary

This graph illustrates the scoring difference between conventional and industrialised building systems for each perspective group. This data is taken from the Final Matrix of the MCCFM tables and functions as a summary as well as a concluding analysis. The following points are noted for each perspective group.

- Government – From the graph and the MCCFM table it is evident that the difference margin between industrialised and conventional is less for government (12%) than for contractor (17.6%) and end user (18.8%). The main reason why government has derived a smaller

margin is because of their criteria. A major requirement for government is job creation which has considerably scored higher for conventional. Socio-economic growth is another similar factor which is favoured by conventional. The other important factors for the government such as delivery rate, adequacy and durability have been considerably favoured by industrialised. Out of the four most important factors considered by government only one, job creation, is in favour of conventional the other three are considerably favoured by industrialised. Another important criteria is the financial implication, this factor is shown as 'Cost per House'. Although this factor was scored in favour of industrialised it was only by a small margin. The government criteria had a total of 9 factors. 4 of the 9 factors were considerably favoured by industrialised, only 2 of the 9 were favoured substantially by conventional and the remaining 3 of the 9 were scored at negligible margin differences. Generally, regarding all factors of the government industrialised is considered to be the better building method for low income housing. The only set back is that industrialised underperforms through job creation which is an essential requirement for government. If job creation becomes a factor of less importance then industrialised would be fitting for low income housing. Otherwise if an industrialised system could be developed that offers a higher degree of job creation without compromising delivery rates, adequacy and durability, then this system would stand a chance of overcoming the housing shortage. Despite job creation industrialised has generally performed better than conventional and this should be reason enough to consider industrialised building system for government subsidised housing in South Africa.

- Contractor – for the contractor industrialised had scored 17.6% more than conventional. Industrialised offers many advantages for the contractor as the contractor aims to profit from the construction of the houses. The contractors criteria is comprised of 13 factors. 6 of the 13 are strongly favoured by industrialised, 4 of the 13 are considerably favoured by conventional and 3 of the 13 are only marginally different. All of the contractors three most important factors are favoured by industrialised. The factors which industrialised can offer a considerable advantage over conventional is manageability, production control, quality control, resource efficiency, product quality, production cost and production rate. These are the factors that make industrialised attractive for housing contractors. However, there are some drawbacks for the contractor, initial capital outlay is the strongest disadvantage for industrialised for the contractors sector. The initial capital outlay is a strong barrier for entry into the industrialised construction industry. A considerable amount of capital is needed to establish all the facilities, machinery and equipment needed to operate an industrialised

production line. Design flexibility, labour intensity and skills dependency are factors which are favoured by conventional and may discourage industrialised as a building system. Labour intensity is only favoured by conventional because the government requires the appointment of certain unskilled labourers within the project area. Industrialised offers fewer jobs than conventional making it more difficult to meet such requirement. In actual fact it is better for the contractor to hire as few labourers as possible because it requires less management and assures productivity and quality. Mechanisation, to a certain extent, is disapproved by government because it denies potential employment especially for a country with high unemployment rates. The other issue is that South Africa has relatively cheap labour which may make labour intensive processes cheaper than mechanised processes.

- End-User – This perspective evaluates the requirements for the resident of the houses. How the building will cater for their needs. It must be kept in mind that this is a housing process for the poor and should provide for the needs and not the luxuries. The end-user criteria is comprised of 9 factors. 5 of the 9 favour industrialised, 2 of the 9 favour conventional and 2 of the 9 are marginal. The end-user group had the highest difference between industrialised and conventional at 18.8% this is a considerable margin considering that government had received a 12% difference. Industrialised fared in favour of the three most important factors of the end user. Adequate Service Provision is the end users most important factor which is substantially higher for industrialised than for conventional. It seems that industrialised is the better building method for the end user. However, there are some drawbacks. Diverse design and aesthetics is favoured by conventional which can have an implication on the user friendliness of industrialised. In countries where industrialised building systems have been extensively used for low income housing have received complaints and a general negative approach towards this type of building system, although it has managed to house the population. This study speaks for itself as industrialised does indeed provide a better opportunity to eradicate the housing backlog in South Africa. The end user should be pleased with their house if it caters for all their needs.

5.7 Conclusion

The Analysis clearly shows that IBS is more feasible than CBS for all three perspectives. The sum of the scores of all the three perspective groups is 166.972 for conventional and 193.850 for industrialised, this is a 16.1% difference. Overall IBS is a more feasible option for government subsidised housing in South Africa. However, this analysis only focuses on the performance of both building systems with respect to the requirements of social housing. If IBS were to be implemented

for government subsidised housing in South Africa then more direct considerations need to be taken. Since this analysis only regards the concept of the two building systems, so the actual application of IBS would need to consider a particular design of an industrialised building. This particular design would need to be tailored for the South African environment, must suit the important criteria of the government especially job creation and it must incorporate materials suitable for the South African climate and resource capacity.

This analysis is seen as the first stage of developing an optimum building design. The analysis regards the requirements of each perspective group which identifies precisely what the building system would need to achieve. This analysis also but more importantly, distinguishes the direction of which building system would be the most suitable, thus either the industrialised system or the conventional system. Since both of these systems are essentially different it is important to know on what building system the optimum building design should be based on. At this stage the analysis can only recommend a most suitable building system from a technical perspective. Ideally, certain qualities form both IBS and CBS would need to be amalgamated into one hybrid building system that is most suitable to the South African environment. The analysis proves that IBS offers more advantages than CBS for social housing and therefore the optimum building design should adopt greater degree of industrialised and certain elements of conventional.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

Perhaps the reader should refresh on the definition of Feasibility: 'the degree to which something can be achieved or put into effect' (Encarta Dictionary). The analysis discovered that IBS suits the demands for low income housing better than CBS, yet the core question of practicality and implementation still remain. This chapter debates this question in the face of IBS for low income housing in South Africa. The knowledge provided in the literature review with the test from the data analysis provide a platform for this debate. If this system is implemented will it provide the same results as it did in other countries, how will it adapt to current policies and will the residents accept these industrialised houses? What extent of reform needs to be taken to adopt IBS into the current system? This study proposes a concept as an ideal from where a methodology can be drawn.

6.2 Summary of Research Process

This research aims to investigate the feasibility of industrialised building systems for housing the poor in South Africa. The aim is comprised of three objectives, thus; literature review, study surveys and data analysis. The literature review involves following: the housing situation in South Africa, conventional building systems, industrialised building systems, sustainable development and the identifying the criteria of each role player. The literature is an important part of the research as it provides a background and an understanding of the aspects to be researched. Furthermore, the literature review provides reasoning and substantiation for the aspects of the analysis. The criteria identification is an important aspect with regard to the analysis framework as it provides the basis of the framework, the interviews and questionnaires.

The study surveys is comprised of three aspects; developing the analysis framework, formulating and conducting/issuing both the interviews and the questionnaires. Developing the analysis framework involves researching and choosing an appropriate analysis tools and developing the tool to suit the needs of this research. The Multi Criteria Comparative Feasibility Matrix (MCCFM) is the analysis tool used for this research. It is based on the Simple Multi Attributable Rating Technique (SMART) which was developed further to include the criteria investigated and allows the comparative analysis between the two building systems. The surveys are based on the MCCFM tool as the interviews add an aspect of importance and the questionnaires provide an aspect of performance. The surveys are important as the factors must be analysed through their performance of either building system as well as the importance of the system towards the role player of the criteria. The interviews are used to weight the importance of each factor of the criteria investigated.

It asks the interviewees to weight each factor from 10 to 50, and then the data is converted to proportional norms after which the proportional data is weighted and averaged. This derives a value of importance for each factor of the criteria which is inserted into the MCCFM analysis tool. The interviews are directed towards each role player or perspective group involved in the government subsidised housing. The questionnaires asked the respondents to rate the performance of each factor of the criteria for industrialised and conventional building systems. The questionnaires were sent to contractors who are directly involved or have a sufficient background in both conventional and industrialised housing. The data of the questionnaires reflects the performance between industrialised and conventional for each factor of the criteria and is thus inserted into the MCCFM analysis matrix.

The Data analysis objective is comprised of three aspects, thus; applying the analysis framework, graphing the results and commentary and analysis on the results. Applying the analysis framework entails the processing of the data obtained from the interviews and questionnaires and applying such data into the MCCFM analysis tool so that it derives a final value which reflects the value of the feasibility. As explained, the interviews reflect the importance while the questionnaires reflect the performance. The raw data collected from interviews are processed by converting the data into proportional norms, then weighting the values against the averages of the respective primary factor category and then weighted again against the value of the primary factor. This derives a weighted average of each factor which is then inserted into the MCCFM analysis tool under each factor to value the importance. The raw data of the questionnaires are simply averaged and inserted into the MCCFM analysis tool for each respective building system in line with each factor. These values reflect the performance of each building system for each factor. Once these values form the surveys have been inserted into the analysis tool the processing of the values can begin. The MCCFM multiplies the values of importance with the values of performance; this is done for each factor of the criteria and for each building system respectively. The result shows a score for each respective factor of each building system. This is done for each of the three matrices, thus the government, contractor and end-user. The score reflects the value of each building system with the respective criteria. These scores are summed together to derive a final score for each perspective group, then those scores are summed together to derive a final score for the whole study. The building system with the highest score is deemed the better option. The scores of each factor and building system are graphed in a bar graph to illustrate the extent of the difference between the building system as well as comparing the level of the score against the other factors. The graphs are important for the analysis since the values are meaningless without relative ground. Therefore bar graphs are chosen as the illustration is ideal for comparative analysis. The commentary and analysis of the results is

largely done by discussing the outcome of each factor against the results of the other factors. The commentary involves the difference between the two building systems and the level of the score. This is the quantitative analysis. Then the scores and the differences are reasoned and substantiated, this involves background knowledge, of both building systems as well as the housing situation, gained through the literature review. This forms the qualitative analysis.

6.3 Research Aim and Objectives

South Africa faces a housing shortage of great proportions. It is estimated that the current housing backlog stands at 2.2 million houses. Despite the large scale housing developments, there has been little deterioration in the backlog since the new government has commenced with their social housing in 1996. Currently the housing delivery stands at an average of 250,000 houses per annum. The demand rate for housing is estimated at 150,000 houses every year, thus only 100,000 houses on average every year is towards the decreasing the housing backlog. At this rate the housing the current housing backlog will take 9 years to overcome, by this stage a new backlog driven by the previous demand would stand at 1.35 million houses and would take another 5 and a half years to overcome which during this time a new backlog of 810,000 houses would have been formed which would take 3.24 years to overcome. After which it would take at least another 4 years to finally eradicate the housing backlog. So a total of 22 years before the housing problem is finally eradicated. Provided that the housing delivery rate remains consistent and the demand rate does not increase.

Conventional building systems could see this housing problem through although but it will take some time before it does. Besides the housing backlog is not the only problem as the funding of the housing subsidies is expensive. The government currently spends around R3.7 billion on housing every year. In 2006 about 250,000 houses were delivered and R3.7 billion were spent on their subsidies, the subsidy in only R14800 per house which is not enough to cover the full cost of the house, it is up to the provincial and municipal governments to subsidise the rest of the houses which is the same as the national government subsidy. The government has spent 2.5% of the national budget on housing, this is planned to be increased to 5% of the national budget. The delivery of the houses is dependent on the subsidy for housing. In 1998 the housing subsidy funded R3.1 billion and the delivery was just under 300,000 houses which is a subsidy of R10,333 per house. The reason why this subsidy is lower than that of 2006 is due to inflation. The BER show that building inflation is at an average of 10% per annum and in some instances it has risen as far as 18% per annum. If the housing must carry on for the next 22 years then the building inflation will increase

the costs by a substantial margin. If the government can afford to subsidise the houses for then it will see then end of the housing shortage. The cheaper the building costs the more houses the government can subsidise and thus deliver.

Construction regards three compromisational requirement aspects; cost, quality and time. The higher the quality standard the higher the cost and the longer the project time period. There is true balance in each element in this equation. Therefore, since government subsidised housing is aimed at delivering houses at the cheapest level and at rapid delivery rate, then the quality cannot be of high expectations. The quality issue of the government subsidised houses are is matter of concern as certain elements of general quality are so poor that the some houses are deemed inadequate or even inhabitable and therefore cannot be classified as a formal adequate house. In which case the house should be demolished and rebuilt to satisfactory standards. The hindrance to quality involves the short time constraints and the tight costs. These are understandable as the houses have after all been subsidised and are aimed at the poor and should therefore provide the need and not a luxury. Job creation and skills shortage is a strong hindrance to the satisfactory quality of the houses. Since the government requires the employment of labourers from the community, who are mostly unskilled and inexperienced, cannot be expected to provide a good quality service. The other issue is that these labourers are aware that when the project is completed that they will be out of work again. As a result the labourers purposely delay or produce substandard work so that the project is delayed and employment is extended. Furthermore, the management and the supervisions or quality control of the construction is also an aspect which requires some attention. Due to the nature of conventional construction and especially for mass housing projects it remains difficult to implement assured quality control procedures. Therefore stronger management systems and a more systematic and fragmented work approach would lend itself to better manageability and thus better product quality. The problem objective of this research regards three main issues of government subsidised housing in South Africa. The first is the supply rate of the houses the second and demand or backlog for housing. The second is the financial aspect of the funding the housing projects. And the third is the quality issue of the houses.

6.4 Research Findings

The key findings of the research are taken from the final analysis and compared with some aspects of the literature review. The following points are listed:

- As the analysis shows overall IBS is the more feasible than CBS, which means IBS offers more advantages than CBS for low income housing.

- The main advantages that IBS offers in terms of social housing in South Africa are delivery rate, production control, quality control and adequate services.
- The main advantages that CBS offers in terms of social housing in South Africa are job creation, socio-economic growth and diverse design and aesthetics.
- For the government sector:
    - IBS would be most successful towards: Delivery Rate and Durability.
    - IBS would be a hindrance towards: Job Creation.
- For the contractors sector:
    - IBS would be most successful towards: Production Cost and Product Quality
    - IBS would be a hindrance towards: Initial Capital Outlay and Design Flexibility
- For the end-user sector:
    - IBS would be most successful towards: Adequate Services and Delivery Period
    - IBS would be a hindrance towards: Diverse Design and Aesthetics

6.5 The Value to Industry

This study investigates the feasibility of industrialised building systems for housing the poor in South Africa. This is done by analysing a comparative study between IBS and CBS for each major role player within social housing in South Africa. Therefore this study can offer beneficial information to each of the three role players, thus to the government housing department, the social housing contractors and to the residents or owners of these houses.

Government

In terms of the potential implementation of IBS for social housing, out of the three role players, the government is the most important as they are the project initiators and funders of social housing. Thus, if government decides to implement IBS the contractors and end-users will follow suit. The government is only a strong role player in the private social housing field. The results of the study do not only show which building systems is more beneficial but also what requirements or criteria conflict and hinder each other's success. A prime example is that the government requires the employment of labour within the community of the housing project with the noble intention of creating jobs and therefore socio-economic upliftment. However, this job creation incentive is a hindrance to the quality and production rate of the houses. Therefore, the results of this study can show what the government criteria is contradictory and can allow the reconsideration of the importance or extent of implementation of certain factors of their criteria.

Contractors and Others

This study can be applied to other mass housing industries, form high density apartment developments to high income estate developments. Therefore in this regard the contractor can benefit from the results of this study. This study shows what advantages IBS can offer and in what circumstances it would be most beneficial. This is potentially valuable information to, not only the contractors, but also property developers, building material suppliers and construction professionals, as each of these organisations seek similar criteria within their line of work. Furthermore, the MCCFM analysis framework can be adapted to suit personal requirements, as only relevant criteria can be selected and the MCCFM will derive comparative feasibility analysis.

End-User and Residents

The residents of the houses can utilise this information as grounds for decision making. Since there is talk of a negative perception against prefabricated or industrialised houses the potential home owner can make justified decision whether an industrialised built home might not be more beneficial than a conventionally built home. This does not only apply to residential buildings but to any other type, be it commercial, industrial or retail. The uses and class of IBS for housing in various countries are of a different nature. For example in Japan a prefabricated industrialised house is highly sought after, where in France industrialised from the bulk of housing.

6.6 Overall Conclusion

Housing the poor is one of the greatest challenges that face the South African Government. It is a broad issue and requires the efforts of every sector to be utilised if this problem to be solved. Since South Africa is a developing country and thus shares similar issues, problems and socio-economic environment with other developing countries, the results of this research can therefore be applied to developing countries in general. This research targets a general relevant problem of substantial proportions. The housing problem is one that affects every country of the world, though some much more than others. There has been some preliminary debate on whether industrialised building systems would not be applicable for social housing in developing countries. Certain countries like Malaysia, Hong Kong even Thailand extensively use IBS for housing and has proved to be a favourable result. Venezuela is developing country that has recently adopted IBS housing and so far has seen drastic results. Most developed countries use IBS for their housing due to its many advantages. For example Japan builds mostly with industrialised methods and has so for some time. However, there are some obvious differences between developed and developing countries that would affect the implementation of IBS. Some developing countries have implemented IBS for low

income housing but have been unsuccessful, for example Pakistan and Egypt in the late 60's and early 70's respectively. Developing countries have been discouraged by IBS through the expensive establishment costs, the lack of job creation and the failures experienced in the 60's and 70's. However, since then the building systems have been further developed and are of better standard, more efficient and in some cases cheaper. Venezuela for example has developed industrialised houses from PVC, these *petro casa's* are providing houses to an extensive range of people. These PVC houses have been developed to suit the environment of the country. Since Venezuela is rich in oil and therefore PVC is a cheap by-product of oil, this makes the production cheap and the delivery rate is rapid. Malaysia is another country who have successfully implemented IBS for housing, and have since become a first world country. There is no reason why IBS would not be successful for social housing, provided that a suitable system and design is developed that suits the environment, the needs and optimises efficiency.

In terms of the social housing situation in South Africa, the government set a goal to replace all informal houses with formal houses by 2015. This requires a delivery rate of about 600,000 houses per annum from 2008. Currently the social housing delivery rate averages 250,000 per annum. Clearly the delivery rate would need to be drastically increased in order to reach the goal. The conventionally built houses cannot offer a sufficient delivery rate for housing, where IBS offers a greater delivery rate it would make sense that this building system should be adopted if the government's goal is likely to be achieved.

The South African government requires that the social housing contractors employ a certain number of labourers from the community where the houses are built. The purpose of this is to create more jobs and for socio-economic progression within these communities. The implication of this noble incentive is that it compromises the product quality and delivery rate of the houses as these employed labourers are mostly unskilled and inexperienced. Since these houses are built for the employed people they determine their own quality of the houses. Furthermore, these jobs will only lasts until the housing project is completed, since humans are gifted with perceptibility, the labourers will purposely work slowly so to delay the completion and in turn extend their employment. Clearly this is not sustainable instead a socio-economic progression factors should be implemented through entrepreneurship, self dependent communities and skills development.

The results of the research between IBS and CBS for social housing are briefly discussed below. The CBS received an unfavourable score for all three perspectives. This building system is associated with a number of problems such as slow delivery rate, poor quality standards and

inefficiency. On the other hand, it is has the benefit of creating more jobs, design flexibility and less skill dependency. Conventional could see the housing problem through as it has been shown that at current rates the conventional housing would take 22 years to overcome. This is provided that the housing demand rate and the delivery rate are consistent. Furthermore, issues such as aids, population growth rates, immigration, emigration and urbanisation are factors that would change the housing demand rate. Generally the communities are familiar with conventional houses as well as the jobs that this system offers. Implementing IBS could lead to initial dissatisfaction as prefabricated houses might stir dissatisfaction and strikes for conventional houses. The opposite may also be true where IBS houses would be welcomed as they produced better quality houses and at a faster rate. Conventional will always have a place in the construction industry since most buildings need to be built to client specifications and therefore having building process that is completely design flexible could be implemented for a variety of needs.

The IBS received a better overall score. This showed that this system is the favourable building system. This system could help produce cheaper mass housing projects, faster delivery rate, at high quality standards and generally more efficient. On the other hand, the shortage of research on the use of IBS for low income housing in developing countries, especially Africa, has made it difficult to predict the fate of IBS for housing the poor in South Africa. Factors where CBS would perform better such as Job creation, skills dependency and capital outlay are strong drawbacks towards implementing IBS for a developing country. Nevertheless, the analysis accommodates most aspects and requirements for government subsidised housing in South Africa and since IBS is more favourable it should be the preferred building system overall as it offers more and stronger advantages than disadvantages.

This research is directed at suggesting alternative ways that would be more beneficial and provide a stronger performance towards overcoming the housing problem in South Africa. Since the analysis regards the then, the analysis identifies precisely what the building system would need to achieve as the requirements of each perspective group are integral to the analysis framework. This analysis also but more importantly, distinguishes the direction between which building system would be the most appropriate, thus either the industrialised or the conventional building system. The analysis thus recommends the most suitable building system form a technical perspective. Unfortunately the actual answer is not as clear cut and precise as the analysis tool suggests. Implications of the actual implementation of IBS for housing would need to be considered. Furthermore, this research focuses on industrialised building systems as a concept of construction low income housing, therefore, the this research can only recommend the type of building system that would be most suitable for low

income housing in South Africa. This research also forms a base or foundation which recommends further research in this research field to develop and design a particular type of building design based on industrialised building systems but also accommodates certain aspects of conventional so to suit the South African environment, requirements, resources and capacity. This does not make the research an exploratory one but only shows how deep and broad this issue can become. This research provides an recommendation and a suggestion towards what building system would be most appropriate, this does not provide proposition for a solution to overcome the housing problem more efficiently and quicker than conventional housing would. Instead this research suggests a direction for formulating and developing a system that would offer a feasible solution in overcoming the housing backlog. This research would suggest two further dependant studies that would propose a solution in overcoming the housing problem in South Africa. The first study would involve developing a certain type of building design which is based on industrialised building systems and includes certain elements of conventional in line with the requirements for housing. This system that this study would develop would need to be suitable to the environment, resources and needs of this country. The second research would be based on the first research which develops the actual design of the proposed building. This, the second research, would involve proposing a method and procedures of implementation. This involves what the governments, the contractors and the end-users role which would be needed to allow the successful implementation of the proposed building design.

6.7 Research Recommendations

This research provides a recommendation to the government housing department, the housing contractors, the home owners of these houses and eager researches. The recommendation of each group is as follows:

Government Housing Department

- This research suggests that the housing department should review their criteria and to ensure that the requirements are not contradictory and that a level of importance should be allocated to each of these requirements so that an optimum criteria is established that will not hinder the development.
- This research's main recommendation to government is that it should consider utilising and implementing certain aspects of industrialised building systems so that their current building system can offer a faster delivery, cheaper costs and better standards without compromising their requirements.

Housing Contractors

- The advantages and disadvantages that IBS and CBS offer for government subsidised housing in South Africa. This research further recommends aspects of the criteria of the contractor that can be beneficial to mass building in general and not only for low cost housing.
- The MCCFM is an analysis framework that is tailored for housing and comparing between IBS and CBS. The contractor can adapt this analysis framework to his own needs by inserting the relevant criteria and processing the calculations. The MCCFM can provide any decision making between the degrees of IBS and CBS for construction.

Home Owners and End-User

- This research makes a recommendation to the home owner when selecting between an industrialised built house and a conventionally built house. As this research illustrates the advantages and disadvantages for each factor of the end user it will help to create a considered decision on which building type to choose in terms of its use, type and future plans.
- In terms of government subsidised housing in South Africa, the end user can utilised IBS to his full benefit as a degree of knowledge is gained through the building system.

Further Research Recommendations

- Developing an appropriate Industrialised Building Design for the South African low income housing industry.
- Proposing the most suitable method of implementing IBS for housing the poor in South Africa.
- Investigating the feasibility of Industrialised Building Systems for town house estate developments.
- Optimising Building efficiency through pre-cast concrete panel construction.
- Standardised Quantitative Quality Assessment Techniques.
- Developing systematic quality control procedures through work package management.
- Investigating the efficiency of automotive modular construction for high rise buildings: a property developer’s perspective.

6.8 Research Publications

This research produced a research paper and book chapter. Copy of each publication is attached in the appendix section and details are below:

- Conrads S.M., Othman A.A.E. (2008). Industrialised Building: Investigating its Feasibility for Housing the Poor in South Africa. *South African Council of the Quantity Surveying Profession (SACQSP) Quantity Surveying Conference 2008 QS + 20/20 Vision Beyond 2010. Midrand, South Africa. 10 October 2008,* pp. 42-52.
- Othman, A.A.E., Conrads, S.M. (2009). Investigating the feasibility of Industrialised Low-Cost Housing In South Africa. In: Kazi, A.S., Hannus, M. and Boudjabeur, S. (eds.) Open Building Manufacturing: Key Technologies, Applications and Industrial Cases. ManuBuild, pp. 103-127.

6.9 Closing Comment

Referring back to the quote from Henry Ford; “Searching for the answers to the dilemma in a world of potential abundance, a crack in the rear view mirror”. The initial idea that should solve a problem needs to be a novelty otherwise it is not a solution. The housing shortfall is dependant on a number of different issues, and a solution for such a wide range of problems needs to come from the drawing board. This study recommends that a building system with greater tendencies towards industrialised techniques as feasible for social low income housing in South Africa.

REFERENCES

Abdellatif, M. A. and Othman, A. A.E. (2006). Improving the Sustainability of Low Income housing projects: The case of residential buildings in Musaffah commercial city, Abu Dhabi, *Emirates Journal for Engineering Research*, 11(2), 47-58.

Associated Press of Pakistan. (2007), Low cost housing facility for the poors top priority. [Online].

Available from:

http://www.app.com.pk/en/index.php?option=com_content&task=view&id=4456&Itemid=2

[Accessed 17/03/2008].

Badir. Y.F., Hashim. A.H. and Abdul Kadir. M.R. (2002). Industrialized Building Systems Construction in Malaysia. *Journal of Architecture and Engineering ASCE* 8:1, 19-23. [Online]. Available from:
http://scitation.aip.org/getpdf/servlet/GetPDFServlet?filetype=pdf&id=JAEIED0000080000010000019000001&idtype=cvips&prog=normal [Accessed 20/02/2008].

Bar, E. (2004). Economies Of Scale Vs. Economies Of Scope, [Online] Available from: http://www.collegestock.com/articles/Economies-Of-Scale-Vs-Economies-Of-Scope.html [Accessed 17/03/2008].

Buckley R.M. and Kalarickal J. (2005). Housing Policies in the Developing Countries: Conjectures and Refutations, *Occasional Paper World Bank, Oxford University Press, Vol.20*, pp233-257.

Charlton, S. and Kihato, C. (2006). Reaching the poor: An analysis of the influence of the evolution of South Africa's housing programme. Democracy and Delivery: *Urban Policy in South Africa*, pp. 252-282. HSRC Press, Cape Town.

Choa K. (1970). Industrialisation and Urban Housing in Communist China.

CIRIA. (1996). Value Management In Construction: A Clients Guide. [Special Publication] England.

Constitution of the Republic of South Africa. (1996). [Online]. Available from: http://unpan1.un.org/intradoc/groups/public/documents/UN/UNPAN005172.pdf [Accessed 07/03/2008].

Culpin C. (1970). Basic Principles of Industrialised Building, *A Paper submitted to the National Congress of Industrialised Concrete Building, Johannesburg, October 1970*.

Csagoly, P. (1999). Post-Com Prefab, [Online] Available from: http://www.ce-review.org/99/24/csagoly24.html [Accessed 21/04/2008].

Department of Housing SA. (1998). Housing Code: Draft1 November 1998.

Department of Housing SA. (2002). Towards Sustainable Settlements: Case studies from South Africa, STE Publishers.

Department of Housing SA. (2004). White Paper, A New Housing Policy and Strategy.

Department of Housing SA. (2005). Social Contract for Rapid Housing Delivery, *Housing Indaba, Cape Town, September 22-23, 2005*. [Online] Available from: http://www.housing.gov.za/Content/Socail%20Housing%20Contract/Socail%20Contract.pdf [Accessed 24/03/2008]

Department of Housing SA. (2007). Annual Report 2006- 2007.

Gann D.M. (1996). Construction as a manufacturing process? Similarities and differences between industrialised housing and car production in Japan. *Construction Management and Economics*, 14, pp. 437-450.

Glass J. (2000). The Future of Precast Concrete in Low-Rise Housing, [Online]. Available from: http://britishprecast.org/publications/bpcfbrochure.pdf [Accessed 04/04/2008].

Gibb A. G. F. (2001). Standardization and pre-assembly- distinguishing myth from reality using case study research, *Construction Management and Economics, Volume 19, Number 3*, 1 April 2001 , pp. 307-315(9), Routledge, [Online] Available from: http://web.ebscohost.com/ehost/pdf?vid=4&hid=115&sid=7c195876-89b4-470a-a0a9-01b727c554b4%40sessionmgr108 [Accessed 04/04/2008].

Gelman.M. (1988). An economic appraisal of industrialised building technique in South Africa.

Hamid Z.A., Ghani M.K., Rahim A.H.A. and Kamar K.A.M. (2007). Industrialised Building Systems (IBS): Current Shortcomings and the Vital Roles of R&D, *Construction Research Institute of Malaysia (CREAM), Kuala Lumpur*, [Online] Available from: http://www.cream.com.my/images/news/IBS%20Shortcomings%20and%20Vital%20Roles%20of%20R&D.pdf [11/04/08]

Hemson, D. And O'Donovan, M. (2006). Putting numbers to the scorecard: presidential targets and the state of delivery. In *State of the nation: South Africa 2005-2006*. Buhlungu, S., Daniel, J., Southall, R. & Lutchman, J. (eds). Cape Town: HSRC Press. pp.11-45

Herbert.G, (1984). The Dream of the Factory Made House, the MIT press, USA.

Hise M. (2007). Venezuela Analysis, Petro Casa's [Online] Available from:

http://www.venezuelanalysis.com/analysis/2555 [Accessed 17/03/2004].

Howell. G, Ballard. G. (1999). What kind of production is Construction? [Online] Available: http://www.leanconstruction.org/pdf/BallardAndHowell.pdf(17/03/04)

Hong O.C. (2006). Analysis of IBS for School Complex , *University of Technology Malaysia*. [Online]. Available from: http://www.efka.utm.my/thesis/IMAGES/3PSM/2006/1JSB/PART6/ongchinhongaa010410d06tht.pdf [Accessed 11/04/2008].

Huovila, P. and Koskela L. (1998). Contribution of the principles of lean Construction to meet the challenges of Sustainable development, [Online]. Available from: http://www.ce.berkeley.edu/~tommelein/IGLC-6/HuovilaAndKoskela.pdf [Accessed 17/03/2004].

Jacks M., Business Report. (2006). Low-cost housing gets promises aplenty but dismal delivery, [Online]. Available from: http://www.busrep.co.za/index.php?fSectionId=552&fArticleId=3430967 [Accessed 20/02/2008].

Keivani R. and Werna E. (2001). Modes of housing provision in developing countries, *Progress in Planning Volume 55, Issue 2, February 2001, pp 65-118* [Online] Available from: http://www.sciencedirect.com/science?_ob=PublicationURL&_tockey=%23TOC%235947%232001%23999449997%23224237%23FLA%23&_cdi=5947&_pubType=J&_auth=y&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=812b113a891ec57e6202d7c30f9528a7 [Accessed 11/04/2008].

Knight R. (2006). South Africa Challenges for the Future 2006, [Online] Available from: http://richardknight.homestead.com/files/SouthAfrica2006-ChallengesfortheFuture.pdf [Accessed 14/04/2008].

Knight R. (2001). Housing in South Africa, [Online] Available from: http://richardknight.homestead.com/files/sisahousing.htm [Accessed 06/02/2008].

Lawrence G.H. (1970). Industrialised Building Standards, Diciplines and Performance, UK Experience of the Sixties. *A Paper submitted to the National Congress on Industrialised Concrete Building, Johannesburg, October 1970.*

Lo T.Y. (2001). Innovative Prefabrication System in Housing Block Construction. [Online]. Available from: http://www.irbdirekt.de/daten/iconda/06059019722.pdf [Accessed 04/04/2008].

Luzulane.N.C. (2002). A comparative analysis of the developer driven process versus peoples housing process: A case study of Wiggins fast track and Piesangs river in Durban South Africa. Unpublished dissertation, University of KwaZulu-Natal, South Africa.

Makala G. (2006). Temprature stability of traditional and low-cost modern housing in the Eastern Cape, South Africa, in *Journal of Building Physics* Vol. 30 No. 1, pp.71-86. [Electronic] Available: http://www.byv.kth.se/avd/byte/reykavik/pdf/art_136.pdf [Accessed 11/04/2008].

Mancheno-Gren A. (2003). Evaluation of Low Income Housing Projects in South Africa: Typologies, Densities, and Gender issues in housing. *KTH – Royal Institute of Technology, Stockholm, Sweden.*

Mccutcheon, R. T. (2001). Employment generation in public works: recent South African experience. *Construction Management & Economics; Apr/May2001, Vol. 19 Issue 3, p275-284, 10p,* [Online]. Available from: http://web.ebscohost.com/ehost/pdf?vid=2&hid=108&sid=2c446d7f-cd00-499b-af26-10d51acba785%40sessionmgr2 [Accessed 04/04/2008].

Mind Tools. (1995). Decision Making Techniques, [Online]. Available from: http://www.mindtools.com/pages/article/newTED_00.htm [Accessed 10/02/2008].

Monkhi, M. (2007). An assessment of low income housing programmes in providing adequate dwellings for the urban poor – A case study of Cato Crest Greenfield, Cato Manor. Unpublished dissertation, University of KwaZulu-Natal, South Africa.

Monsted J.M. and Percinel O. (1982). The Technical and Economic Advantages of Industrialized Building Methods, *Construction Methods and Delivery Systems pp. 54-59.*

MOST Clearing House, Self Contained Housing Delivery System Thailand (2005) [Online]. Available from: http://www.unesco.org/most/asia10.htm. [Accessed 20/02/2008].

Neuwirth, R. (2006). Shadow Cities. Routledge

Radikeledi, Economic Society of South Africa (ESSA) (2005). An Analysis of the South African Government Low Cost Housing Provision Strategy. [Online]. Available from: http://www.essa.org.za/download/2005Conference/Radikeledi.pdf. [Accessed 20/02/2008].

Reddy, A.M. (1987). A critical analysis of industrialised building method in South Africa.

Rodin, J. (1970). Ronan Point and After. *A Paper submitted to the National Congress on Industrialised Concrete Building, Johannesburg, October 1970.*

Shutt, R. (1988). Economics for the construction industry. 2nd Ed, Longman. Essex England. pp. 24-42.

Solomon, M. (2005). Low Cost Housing in South Africa. [Online]. Available from: http://ghettoverit.wordpress.com/ [Accessed 04/04/2008].

Statistics South Africa. (2007). Midyear Population Estimates.

Statistics South Africa. (2001). Census 2001: Primary tables South Africa Census '96 and 2001 compared, Report No. 03-02-04 (2001).

Thanoon W.A., Peng L.W., Kadir M.R.A., Jaafar M.S. and Salit M.S. (2003). The Essential Characteristics of Industrialised Building Systems, *International Conference on Industrialised Building Systems, Kuala Lumpur, Malaysia, 10-11 September, 2003 283,* [Online] Available from: http://leewp33.tripod.com/sitebuildercontent/sitebuilderfiles/characteristic-ibs.pdf [Accessed 04/04/2008].

Unger C. (2006). Industrialised house building – fundamental change or business as usual? *Doctoral Thesis, KTH School of Industrial Engineering and Management,* Stockholm. [Online] Available: http://www.diva-portal.org/diva/getDocument?urn_nbn_se_kth_diva-4120-2__fulltext.pdf. [Accessed 20/02/2008].

UN-Habitat. (2003). The Challenge of Slums, Global Report on Human Settlements 2003: UN-Human Settlement Programme. Earthscan Publications.

World Press. (1965). London Panel Apartment Block. [Online]. Available from: http://www.worldpress.org/europe.htm [Accessed 20/02/2008].

Yeung N.S.Y., Chan A.P.C., Chan D.W.M. (2002). Application of Prefabrication in Construction – A New Research Agenda for Reform by CII-HK. [Online] Available from: http://www.ciihk.org.hk/sheet/26112002_apc.pdf [Accessed 04/04/2008].

BIBLIOGRAPHY

Anatos Engineering Associates. (2002). Modular Construction. [Online] Available from: www.anastoseng.com/aea/ [Accessed 24/03/2008].

Bender, R. (1973). A crack in the rear view mirror – a view of industrialised building. VNR, USA - NY.

Builders, C. (2003). Custom Modular Homes. [Online]. Available from: www.c-builders.net/newpage3.htm [Accessed 24/03/2008].

CSSA. (1970). National Congress of Industrialised Building – Selected Papers, Suparocla.

Department for Communities and Local Government. (2007). Homes for the future: more affordable, more sustainable, [Electronic]. Available from: http://www.communities.gov.uk/publications/housing/homesforfuture [Accessed 25/03/2008].

Gianino, (2005) The Modular Home - the essential guide to building your own modular home. [Online]. Available from: http://www.modularhomebook.com/book/chapter01.html [Accessed 24/03/2008].

Main, H. and Williams S.W. (1994). Environment and Housing in Third World Cities. Wiley.

Moodely, N. (2006). Minister backs emergency fold-away-house concept, *Engineering News 24 November 2006* [Online] Available from: http://www.engineeringnews.co.za/article.php?a_id=98345 [Accessed 11/04/2008].

Snell, M. (1997). Cost Benefit Analysis for engineers and planners. Thomas Telford, London.

Tipple G.A. and Willis K.G. (1991). Housing the Poor in the Developing World: Method of Analysis, case studies and policy. Routledge.

APPENDICES

Appendix 1 – Interview Sheet Government

Government Interview

Date:
Name:_____
Position:_____
Tel:_____ Fax:_____
Email:_____

1. Factor Weighting Questions:

Primary Factor	10 to 50 Primary Rating	Secondary Factor	10 to 50 Secondary Rating
		1.1 Delivery Rate	
1 Housing Provision		1.2 Adequate Housing & Quality	
		1.3 Durability & Structural Quality	
		2.1 Cost per House	
2 Affordability & Job Creation		2.2 Initial Capital	
		2.3 Job Creation	
		3.2 Socio-Economic Growth	
3 Sustainable Development		3.3 Building Reuse & Adaptability	
		3.4 Green & Resource Efficiency	

2. Any Further Factors that may be necessary?
   a. _____
   b. _____
   c. _____
   d. _____
   e. _____

Thank you for your Time

Appendix 2 – Interview Sheet Contractor

Contractor Interview .1

Date:
Name: _____
Company: _____
Position: _____
Tel: _____ Cell: _____
Email: _____

1. Factor Weighting Questions:

	Primary Factor	10 to 50 Primary Rating	Secondary Factor	10 to 50 Secondary Rating
1	Production		1.1 Production Cost 1.2 Initial Capital Outlay 1.3 Production Rate 1.4 Product Quality	
2	Management		2.1 Manageability 2.2 Production Control 2.3 Quality Control 2.4 Skills Dependency 2.5 Labour Intensity	
3	Physical Implications & Sustainability		3.1 Design Flexibility 3.2 Construction Complexity 3.3 Carbon Footprint 3.4 Resource Efficiency	

1. Any Further Factors that may be necessary?
    a. _____
    b. _____
    c. _____
    d. _____
    e. _____

Thank you for your Time

Appendix 3 – Interview Sheet End-User

End-User Interview .1

Date:
Name: _____
Company: _____
Position: _____
Tel: _____ Cell: _____
Email: _____

1. Factor Weighting Questions:

	Primary Factor	10 to 50 Primary Rating	Secondary Factor	10 to 50 Secondary Rating
			1.1 Delivery/Waiting Period	
1	Time & Future Value		1.2 Adaptability & Alteration	
			1.3 House Value	
			2.1 Affordability	
2	Cost		2.2 Maintainability	
			2.3 Life Cycle Period	
			3.1 Diverse Design & Aesthetic	
3	Quality		3.3 General Quality of House	
			3.4 Adequate Service Provision (L&W)	

2. Any Further Factors that may be necessary?
   a. _____
   b. _____
   c. _____
   d. _____
   e. _____

Thank you for your Time

Appendix 4 – Survey Questionnaire Sheet

Questionnaire

This research investigates the feasibility of industrialised building as a concept for housing the poor in South Africa. The Simple Multi Attributable Rating Technique (SMART) is a decision making tool that analyses the feasibility by comparing industrialised housing against conventional housing at certain factors. Each factor is weighted according to its importance and each proposal (conventional or industrialised) is then rated according to its performance for each factor. The weighting is then multiplied by the rank which shows the score of each factor, these are then added together and the proposal with the highest score is the better proposal. Table 1 below shows all 19 factors which need to be ranked according to their performance on a scale form 10 to 100 (10 being least & 100 being most). For example:

		Conventional	Industrialised
Building Quality			

Conventional and industrialised can receive the same rating for a particular factor. The use of extreme rating thus 10 or 100 is not recommended as no factor should have no performance what so ever or complete and perfect performance. A set of definitions and clarifications for each factor is given below, this also defines what direction the rating scale should tend towards.

At the end of the table space is provided for respondents to substantiate their answers given for each factor in the rating table. Short reasons by listing keywords is sufficient, otherwise if time permitting more detailed reasons are welcome.

If there are any further factors that may be relevant which have not been included then please fill and rank them in at the blank rows at the end of the table. If you have any further suggestions or comments then please provide them at the end of the questionnaire.

Please provide the following details:
Company Name: _____
Name of Respondent: _____
Position of Respondent: _____

A brief description and classification of your housing product:

_____

_____

Underline one type of material that is mainly used for your product:

↑ Timber ↑ Steel ↑ Concrete

Definition of terms:

- Industrialised Building Systems (IBS) – is the concept of utilising mass production techniques for construction by prefabricating larger standard building components in a factory, on or off site, and minimising construction and assembly periods.
- Industrialised housing refers the same definition as IBS (as above) just with particular use towards housing.
- Conventional Building (or Housing) – is the standard building process, thus concrete block and mortar construction. This definition can be made with particular reference towards the current low cost housing construction method in South Africa.

Definition and clarification of factors:

1. Delivery Rate – The speed at which the house can be built. (The faster the better)
2. Adequacy & Housing Quality – The capability of a building to fix services, provide finishes and install doors and windows. (The easier the better)
3. Durability & Structural Quality – The level of durability and structural standard of the building. (The higher the level the better)
4. Cost per House – The affordability of the price of the house. (The cheaper the better)
5. Initial Capital - How much capital is needed to establish facilities and equipment needed for building such houses. (The cheaper the better)
6. Job Creation - How many job opportunities are created through either system? (the more the better)
7. Socio-Economic Growth – The extent to which the building system impacts on the surrounding community.
8. Building Reuse & Adaptability - To what extent can the building be taken down and rebuilt or allow modification with minimal demolishment? (the more reusable or recyclable it is the better)
9. Green & Resource Efficiency – How efficiently does either process consume resources (say cement) or what is the extent of the waste margin of either system and how it impact on the environment? (the less wastage and less impact the better)
10. Production Cost – How cheap is it to build or produce such a building. (The cheaper the better)
11. Initial Capital Outlay – How much capital is needed to establish facilities and equipment needed for building such houses. (The cheaper the better)
12. Production Rate – The rate at which the contractor can construct the houses. (The faster the better)
13. Product Quality – The general standard of the houses constructed. (The higher the standard the better)
14. Manageability – How well can either system allow itself to be managed at a general perspective? (the more manageable it is the better)
15. Production Control – How well does either system allow production control, in terms of quantity, inventory and out put management? (the easier production control can be implemented the better)

16. Quality Control – How well can quality control procedures be implemented for either system, this includes supervision, snagging, material and component checks? (the easier quality control can be implemented the better)
17. Skills Dependency – To what extent does either system rely on skilled employment, please take into account the number of skilled positions needed, the standard of the skills or education required and extent of responsibility of the skilled positions? (the less skills dependant the better)
18. Labour Intensity – To what extent does either system utilise intensive labour orientated practices, please account for the difficulties that labour intensiveness presents (health and safety, etc.) and quality labour availability? (the less intensive the better)
19. Design Flexibility – How easily can the design of the building be modified? (the more flexible the better)
20. Construction Complexity – How complex is the construction process? (the less complex the better)
21. Carbon Footprint – Which system has a greater carbon footprint per unit or house produced? (the less the better)
22. Resource Efficiency – Which system allows less wastage of materials and which has a more efficient production process. (the less wastage and more efficient the better)
23. Delivery/Waiting Period – The time it takes from ordering a house to the complete delivery of the house. (The less time the better)
24. Adaptability & Alteration – The ease of which the building system can be altered and be used for a different purpose. (The more adaptable the better)
25. House Value – The extent to which the house can receive better resell value with regard to the building system used. (The more the better)
26. Affordability – How affordable the house would be to the owner, taking into account modifications, maintenance and alterations. (The cheaper the better)
27. Maintainability – The level of maintenance required. (The less the better)
28. Life Cycle Period – For how long should the building last and be used for the same purpose. (the longer the better)
29. Diverse Design & Aesthetic – The flexibility of changing the design of the houses so not to produce monotonous housing and the aesthetic appeal. (The more diverse and aesthetic the better)
30. General Quality of the House – All quality aspects that the resident should require. (the higher the standard the better)
31. Adequate Service Provision (L&W) – The ability and standard to provide lights and running water to the houses, in terms of the plumbing layout, electrical conduits, fixing and installations within the house. (The more able the better)

Questionnaire Table

Sec	Primary Factor	No.	Secondary Factor	Industrialised 10 to 100	Conventional 10 to 100
GOVERNMENT	Housing Provision	1	Delivery Rate		
		2	Adequacy & Housing Quality		
		3	Durability & Structural Quality		
	Affordability & Job Creation	4	Cost per House		
		5	Initial Capital		
		6	Job Creation		
	Sustainable Development	7	Socio-economic Growth		
		8	Building Reuse & Adaptability		
		9	Green & Resource Efficiency		
CONTRACTOR	Production	10	Production Cost		
		11	Initial Capital Outlay		
		12	Production Rate		
		13	Product Quality		
	Management	14	Manageability		
		15	Production Control		
		16	Quality Control		
		17	Skills Dependency		
		18	Labour Intensity		
	Physical Implications & Sustainability	19	Design Flexibility		
		20	Construction Complexity		
		21	Carbon Footprint		
		22	Resource Efficiency		
END-USER	Time & Future Value	23	Delivery & Waiting Period		
		24	Adaptability & Alteration		
		25	House Value		
	Cost	26	Affordability		
		27	Maintainability		
		28	Life Cycle Period		
	Quality	29	Diverse Design & Aesthetic		
		30	General Quality of House		
		31	Adequate Service Provision		

Please provide a short reason to substantiate your rating for each factor from the table above. Listing keywords for the reasons will suffice.

1. Delivery Rate

2. Affordability towards Client

3. Production Cost per House

4. Capital Outlay for Business

5. Building Quality

6. Building Durability

7. Maintainability

8. Building Reuse

9. Adaptability

10. Design Flexibility

11. Construction Complexity

12. Resource Efficiency

13. Carbon Footprint

14. Manageability

_____

15. Production Control

_____

16. Quality Control

_____

17. Job Creation

_____

18. Skills Dependency

_____

19. Labour Intensity

_____

Please send the completed questionnaire via email as addressed below.

Thank-you for your time

SACQSP2008-05

INDUSTRIALISED BUILDING: INVESTIGATING ITS FEASIBILITY FOR HOUSING THE POOR IN SOUTH AFRICA

Conrads SM [1] and Othman AAE [2]

School of Civil Engineering, Surveying & Construction, Faculty of Engineering, University of KwaZulu-Natal, Durban, South Africa. E-mail[1]: Stefconrads@gmail.com, Tel: 031 2602687; E-mail[2]: Othman@ukzn.ac.za, Tel: 031 2602821

ABSTRACT

Purpose of this paper - This paper aims to investigate the feasibility of industrialised building as a strategic approach for housing the poor in South Africa.

Methodology – the research methodology designed to achieve the abovementioned aim consists of literature review, interviews and survey questionnaires. Firstly, literature review is used to: (i) investigate the housing situation in South Africa, the conventional and industrialised building systems and sustainable development; (ii) identify the criteria for comparing between the two building systems, (iii) develop a decision making matrix to facilitate achieving informed decision. Secondly, interviews are used to weight the importance of each factor of the identified criteria. Finally, the survey questionnaires are used to apply the developed matrix through rating the performance of conventional and industrialised building systems according to each factor of the identified criteria. Data will be analysed quantitatively and qualitatively to identify the feasible system for housing the poor in South Africa.

Findings - Housing the poor is one of the great challenges that face the South African government. The housing problem could be attributed to a number of reasons, amongst them the slow supply rate in terms of lengthy erection time, cost of construction, adaptability, inadequacy and non sustainability. The results of this study aims to inspire the development of an alternative strategy and building technique that will ultimately become a solution to housing the poor in South Africa. Industrialised building is a feasible solution that mitigates the difficulties associated with low cost housing in South Africa. However, job creation, is a major government requirement and is disfavoured by industrialised building systems.

Research Implications - The research investigated the housing problem in South Africa and identified its root causes. In addition, the traditional and industrialised buildings concepts are reviewed in order to identify the characteristics of each system. Furthermore, the criteria for comparing between the two building systems is identified and weighted. A decision making tool is developed to assist finding out the feasibility of industrialised building.

Practical Implications - Results of this research are recommended to the government on the feasibility of industrialised buildings as an effective solution for housing the poor in South Africa.

Value - This paper intended to support the government initiatives for housing the poor in South Africa. The research work presented in this paper is genuine and was not done before in the South African context. It is a highly debatable topic because of its importance, relevance to government subsidised housing objectives and the actual implications and performance of IBS for low income housing in South Africa.

Keywords: Housing the Poor, Traditional Building System, Industrialised Building System, Decision Making Tool, Sustainable Development.

1. INTRODUCTION AND METHODOLOGY

The state of housing in a country has a direct impact on the level of public health, the crime rate and many other social problems of importance. It also has an indirect effect on labour productivity in the economy through the general morale of the workers. Practically all countries today are facing housing problems of varying degrees, especially in urban areas. For an underdeveloped country, its ability to provide adequate housing in urban areas is a vital prerequisite for successful industrialisation (Chao, 1970: 381). It is estimated that one billion people are living in inadequate housing conditions in developing countries, therefore the need to provide adequate housing has become an urgent focus of policy debate not only in South Africa but also across the world (Keivani and Werna, 2001: 82). It is clear that the shortage of adequate housing hinders socio-economic growth in developing countries.

The new South Africa inherited an estimated housing backlog of 1.5 million units. In 1994, the African National Congress (ANC) adopted the Reconstruction and Development Programme (RDP), which is a policy framework for socio-economic integration; targeted to build 320,000 houses per year (Knight, 2001: 5). Between 1994 and 2001 about 1.129 million houses had been built. Despite these efforts, 2 to 3 million houses were still needed (Department of Housing, 2001:10). Then by 2007 a total of 2.35 million houses were built, yet the housing backlog remains at 2.2 million houses. Although the housing delivery had doubled, the housing backlog still remained the same. This shows that the housing production only covered the housing demand rate and not the backlog itself (Department of Housing, 2007: 17). Mthembi Mahanyele, the former housing minister, stated in 2001 that the housing delivery would slow down due to quality issues and tenure difficulties. This shows that government housing initiatives had realised housing difficulties in sustainable production, quality and tenure. The government had set delivery targets in the housing policies, yet consistency falls short from its commitment as so far no housing targets has been met and most of the houses that have been delivered are 'inadequate' (Monkhi, 2007: 23). In 2004, the Sustainable Human Settlement Plan, also known as the Breaking New Ground (BNG), was approved. It is a new housing framework that brings a larger emphasis to sustainability. Its prime target is to eradicate or upgrade all informal settlements by 2014/15 (Department of Housing, 2004:18). While the housing situation is growing more acute, South Africa is struggling to meet its own housing needs. The conventional construction method, due to its slow pace of construction, fragmented control and higher cost, is not able to meet this housing demand (Angus, 1997 cited by Badir et al., 2002: 20).

Because of the importance of supporting the government initiatives, this research aims to investigate the feasibility of industrialised building as a strategic approach for housing the poor in South Africa. In order to achieve this aim a research methodology, consists of literature review, interviews and survey questionnaires, is designed to accomplish a number of objectives:
Firstly, literature is used to:

- Build a comprehensive background of the housing situation in South Africa, the conventional and industrialised building systems with regard to low income housing projects and sustainable development.
- Identify the criteria for comparing between the conventional and industrialised building systems.
- Develop a decision making tool called the *Multi Criteria Comparative Feasibility Matrix (MCCFM)* to facilitate reaching an informed decision.

Secondly, interviews are used to weight the importance of each factor of the identified criteria. Three different perspective groups namely: government (initiator and developer), contractor (service provider) and end-user (resident) are interviewed to weigh their own criteria respectively. The sample size of the interviewee was 15 individuals.

Finally, survey questionnaires are used to utilise the weights gained from the interviews and apply the developed decision making matrix in order to rate the performance of conventional and industrialised building systems according to each factor of the criteria identified. The questionnaires are sent to a sample of contractors who are directly involved with industrialised and conventional building systems in South Africa. The sample size of the questionnaire was 12 contractors, this being the total identified population size of the industrialised housing contractors throughout South Africa (Yellow Pages, 2008).

Data will be analysed quantitatively and qualitatively to investigate the feasibility of implementing industrialised building systems for housing the poor in South Africa. Quantitative analysis will be achieved through calculating the sum of multiplying the average of rates given by respondents for every building option by the appropriate criteria weight gained from the interviews. This will help arriving at a summary matrix where the results of each group is presented. Results will be analysed qualitatively to explore the reasons behind scoring some factors higher than others.

The validity and reliability is of importance to this research. The use of ranking and rating questions in both the questionnaire and interviews helped minimise the risk of potential subjectiveness and biasness towards the factors analysed and the particular building systems. Furthermore, meeting people who are directly related to the research problem (i.e. government housing officials, housing contractors and community resident) helped increase the reliability and validity of collected data and research findings.

2 LITERATURE REVIEW

2.1 The Housing Problem in South Africa

South Africa faces an increasing housing backlog. The problem is that the housing delivery rate cannot keep up with housing demand rate. The rate of supply is too slow if compared to the increasing rate of demand. Despite the government housing supply achievements, there remain issues for concern. Many South Africans are still homeless, settlements are located far from job opportunities, shelter performance is poor, layouts are monotonous and services are inadequate (Department of Housing, 2001:13). The urban housing shortage that was inherited by the ANC led government was estimated at 1.3 million houses (Knight, 2001:6). The ANC realised that lifting the apartheid's segregation laws would burst the flood gates of urbanisation, exploding population growth rates and forming housing problems.

2.1.1 Housing Delivery

The 1994 delivery target, according to the National Housing policy, was calculated as follows:

- The housing backlog in 1994 was estimated at 1.5 million units, the goal was set to build 150000 houses a year to overcome this backlog over a period of 10 years.
- New housing formation, in terms of population growth and urbanisation, required an additional delivery rate of 150000 houses a year so that the backlog would not increase.
- So the target was set to build 300000 to 350000 units per annum (Department of Housing, 2001:22).

Figure (1) Housing Demand vs Total Delivery

Table (1): Delivery and Demand Rates

Rate Houses p.a.

	Delivery	Demand	Difference
1997/2001	221,854	406,207	-184,353
2001/2004	182,017	164,387	17,630
2004/2007	248,278	149,241	99,037

Figure (1) shows that the housing shortage has not decreased despite the progressive housing supply as the two curves move further apart over time. From 1997 to 2001 the gradient of the housing demand curve is more than the gradient of the delivery curve, this indicates that the delivery rate was less than the growth in demand. It is only since 2001 that the growth in the housing backlog had started to decrease. Progress in eradicating the housing shortage will only occur when the delivery curve is steeper than the demand curve and will be fully eradicated when the two curves meet.

Table (1) shows the average delivery and demand rate per annum over the indicated periods. The difference column indicates by how much the delivery has exceeded the demand and by how much the housing backlog has decreased. Between 1997 and 2001 the delivery rate was less than the demand rate which added an average of 184,353 houses to the housing backlog every year. However from 2001 onwards the average housing delivery rate had started to overtake the housing demand rate. This decreased the housing backlog by 17,630 houses p.a. from 2001 to 2004 and by 99,037 houses p.a. from 2004 to 2007. This is due to the sudden decrease in demand, which is also evident on the graph.

2.1.2 Cost

Building cost inflation is a hindrance to housing delivery as the allocated housing budgets could deliver more houses over time if this inflation were to be remain steady. The building cost index showed levels of 13% and 20% during 2002, end of 2004 and throughout 2005 have experienced levels from 16% to 20%. (BER, 2007 cited by: Department of Housing, 2007:17) Escalating prices increases the cost of delivering housing, thereby reducing the value of subsidies. This necessitates the department to adjust subsidies by a higher margin to ensure that the housing quality is not compromised. The housing subsidy per unit has increased from R23100 in 2003 to R36528 in 2006. Furthermore, the inflation rates decrease the profit margins of the developers as the subsidies are only adjusted annually making the public housing market unattractive during inflationary times (Department of Housing, 2007:17).

2.1.3 Employment

The construction sector contributed 8% of the total employment of the country with 1,024,000 people in 2006. Out of the total number of people employed in the construction sector, 45,676 (4.5%) are job opportunities created by the government subsidised market during 2006-2007. (Department of Housing, 2007: 17) During this period 274,219 houses have been produced and

therefore an average of 6 houses per job per year. This employment to productivity ratio has been consistent from 2000 to 2007.

2.1.4 Quality

The issues of the housing standards in terms of the technical aspects are as follows:

- Most houses lack internal finishes, bare concrete block walling is not aesthetically pleasing. (Monkhi, 2007: 20)
- The RDP houses lack thermal insulation. In a research conducted by Makala (2006: 76), which compares RDP houses with traditional stone-clay houses, found that the traditional houses present better thermal conditions (up to 7°C) than the RDP units. The reasons were: corrugated iron roof sheeting, the absence of ceilings and the use of thin concrete block walls which lacks thermal insulation.
- Ineffective management and construction supervision caused poor quality houses. The main structural problems are sagging of foundations resulting in cracking walls, poor sealing between frames and walls and the use of poor materials. Radikeledi (2005: 5) argues that the private sector who build the houses seem to use improper building techniques and standards to cut costs and time.
- The RDP square single standing houses are $30m^2$ in size. An average of 4 people per house which is about $7.5m^2$ per person, this is inadequate for a family dwelling (Monkhi, 2007: 19)

2.2 Building Systems Approach

There are two building systems; the Industrialised Building System (IBS) and the Conventional Building System (CBS). The following section illustrates the characteristics of both building systems and compares them in terms of mass low income housing. IBS as production has a relevant trade-off between mass production and product variety. Mass production of a standardised product can increase production efficiency but decrease the ability to change aspects of the product with ease as conventional building can offer. The characteristics of IBS are:

(1) Employment

- On average about 70% of the labour consumption is in the factory, 30% for transportation and on the building site.
- Industrialised building systems offer higher productivity per labourer with the same amount invested. The onsite production is substantially less than conventional and the factory workers are generally more productive per house produced, this is the reason why the productivity levels are higher for IBS than for conventional (Monsted and Percinel, 1982: 56).

(2) Management and Professionals

- Industrialised building requires less managers and professionals per project. This is because plans and drawings are reused, the building process is well rehearsed, less labour is employed which requires less employee management and facilities.
- Inspections and quality control can be better implemented as the product quality is better controlled on a systematic and standardised production line process (Thanoon et al., 2003: 251).

(3) Cost

- Industrialised building offers savings for finishes compared to conventional building as the concrete panels are cast on a smooth surface in a factory. This is an advantage as costs are saved by eliminating the need for plastering, touch ups and further finishing.
- In the third world, the timber consumption is about 2-3 cubic meters per apartment of 100 square meters making it an expensive item, where industrialised system would not need timber at all. Waste for materials in industrialised building is about half that of traditional building (Monsted and Percinel, 1982: 57).

(4) Large initial Capital outlay

- In order to implement industrialised building system for large scale housing projects a large initial capital outlay is required to finance a factory and its pricy manufacturing machinery, tools and the training of specialists that will manage the factory. (Badir et al., 2002: 22)

(5) Material Price Hikes

- Industrialised building can run on pre ordered materials and therefore material price hikes can be more forgiving on the cost of the building as the pre orders can be increased at set prices when a major escalation is expected. Since the use of mostly precast elements, the shelf life exceeds that of dry cement thus more able to bulk buy in advance. (Gelman, 1988: 11).

(6) Rapid Production and Onsite periods

- The builder can take more contracts at a time with less plant, labour and equipment than conventional construction. This is because the rapid production utilises less resources per building and less on site erection periods which makes plant, labour and equipment more available (Thanoon et al., 2003: 286).

(7) Weather delays

- Industrialised construction is less weather dependant than conventional construction, as most of the building is built in a factory and less time is spent on site where conventional would spend more time on site thus more reliant on the weather. This is a contingency cost and building duration advantage (Thanoon et al., 2003: 286).

(8) Standardisation

- Mass production requires the standardisation of the product, with no exception to industrialised buildings. In order to maximise production efficiency elements of the building product need to be standardised, so machinery and worker's training can be best absorbed to the characteristics of the product (Thanoon et al., 2003: 287).
- Conventionally constructed current low income houses are completely standardised, one RDP block house is nearly identical to the next.

(9) Lean Construction

- Lean production philosophies can be better applied to industrialised construction as opposed to conventional. This is because industrialised building system is more of a manufacturing orientated process, where conventional is service orientated. The materials are standardised and supply deliveries are easier to manage, wastage is minimised and production is more efficient (Gann, 1996: 442 and Howell and Ballard, 1999: 7).

Table (2) Comparing Industrialised Building System with Conventional System

Table (2) shows the views, of a selected sample from a study of the Malaysian construction industry, towards IBS in comparison to conventional construction. This table must be read: IBS is *more*, *less* or *same* as CBS. A study conducted by Badir et al. (2002: 23) mentioned that:

- Construction costs show substantially less
- High rates of rapid construction
- Less employment of labour

	Answering percentage of respondents (with reference to conventional system)		
Factors	More (%)	Less (%)	Same (%)
Cost of construction	5	86	9
Cost of transportation	20	50	30
Speed of construction	77	23	—
Save in raw material	55	27	18
Total number of laborers	5	86	9
Unskilled	41	50	9
Skilled	14	86	—
Expert	14	63	23
Initial capital investment	57	10	33
Flexibility of design	59	9	32
Heavy equipment	24	48	28
Ease of erection	68	32	—
Quality of building	95	—	5

Source: (Badir et al., 2002:23)

2.3 Sustainable Development

A widely accepted definition of sustainable development is provided by the World Commission of Environment and Development (1987:106) as the development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. The definition implies that sustainable development requires development efforts that address social needs while simultaneously striving to preserve the natural environment and fostering economic growth (Glass, 2000: 42). To achieve sustainable development, there should be changes in thinking, behaving, producing and consuming (Ofori, 1998). Miyatake (1996) suggests that in order to achieve sustainability in construction, the industry must change the process of creating the built environment from linear to cyclic processes which will bring increased use of recycled, renewed and reused resources, and decrease in the use of energy and other natural resources. To attain environmentally responsible construction, all practitioners must make a commitment, change their behaviour, adopt new products, ideas and practices, integrated environment system with normal work processes, involve close co-operation of all project participants, starts as early as possible, and be visible throughout the building's life cycle (Ofori et al., 2000). Investigating the sustainability implications of adopting IBS for low income housing in South Africa is an important issue. Generally, IBS is seen as more sustainable building system when compared to conventional as it can offer higher degree of resource efficiency, recyclability and smaller impact on the natural environment of the building site (Glass, 2000: 42). In addition, IBS products are at a quality standard that can enhance the quality of life and adaptable to future changes. This will help by increasing the productivity of their users, which will be reflected positively on the social and economical development.

2.4 The Multi Criteria Comparative Feasibility Matrix

The Multi Criteria Comparative Feasibility Matrix (MCCFM) is a decision making tool developed by the authors to compare proposals against a number of factors. The Simple Multi Attribute Rating Technique (SMART) is used to formulate the MCCFM (Edwards, 1977; Edwards and Newman, 1982; Edwards et al., 1988 cited Green, 1992). MCCFM works by valuing each factor on a hierarchy basis which is done through the interviews with representatives of each group. The

primary factors are rated amongst each other from 10 to 50, then the secondary factors that fall under the primary factors are rated in the same way after which they are weighted. Conventional and Industrialised Housing are then valued separately in terms of their performance respective to each factor. The valued proposed building systems are then multiplied by the weighted factors to derive a score for each factor. These scores are then all added up and the score with the highest value is deemed the better option, as can be seen in the total column of each of the following tables. A summary matrix provides a final score of each group.

2.5 Identifying the Criteria for Comparing CBS and IBS

Literature review identified the factors for comparing between CBS and IBS. The sources for literature review were previous case studies, housing reports and various relevant research articles. These factors are general housing requirements that relate to the current housing problems in South Africa, the potential application of industrialised building systems and the issues facing conventional systems. Each of these criteria separately regards the role of each perspective group. This is done to maintain relevance between factors analysed and the role of each group. The factors selected for the government are relevant to their three basic requirements for housing: Housing provision, affordability, job creation and sustainable development. The Contractor's requirements are those which make it feasible for private contractors to enter into the government subsidised housing market. The contractors main requirements are: Production, management, physical implications and sustainability. Low income housing for the end user is established to provide the necessities for shelter, social security, timeous delivery and adequate standards. The end-user's requirements are: Time, future value, cost, and quality. The criteria mentioned above are listed in the matrix tables mentioned below. The government criteria are: housing provision, job creation, affordability and sustainable development, see table (5). The Contractor criteria are: Production, Management, Physical Implications and Sustainability, see table (6). The end user criteria are: Time, Future Value, Cost and Quality, see table (7).

3. DATA ANALYSIS

Out of twelve questionnaires only five have been completed and received, and twelve interviews have been conducted. Results of the questionnaires and interviews have been placed in the MCCFM analysis tables. The analysis includes a total of four tables, one for each perspective group and one summary table. Table (3) shows the three most and the three least important factors rated by each group interviewed.

Table (3) Rating the Criteria for Comparing between CBS and IBS

Group	Most Important Factors	Least Important Factors
Government	1. Durability & Structural Quality 2. Job Creation 3. Delivery Rate 4. Adequacy & Housing Quality	1. Building Reuse, 2.Green & Resource Efficiency, 3. Initial Capital
Contractor	1. Production Cost 2.Product Quality 3.Carbon Footprint	1.Construction Complexity 2.Skills Dependency 3.Design Flexibility
End-User	1.Adequate Service Provision 2.Delivery/Waiting Period 3.Affordability	1.House Value 2.Life Cycle Period 3.Diverse Design & Aesthetic

The government matrix derived a score of 57.3 points for CBS and 64.1 points for IBS. This is a 12% difference, see tables (4&5). The most important factors as mentioned in table (3) are four major requirements that the government aims to achieve through their housing process. The three least important factors are those which are currently unimportant but may become more considered in the future. From the government side, the most important factors are: Durability, Delivery and Adequacy show to be more favourable towards IBS where Job Creation and Socio-economic development are favoured by CBS. Since three of the four most important factors scored substantially higher for IBS than CBS, it illustrates that IBS is the favourable option. The reason behind rating these factors higher than others could be referred to the government aim of building

houses that last long enough for the next generation, creating jobs for socio-economic improvement, delivering fast houses to supply the need and overcome the housing backlog and constructing houses at an acceptable standard of life.

The contractor matrix derived a score of 56.1 points for CBS and a score of 66.0 points for IBS at a difference margin of 17.6%, see tables (4&6). The contractors' primary goal is to make a profit from their housing production. Therefore, the product cost and product quality are the most important requirements. Carbon footprint is a corporate incentive driven requirement. Production rate, production quality and resource efficiency are factors that have scored higher for IBS. Labour Intensity and Design Flexibility are factors that have considerably scored higher for CBS. The fact that most of the important factors have scored higher for IBS justifies it as the favourable option for contractors. The reason behind rating the top factors could be attributed to the profit that the contractor can gain from building cheaper houses on the long run, the quality of the houses must be good enough to ensure future contracts, and the corporate incentive to reduce carbon emissions.

The end user matrix scored 53.8 points for CBS and 63.9 points for IBS. This is the largest difference margin of the three at 19%, see tables (4&7). The requirements of the end user are generally towards basic needs of a house as table 3 indicates that their most important factors are Adequate Services and Housing Delivery. Factors like House Value and Aesthetics are the least important for low income housing. The reason of the top rating of the three factors could be referred to the end users' need for essential services like water and electricity in their houses, reducing the time for building houses and getting an affordable house that suits the user's income and reduce the cost of upgrading and maintaining their house.

The summary final matrix margin shows 16% which is a well average of the other three margins. This shows that IBS is indeed the more feasible option regarding all three perspectives. Generally industrialised housing can offer more advantages than conventional housing, however the certain but few advantages that conventional construction can offer are important to government subsidised housing in South Africa such as labour intensity, job creation, and less skills dependency.

Table (4) MCCFM Summary Matrix

Final Matrix	Government	Contractor	End-User	**Total**
Conventional CBS	508	734	490	1732
Rating	57.271	56.145	53.775	167.190
Industrialised IBS	570	852	562	1984
Rating	64.124	66.010	63.888	194.022

4. CONCLUSIONS AND RECOMMENDATIONS

Having investigated the housing situation in South Africa, the conventional and industrialised building systems, sustainable development and identified the criteria for comparing between the two building systems as well as bearing in mind the results of interviews and survey questionnaires, the research may come to the following conclusions and recommendations:

- Housing the poor is one of the greatest challenges that face the South African Government. It is a broad issue and requires the efforts of every sector to be utilised if this problem to be solved.
- The CBS received an unfavourable score for all three perspectives. This building system is associated with a number of problems such as slow delivery rate, poor quality standards and inefficiency. On the other hand, it is has the benefit of creating more jobs, design flexibility and less skill dependant.

- The IBS received a better overall score. This showed that this system is the favourable building system. This system could help produce cheaper mass housing projects, faster delivery rate, at high quality standards and generally more efficient. On the other hand, the shortage of research on the use of IBS for low income housing in developing countries has made it difficult to predict the fate of IBS for housing the poor in South Africa. Factors where CBS would perform better such as Job creation, skills dependency and capital outlay are strong drawbacks towards implementing IBS for a developing country.
- Knowing this, it is essential to look for ways of combining the benefits of the two systems and such to avoid their drawbacks. This could be achieved by adopting certain degree of industrialised building and applying it to the current conventional ways. To establish the optimum levels and elements offered by both systems a whole new design would be needed. This particular hybrid system would need to be applicable to the environment in which it is adopted. The applicability must be judged by the available resources, the use of the right materials and the social economic structure. This design must offer more rapid production without compromising job creation, quality or durability furthermore it must be transparent, efficient and directly benefit the surrounding community. Only if this system champions each of these factors will it stand to eradicate the housing backlog.

REFERENCES

Badir Y.F. Hashim A.H..Kadir M. R.A, 2002. Industrialized Building Systems Construction in Malaysia. *Journal of Architectural Engineering ASCE* 8:1, 19-23. [electronic] Available: <http://scitation.aip.org/getpdf/servlet/GetPDFServlet?filetype=pdf&id=JAEIED000008000001000019000001&idtype=cvips&prog=normal> [Accessed 20 February 2008]

Charlton S, and Kihato C 2006. Reaching the poor? An analysis of the influence of the evolution of South Africa's housing programme. Democracy and Delivery: *Urban Policy in South Africa*, pp. 252-282. HSRC Press, Cape Town.

Choa K. (1970) Industrialisation and Urban Housing in Communist China.

Department of Housing SA. 2001. Towards Sustainable Settlements: Case studies from South Africa, STE Publishers.

Department of Housing SA, 2004. White Paper. A New Housing Policy and Strategy

Department of Housing SA, 2007. Annual Report 2006- 2007.

Gann D.M., 1996. Construction as a manufacturing process? Similarities and differences between industrialised housing and car production in Japan. Construction Management and Economics, 14, 437-450.

Gelman.M, 1988. An economic appraisal of industrialised building technique in South Africa.

Glass J. 2000. The Future of Precast Concrete in Low-Rise Housing, [electronic] Available: <http://britishprecast.org/publications/bpcfbrochure.pdf> [Accessed 04 March 2008]

Green, S. D. (1992) A SMART Methodology for Value Management. Occasional Paper Number 53, The Chartered Institute of Building, Ascot

Howell G., Ballard G. 1999. What kind of production is Construction? [online] Available: <http://www.leanconstruction.org/pdf/BallardAndHowell.pdf> [Accessed 17 March 2004]

Keivani R. and Werna E. 2001. Modes of housing provision in developing countries, *Progress in Planning Volume 55, Issue 2, February 2001, pp 65-118*

Knight R. 2001. *Housing in South Africa*, [online] Available: http://richardknight.homestead.com/files/sisahousing.htm [Accessed 06 February 2008]

Makala G. 2006. Temperature stability of traditional and low-cost modern housing in the Eastern Cape, South Africa, in *Journal of Building Physics* Vol. 30 No. 1, pp.71-86. [Electronic] Available: <http://www.byv.kth.se/avd/byte/reykavik/pdf/art_136.pdf> [Accessed 11April 2008]

Miyatake, Y. (1996), Technology development and sustainable construction, Journal of Management in Engineering, Vol. 12, No. 4, 23 – 27.

Monsted J.M. and Percinel O. 1982. The Technical and Economic Advantages of Industrialized Building Methods, *Construction Methods and Delivery Systems pp. 54-59.*

Monkhi.M, 2007. An assessment of low income housing programmes in providing adequate dwellings for the urban poor – A case study of Cato Crest Greenfield, Cato Manor. *UKZN*

APPENDIX

Table (5) MCCFM Matrix - Government

Government	Housing Provision			Affordability & Job Creation			Sustainable Development			
Factors	Delivery Rate	Adequacy & Housing Quality	Durability & Structural Quality	Cost per House	Initial Capital	Job Creation	Socio-Economic Growth	Building Reuse & Adaptability	Green & Resource Efficiency	Total
Weighing	0.125	0.125	0.140	0.118	0.095	0.129	0.114	0.073	0.080	1.000
Conventional	46	58	54	60	58	70	70	44	48	508
Score	5.760	7.262	7.557	7.073	5.514	9.051	7.989	3.206	3.858	57.271
Industrialised	76	78	76	68	52	48	48	54	70	570
Score	9.516	9.767	10.636	8.016	4.944	6.206	5.478	3.935	5.626	64.124

Table (6) MCCFM Matrix - Contractor

Contractor	Production				Management					Physical Implications & Sustainability				
Factors	Production Cost	Initial Capital Outlay	Production Rate	Product Quality	Manageability	Production Control	Quality Control	Skills Dependency	Labour Intensity	Design Flexibility	Construction Complexity	Carbon Footprint	Resource Efficiency	Total
Weighing	0.118	0.096	0.070	0.101	0.073	0.080	0.080	0.056	0.061	0.058	0.051	0.099	0.058	1.000
Conventional	60	60	46	58	46	40	40	68	70	82	54	62	48	734
Rating	7.053	5.779	3.225	5.831	3.354	3.189	3.189	3.834	4.287	4.735	2.728	6.169	2.772	56.145
Industrialised	70	40	76	78	68	74	74	56	62	66	52	66	70	852
Rating	8.229	3.852	5.328	7.842	4.958	5.899	5.899	3.158	3.797	3.811	2.627	6.567	4.042	66.010

Table (7) MCCFM Matrix – End user

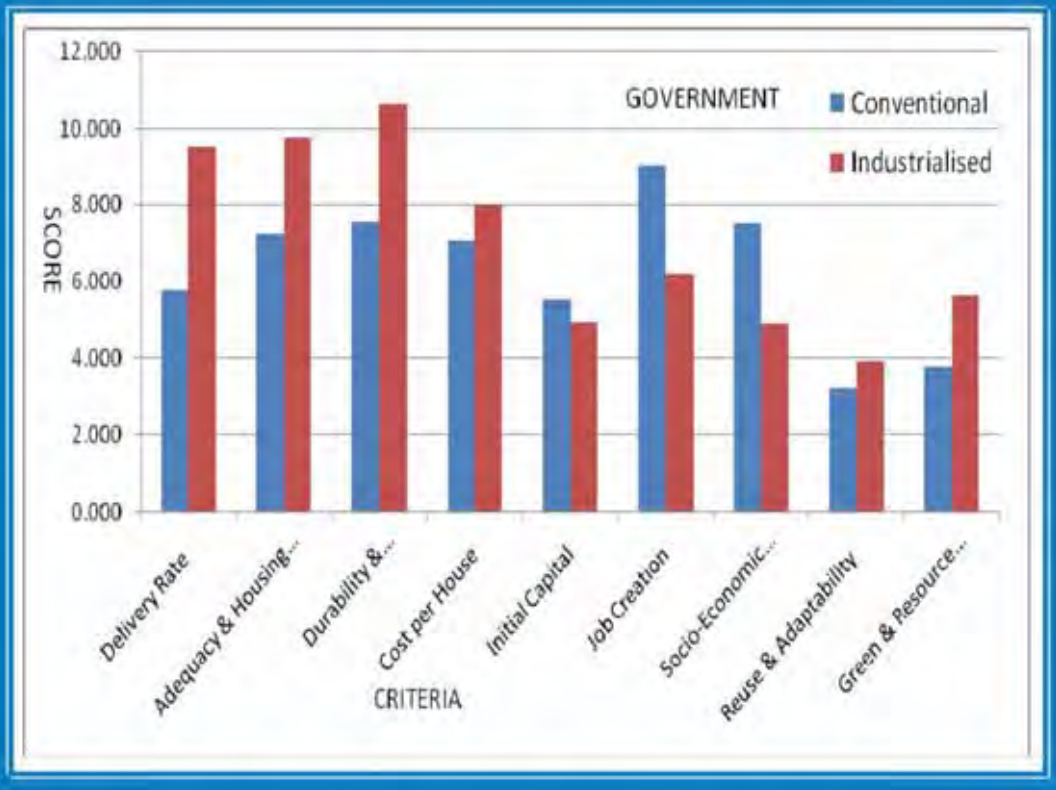
End-User	Time & Future Value			Cost			Quality			
Factors	Delivery/ Waiting Period	Adaptability & Alteration	House Value	Affordability	Maintainability	Life Cycle Period	Diverse Design & Aesthetic	General Quality of House	Adequate Service Provision (L&W)	Total
Weighing	0.134	0.129	0.082	0.129	0.098	0.088	0.099	0.103	0.137	1.000
Conventional	46	52	60	60	60	36	82	54	40	490
Rating	6.178	6.699	4.934	7.713	5.910	3.177	8.092	5.577	5.495	53.775
Industrialised	76	56	40	68	54	52	66	76	74	562
Rating	10.207	7.214	3.289	8.742	5.319	4.590	6.513	7.849	10.166	63.888

53

7

Investigating the Feasibility of Industrialised Low-Cost Housing in South Africa

Ayman Ahmed Ezzat Othman,
and Stefan Mathias Conrads



Investigating the Feasibility of Industrialised Low-Cost Housing in South Africa

Ayman Ahmed Ezzat Othman, University of KwaZulu-Natal, South Africa (aaeothman@gmail.com)
Stefan Mathias Conrads, University of KwaZulu-Natal, South Africa (stefconrads@gmail.com)

Abstract

At the dawn of democracy in South Africa in 1994, there was 1 formal brick house for every 43 Africans. Hence, the new government inherited an estimated housing backlog of 1.5 million units. Since that time, the African National Congress (ANC) adopted Reconstruction and Development Programme (RDP) which is a policy framework for socio-economic integration aimed to build 320,000 houses annually and at least 1million houses over five years. Between 1994 and 2001 about 1.129 million houses have been built, despite these efforts 2 to 3 million houses were still needed. In 1994, the Department of Housing initiated the 'White Paper' legislation which explained the situation of low cost housing in South Africa and highlighted the issue of inadequate supply and constraints of housing provision. In addition, it suggested a number of development initiatives and indicated the need for more rapid construction of houses. In spite of the current Conventional Building System (CBS) is associated with a number of problems such as slow delivery rate, poor quality standards and inefficiency, it has the benefit of creating more jobs, design flexibility and less skill dependency. Because of its capabilities to erect mass projects faster than CBS, Industrialised Building System (IBS) was used to meet the desperate need for housing the homeless followed the Second World War in many of its affected countries. Although IBS was not used widely in South Africa, it is expected to deliver fast, affordable, quality, sustainable houses that meet or exceed the expectations of end-users. To gain the benefits of both building systems, a hybrid system, that utilise the qualities of IBS and CBS, needs to be developed in order to suite the South African context. Adopting such system will achieve the government goals, benefit contractors and satisfy the needs of end-user.

Keywords: Industrialised Building Systems, Conventional Building System, Industrialised Construction Projects, Low-Cost Housing, Feasibility, South Africa.

Background

Industrial Context

Industrialised Building System is difficult to define as it can apply to such a broad spectrum in construction and therefore a variety of definitions have arisen. Kitchener (1979 cited Reddy, 1987) defined IBS as technological and managerial procedures for the repetitive manufacture and erection of buildings that are unique to and can be identified with particular building companies attached to them. Warswaki (1999 cited Hong, 2006) stated that Industrialised process is an investment in equipment, facilities, and technology with the objectives of maximising production output, minimising labour resources and improving quality while a building system is a set of interconnected elements that joint together to enable the designated performance of a building. The Malaysian construction industry defined IBS as a construction

system in which components are manufactured in a factory, on or off site, positioned and assembled into structure with minimal additional site work (CIDB, 2003 cited Hamid et al., 2007). Within this chapter IBS is described as a system, that utilise technology advancement and management capabilities, to produce mass low-cost housing projects that are fast, affordable, quality, sustainable housing projects that meet or exceed the end-users expectations.

Industrialisation in building is not a new thing it has been a subject of a growing process over many years (Culpin, 1970). A long time ago in the history of the art of building, prefabrication was used in the construction of Egyptian temples and Roman edifices (Hong, 2006). The first panelised wood house was shipped from England in 1624 to provide temporary housing for fishing fleets (Culpin, 1970). In 1830s John Manning manufactured 'Portable Colonial Cottages' for the West coast area of Australia (Herbert, 1984). In the USA around the 1920s and the 1950s the "Packaged House" companies produced 'factory made' steel singular houses (Herbert, 1984). After the Second World War the immense housing shortage needed to be overcome. At this time construction methods were to a great extent craft production, which forced governments and housing producers to search for more efficient and faster methods to be able to cope with the situation. As many European countries lacked labour as well as building materials which strained the building capability. Industrialised mass production as a new construction approach offered a way to increase productivity utilising relatively minimal resources and thus seen as a viable solution to meet the enormous housing shortage (Unger, 2006). The history of prefabrication has been described as a record of successful response to the challenge of recurring crises, when local demand exceeds the local capacity to supply (Herbert, 1984).

Problem

Housing the Poor

A Global Perspective

Housing the poor is one of the greatest challenges facing the governments around the world, especially the developing countries. Slums are intolerable human dwellings, of which a few can be called houses, these are shacks or shelters that are constructed by materials found on rubbish dumps, self built and are unfit for human dwelling. These slums are inadequate and unsafe building structures, lack of basic services, especially water and sanitation, insecurity of tenure, overcrowding and located on hazardous land (UN Habitat, 2003). A house is essential for the human being to survive as food and oxygen would be, yet it is not only a physical need but is also vital for the social and physiological health of a human being. A house is a place to live our lives, to interact with others, to rest, to nurture and feed ourselves, therefore adequate houses are for our well being (Neuwirth. 2006). In 2001, 924million people, which are 31.6% of the world's total urban population, live in slums. This is mainly due to the developing countries of which 43% of the urban population live in slums, where in contrast only 6% are slum dwellers in the developed countries. The sub-Saharan African region has the largest slum proportion of 73.2%, however Asia has the largest slum population of 554million (UN Habitat, 2003).

The Housing Problem in South Africa

The Apartheid's Group Areas Act was a law of segregation allocated areas according to race groups. Blacks could not live in white areas and were forced to move to townships, which were located on the outskirts of the cities. The apartheid regime built very few houses for the Blacks such that in 1994 it was estimated that only 1 formal brick house was built for every 43 Blacks, this was less than 10% of what was needed (Knight, 2001). At the dawn of democracy in South Africa in 1994 the new government inherited an estimated housing backlog of 1.5 million units.

Since that time, the African National Congress (ANC) adopted the Reconstruction and Development Programme (RDP) which is a policy framework for socio-economic integration aimed to build 320,000 houses annually and at least 1million houses over five years. Between 1994 and 2001 about 1.129 million houses have been built, a far miss from the set target (ESSA, 2005; Knight, 2001). In 1994, the Department of Housing initiated the 'White Paper' legislation which explained the situation of low cost housing in South Africa and highlighted the issue of inadequate supply and constraints of housing provision. In addition, it suggested a number of development initiatives and indicated the need for more rapid construction of houses (Department of Housing, 1994). Despite the government initiatives, many South Africans are still homeless, settlements are located far from job opportunities, shelter performance is poor, layouts are monotonous and services are inadequate (Department of Housing SA, 2002). The housing problem in South Africa has four dimensions, namely: housing delivery, cost employment and quality.

(a) Housing Delivery

The slow delivery of houses mentioned above raised the question of: "are the government delivery targets set too high or are the policies, plans, procedures and implementation thereof not efficient enough?" The 1994 delivery target, according to the National Housing policy, was calculated as follows:

- The housing backlog in 1994 was estimated at 1.5 million units. The goal was set to build 150,000 houses a year to overcome this backlog over a period of 10 years.
- New housing formation, in terms of population growth and urbanisation, required an additional delivery rate of 150,000 houses a year so that the backlog would not increase.
- The target was set to build 300,000 to 350,000 units per annum.

This gives reason for the stated delivery targets yet its reality was uncertain at the time (Department of Housing SA, 1998). In 2001, the housing backlog was estimated to be 2.5 million houses, which is a 66% increase from the initial backlog. This could have been predicted as the housing delivery rates were half of what was planned as only 1.1 million houses were built instead of 2.1 million.

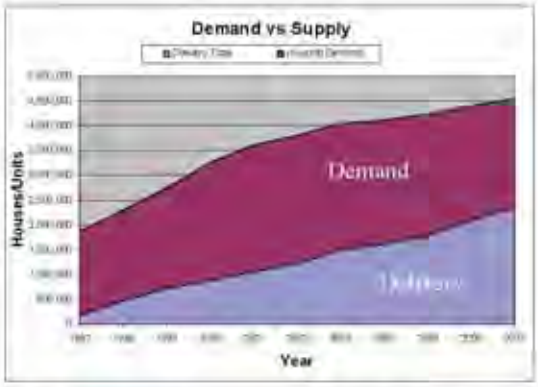


Figure (1) shows the housing delivery, in 1998 as 295,811 units were built and in 1999 248,391 units. This proves that the target of 300,000 units is possible. However, 1998 was the highest delivery and the housing delivery averaged 208,856 where most years delivered less than 200,000 units. This shows that the target could not be sustained and may after all be difficult to provide.

(b) Cost

Building cost inflation is a hindrance to housing delivery as the allocated housing budgets could deliver more houses over time if this inflation were to remain steady. The building cost index showed levels of 13% and 20% during 2002, end of 2004 and throughout 2005 have experienced levels from 16% to 20%. (BER, 2007 cited by Department of Housing, 2007). Escalating prices increases the cost of delivering housing, thereby reducing the value of subsidies. This necessitates the department to adjust subsidies by a higher margin to ensure that the housing

quality is not compromised. The housing subsidy per unit has increased from R23100 in 2003 to R36528 in 2006. Furthermore, the inflation rates decrease the profit margins of the developers as the subsidies are only adjusted annually making the public housing market unattractive during inflationary times (Department of Housing, 2007).

(c) Employment

The construction sector contributed 8% of the total employment of the country with 1,024,000 people in 2006. Out of the total number of people employed in the construction sector 45,676 (4.5%) are job opportunities created by the government subsidised market during 2006-2007 (Department of Housing, 2007). During this period 274,219 houses have been produced and therefore an average of 6 houses per job per year. This employment to productivity ratio has been consistent from 2000 to 2007.

(d) Quality

The issues of the housing standards in terms of the technical aspects are as follows:

- Most houses lack internal finishes, bare concrete block walling is not aesthetically pleasing (Monkhi, 2007).
- The RDP houses lack thermal insulation. In a research conducted by Makala (2006), which compared RDP houses with traditional stone-clay houses, found that the traditional houses present better thermal conditions (up to 7°C) than the RDP units. The reasons were: corrugated iron roof sheeting, the absence of ceilings and the use of thin concrete block walls which lacks thermal insulation.
- Ineffective management and construction supervision caused poor quality houses. The main structural problems are sagging of foundations resulting in cracking walls, poor sealing between frames and walls and the use of poor materials. ESSA (2005) argues that the private sector who build the houses seem to use improper building techniques and standards to cut costs and time.
- The RDP square single standing houses are $30m^2$ in size. An average of 4 people per house which is about $7.5m^2$ per person, this is inadequate for a family dwelling (Monkhi, 2007).

Potential Solution

Key Requirements

Could the Industrialised Building System be a feasible approach for solving the housing problem in South Africa? The key requirements expected from the Industrialised Building System is to deliver fast, affordable, quality, sustainable housing projects that meet or exceed the end-users expectations.

Open Building Manufacturing

Building Systems Approach

There are two building systems; the Industrialised Building System (IBS) and the Conventional Building System (CBS). The following section illustrates the characteristics of both building systems and compares them in terms of mass low income housing. IBS as production has a relevant trade-off between mass production and product variety. Mass production of a standardised product can increase production efficiency but decrease the ability to change aspects of the product with ease as conventional building can offer. The characteristics of IBS are:

(a) Employment

- On average about 70% of the labour consumption is in the factory, 30% for transportation and on the building site.
- Industrialised building systems offer higher productivity per labourer with the same amount invested. The onsite production is substantially less than conventional and the factory workers are generally more productive per house produced, this is the reason why the productivity levels are higher for IBS than for conventional (Monsted and Percinel, 1982).

(b) Management and Professionals

- Industrialised building requires less managers and professionals per project. This is because plans and drawings are reused, the building process is well rehearsed, less labour is employed which requires less employee management and facilities.
- Inspections and quality control can be better implemented as the product quality is better controlled on a systematic and standardised production line process (Thanoon et al., 2003).

(c) Cost

- Industrialised building offers savings for finishes compared to conventional building as the concrete panels are cast on a smooth surface in a factory. This is an advantage as costs are saved by eliminating the need for plastering, touch ups and further finishing.
- In the third world, the timber consumption is about 2-3 cubic meters per apartment of 100 square meters making it an expensive item, where industrialised system would not need timber at all. Waste for materials in industrialised building is about half that of traditional building (Monsted and Percinel, 1982).

(d) Large initial Capital outlay

- In order to implement industrialised building system for large scale housing projects a large initial capital outlay is required to finance a factory and its pricy manufacturing machinery, tools and the training of specialists that will manage the factory (Hashim et al., 2002).

(e) Material Price Hikes

- Industrialised building can run on pre ordered materials and therefore material price hikes can be more forgiving on the cost of the building as the pre orders can be increased at set prices when a major escalation is expected. Since the use of mostly precast elements, the shelf life exceeds that of dry cement thus more able to bulk buy in advance. (Gelman, 1988).

(f) Rapid Production and Onsite periods

- The builder can take more contracts at a time with less plant, labour and equipment than conventional construction. This is because the rapid production utilises less resources per building and less on site erection periods which makes plant, labour and equipment more available (Thanoon et al., 2003).

(g) Weather delays

- Industrialised construction is less weather dependant than conventional construction, as most of the building is built in a factory and less time is spent on site where conventional would spend more time on site thus more reliant on the weather. This is a contingency cost and building duration advantage (Thanoon et al., 2003).

(h) Standardisation

- Mass production requires the standardisation of the product, with no exception to industrialised buildings. In order to maximise production efficiency elements of the building product need to be standardised, so machinery and worker's training can be best absorbed to the characteristics of the product (Thanoon et al., 2003).

- Conventionally constructed current low income houses are completely standardised, one RDP block house is nearly identical to the next.

(i) Lean Construction

- Lean production philosophies can be better applied to industrialised construction as opposed to conventional. This is because industrialised building system is more of a manufacturing orientated process, where conventional is service orientated. The materials are standardised and supply deliveries are easier to manage, wastage is minimised and production is more efficient (Gann, 1996; Howell and Ballard, 1999).

A study by Hashim et al., (2002) carried out in the Malaysian construction industry aimed to compare between IBS and conventional construction showed that IBS construction cost is substantially less, high delivery rate and less employment of labour.

The abovementioned characteristics of the IBS showed that it can deliver fast houses due to its rapid production system, less weather dependent and design standardisation. In spite of the large initial capital outlay needed to establishing IBS for mass production, IBS can provide affordable house through eliminating the need of plastering, touch ups and further finishing, reducing material wastage and avoiding the hikes of material prices. In addition, IBS is capable to deliver quality products because of the implementation of proper inspection and quality control carried out during the production process. One of the important advantages of IBS is its capability to deliver sustainable houses in terms of material use and waste, durable, easy to maintain, adaptable to future user requirements. Constructing houses that possess these characteristics helps meet or exceed end-users expectations.

Approach

The abovementioned aim called for a research strategy that could gather data sufficiently rich to investigate the feasibility of industrialized building system as a strategic approach for housing the poor in South Africa. The research methodology to achieve this aim consists of four phases: Plan, Do, Study and Act, see figures (2&3). It is called the PDSA Cycle which was firstly developed by Shewhart and then modified by Deming. The PDSA cycle is an effective problem solving technique and essential tool for continual improvement of process management (Besterfield et al., 1999). The PDSA is used as a model for continuous improvement, establishing new improvement project, developing a new or improved design of a process, product or service, defining a repetitive work process, planning data collection and analysis in order to verify and prioritize problems or root causes, implementing change procedure. The PDSA is an ongoing process where the cycle continues to repeat as an approach for improvement.

Figure (1) PDSA Cycle

Plan Phase

The objective of this phase is to identify and prioritise opportunities for improvement. It aims to identify the problem and define exactly what needs to be done in order to achieve a specific task effectively and efficiently. Examples of questions that should be answered include: "what are we trying to improve?", "What data do we need to collect?" "Where will we find this data?". During the course of this research, the plan phase was used to identify the research problem and rationale, establish the research aim and objectives, design the research methodology and methods appropriate for achieving the research aim and objectives.

Do Phase

The objective of the "Do Phase" is to implement the abovementioned plans and execute the required processes using the research methods selected. This stage requires the researcher to observe the results once the plan has been put into operation. During this phase, Firstly, literature is used to: (i) build a comprehensive background of the housing situation in South Africa, the conventional and industrialised building systems for low-income housing projects and sustainable development, (ii) Identify the criteria for comparing between the conventional and industrialised building systems, and (iii) develop a decision making tool called the *Multi Criteria Comparative Feasibility Matrix (MCCFM)* to facilitate making an informed decision. Secondly, interviews are used to weight the importance of each factor of the identified criteria. Three different perspective groups, namely: government (initiator and developer), contractor (service provider) and end-user (resident) are interviewed to weigh their own criteria respectively. The sample size of the interviewee was 15 persons. Finally, survey questionnaires are used to utilise the weights gained from the interviews and apply the developed decision making matrix in order to rate the performance of conventional and industrialised building systems according to each factor of the criteria identified. The questionnaires are sent to a sample of contractors who are directly involved with industrialised and conventional building systems in South Africa. The sample size of the questionnaire was 12 contractors, this being the total identified population size of the industrialised housing contractors throughout South Africa (Yellow Pages, 2008).

Study Phase

The "Study Phase" aims to observe the effects of the course of actions taken, analyse the results gained, identify the lessons learned and expect what can be predicted. Within this research, data analysis helped identifying the causes of housing the poor in South Africa and areas of pitfalls and shortcomings, so particular course of action could be taken for improvement. Collected data is analysed quantitatively and qualitatively. Quantitative analysis is achieved through calculating the sum of multiplying the average of rates given by respondents for every building option by the appropriate criteria weight gained from the interviews. This will help arriving at a summary matrix where the results of each group is presented. Results will be analysed qualitatively to explore the reasons behind scoring some factors higher than others.

Act Phase

The objective of the "Act Phase" is to highlight research findings and apply actions needed for improvement. This necessitates that changes required need to be identified and implemented in order to improve the process and solve the problem in hand (Bounds at al., 1994). During the course of this research, the research findings are identifies, the suggested building system is explained and recommendations for the industry and further research are summarised.

Validity and Reliability

In order to increase the validity and reliability of research methods and findings, ranking and rating questions in both the questionnaires and interviews helped minimise the risk of potential subjectiveness and biasness towards the factors analysed and the particular building systems. Furthermore, meeting people who are directly related to the research problem (i.e. government

housing officials, housing contractors and community resident officials) helped increase the reliability and validity of collected data and research findings.

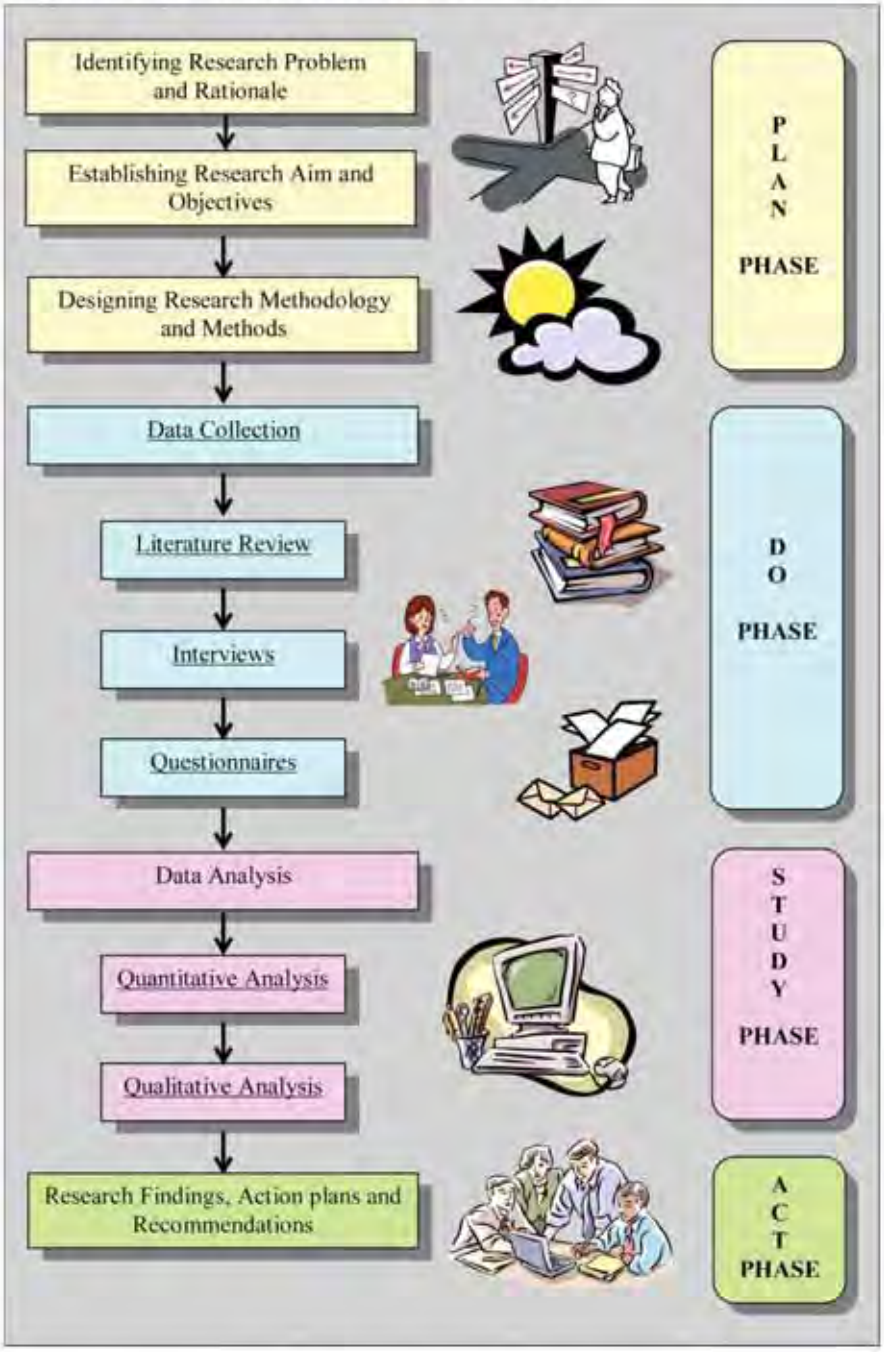


Figure (2) Research activities and PDSA Cycle

Analysis

Analysis of Survey Questionnaires Responses

Out of 12 survey questionnaires sent to a sample of contractors who are involved in both building systems, only 5 were completed and returned which represent 42%. The respondents are asked to rate each factor from 10 to 100 for both conventional and industrialised building systems, in terms of their performance (10 being the least and 100 being the most). see table (1)

Table (1) Rating criteria factors for CBS and IBS

Group	Primary Factor	Secondary Factor	Conventional	Industrialised
GOVERNMENT	Housing Provision	Delivery Rate	46	76
		Adequacy & Housing Quality	58	78
		Durability & Structural Quality	54	76
	Affordability & Job Creation	Cost per House	60	68
		Initial Capital	58	52
		Job Creation	70	48
	Sustainable Development	Socio-economic Growth	53	29
		Building Reuse & Adaptability	44	54
		Green & Resource Efficiency	47	70
CONTRACTOR	Production	Production Cost	60	70
		Initial Capital Outlay	60	40
		Production Rate	46	76
		Product Quality	58	78
	Management	Manageability	46	68
		Production Control	44	79
		Quality Control	40	74
		Skills Dependency	68	56
		Labour Intensity	70	62
	Physical Implications & Sustainability	Design Flexibility	82	66
		Construction Complexity	54	52
		Carbon Footprint	62	66
		Resource Efficiency	48	70
END-USER	Time & Future Value	Delivery & Waiting Period	46	76
		Adaptability & Alteration	52	56
		House Value	60	40
	Cost	Affordability	60	68
		Maintainability	60	54
		Life Cycle Period	36	52
	Quality	Diverse Design & Aesthetic	82	66
		General Quality of House	54	76
		Adequate Service Provision	40	74

Generally industrialised housing can offer more advantages than conventional housing, however the certain but few advantages that conventional construction can offer are important to government subsidised housing in South Africa such as labour intensity, job creation, and less skills dependency. Yet the importance of each factor must be considered together with this rating from the questionnaires to derive a valid conclusion of which building system would more functional for housing the poor in South Africa.

Analysis of Interviews Responses

Out of 15 interviews planned to be achieved, 12 were conducted. The purpose of the interviews is to value the importance of the criteria for each perspective group. This is done by weighting each factor of the criteria on a scale of 10 to 50 (10 being the lowest and 50 being the highest). These results are then calculated to a relative norm and converted to weighted averages, see table (2). These weighted values are then multiplied with the values of performance form the questionnaires to derive a score which is expressed in MCCFM tables (3, 4, 5&6).

Table (2) Weighting factors by three Perspective groups

Group	Primary Factor	Secondary Factor	Rate
GOVERNMENT	Housing Provision	Delivery Rate	0.125
		Adequacy & Housing Quality	0.125
		Durability & Structural Quality	0.140
	Affordability & Job Creation	Cost per House	0.118
		Initial Capital	0.095
		Job Creation	0.129
	Sustainable Development	Socio-economic Growth	0.114
		Building Reuse & Adaptability	0.073
		Green & Resource Efficiency	0.080
CONTRACTOR	Production	Production Cost	0.118
		Initial Capital Outlay	0.096
		Production Rate	0.070
		Product Quality	0.101
	Management	Manageability	0.073
		Production Control	0.080
		Quality Control	0.080
		Skills Dependency	0.056
		Labour Intensity	0.061
	Physical Implications & Sustainability	Design Flexibility	0.058
		Construction Complexity	0.051
		Carbon Footprint	0.099
		Resource Efficiency	0.058

END-USER	Time & Future Value		Delivery & Waiting Period	0.134
			Adaptability & Alteration	0.129
			House Value	0.082
	Cost		Affordability	0.129
			Maintainability	0.098
			Life Cycle Period	0.088
	Quality		Diverse Design & Aesthetic	0.099
			General Quality of House	0.103
			Adequate Service Provision	0.137

Table (3) MCCFM Matrix - Government

Government	Housing Provision			Affordability & Job Creation			Sustainable Development			
Factors	Delivery Rate	Adequacy & Housing Quality	Durability & Structural Quality	Cost per House	Initial Capital	Job Creation	Socio-Economic Growth	Building Reuse & Adaptability	Green & Resource Efficiency	**Total**
Weighing	0.125	0.125	0.140	0.118	0.095	0.129	0.114	0.073	0.080	1.000
Conventional	46	58	54	60	58	70	70	44	48	508
Score	5.760	7.262	7.557	7.073	5.514	9.051	7.989	3.206	3.858	57.271
Industrialised	76	78	76	68	52	48	48	54	70	570
Score	9.516	9.767	10.636	8.016	4.944	6.206	5.478	3.935	5.626	64.124

Table (4) MCCFM Matrix - Contractor

Contractor	Production				Management					Physical Implications & Sustainability				
Factors	Production Cost	Initial Capital Outlay	Production Rate	Product Quality	Manageability	Production Control	Quality Control	Skills Dependency	Labour Intensity	Design Flexibility	Construction Complexity	Carbon Footprint	Resource Efficiency	**Total**
Weighing	0.118	0.096	0.070	0.101	0.073	0.080	0.080	0.056	0.061	0.058	0.051	0.099	0.058	1.000
Conventional	60	60	46	58	46	40	40	68	70	82	54	62	48	734
Score	7.053	5.779	3.225	5.831	3.354	3.189	3.189	3.834	4.287	4.735	2.728	6.169	2.772	56.145
Industrialised	70	40	76	78	68	74	74	56	62	66	52	66	70	852
Score	8.229	3.852	5.328	7.842	4.958	5.899	5.899	3.158	3.797	3.811	2.627	6.567	4.042	66.010

Table (5) MCCFM Matrix – End user

End-User		Time & Future Value			Cost			Quality			
Factors		Delivery/ Waiting Period	Adaptability & Alteration	House Value	Affordability	Maintainability	Life Cycle Period	Diverse Design & Aesthetic	General Quality of House	Adequate Service Provision (L&W)	**Total**
Weighing		0.134	0.129	0.082	0.129	0.098	0.088	0.099	0.103	0.137	1.000
Conventional		46	52	60	60	60	36	82	54	40	490
	score	6.178	6.699	4.934	7.713	5.910	3.177	8.092	5.577	5.495	53.775
Industrialised		76	56	40	68	54	52	66	76	74	562
	Score	10.207	7.214	3.289	8.742	5.319	4.590	6.513	7.849	10.166	63.888

Table (6) MCCFM Summary Matrix

Final Matrix		Government	Contractor	End-User	**Total**
Conventional CBS		508	734	490	1732
	Score	57.271	56.145	53.775	167.190
Industrialised IBS		570	852	562	1984
	Score	64.124	66.010	63.888	194.022

Analysis of Government Response

Figure (3) illustrates the scoring difference between conventional and industrialised housing for the government sector. The following points are noted for the four most important factors:

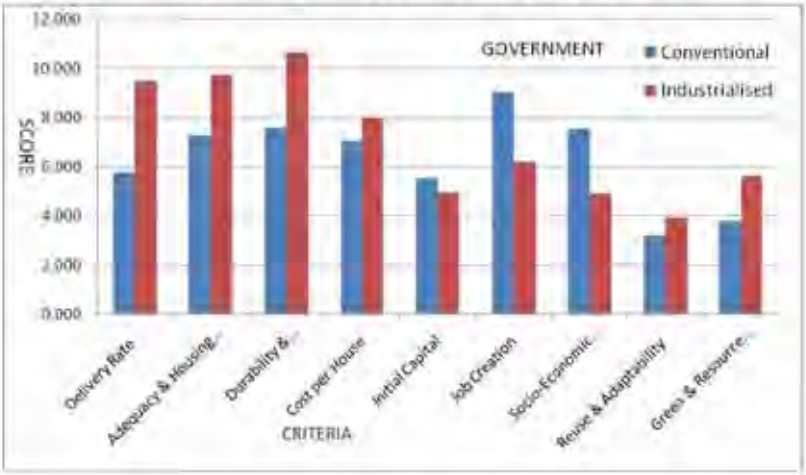


Figure (3) Government Scoring for CBS and IBS factors

- **Delivery Rate** – This factor shows a substantial difference between Industrialised and conventional. Industrialised has the higher score as the construction of an industrialised house is quicker than that of a conventionally built house. In terms of mass low income housing delivery rate is an important factor to consider and is amongst the top three most important for government. Hence the high score.

- **Adequacy & Housing Quality** – This is an important factor for housing and shares the same level of importance as Delivery Rate. The difference between the two building systems is considerable. The standard of the house in terms of adequate finishes and services is of crucial importance. As these houses are built for the poor only adequacy and not luxury can be expected. However, this standard of services and finishes must still serve it functional use well enough to last a generation. The other issue is the time taken for the services to be installed and connected as this is currently a problem for government subsidised housing. IBS can offer installation of services before the assembly of the house, which optimises time and delivery of the services.

- **Durability & Structural Quality** – This is different to the previous factor as this involves the physical aspects of the building where Adequacy and Housing Quality regards matters such as finishes, lights, water and layout design. This factor has a considerable difference in favour of industrialised. The reason for this is that currently in South Africa conventional building system is used to construct the low income houses and since the use of poor materials and mostly unskilled labour which results in a poor product. Industrialised offers better quality control measures and requires less labour and skills, it uses standardised materials and is said to be more durable. This factor is the most important for government and is thus the highest scored.

- **Job Creation** – This is an important requirement for government. The contractors who build government subsidised houses are required by government to employ a certain

percentage of labourers from the community in which the houses are built. This is to increase job creation and to maximise wealth distribution. Conventional has outperformed industrialised by a considerable margin for this factor. This is seen as the as the strongest drawback for industrialised since job creation is rated one of the top requirements for housing. The reason for this is that industrialised is a manufacturing orientated construction and through efficiency and mechanisation it decreases the need for employment which is in direct contrast with conventional.

Analysis of Contractors Response

Figure (4) illustrates the scoring difference between conventional and industrialised housing for the contractor sector. The following points are noted the three most important factors:

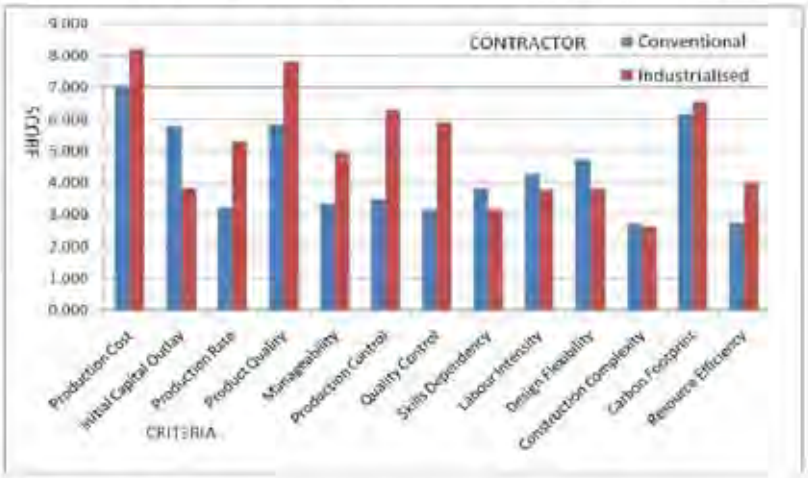


Figure (4) Contractors Scoring for CBS and IBS factors

- **Production Cost** – This is an important factor to consider as the cost of producing houses needs to be within the government subsidy margin and must still make a profit. The cheaper the production cost the more profitable the production becomes. This factor is the most important for contractors, this is shown on the graph as it has the highest score. The difference, although only marginal, is in favour of industrialised. This is because industrialised offers a lower production cost per unit due to its high production capacity, production rate and efficiency. Conventional has a cheap production cost through utilising cheap materials, cheap labour and minimising the use of machinery.

- **Product Quality** – This factor measures the general quality of the product, form a contractor's perspective. This is an important factor as contractors aim to produce a product that would please their clients and ensure future contracts. Industrialised has a considerably higher score than conventional in this regard. This is mainly because industrialised produces standardised products which are, to a large extent, identical. Standardisation and less onsite construction provides greater quality assurance. On the other hand, conventional is largely onsite construction which leaves more room for error, although building plans and processes are standardised product quality outcome is more likely to vary. Conventional is more dependent on onsite labour quality, and since labour

with no experience is employed the housing product quality reflects the standard of workmanship.

- **Carbon Footprint** – This is factor is a corporate requirement and is chosen in the light of environmental issues. This is a factor that is rated as the third most important, which shows that it is considered for low income housing. The graph shows this by its high rating. Industrialised has been scored higher than conventional for this factor. This is because industrialised is generally more resource efficient and has less of an impact on the building site. Industrialised also includes a factory which produces the components which impacts on the carbon footprint of this system. Conventional, on the other hand, doesn't have a factory but has a greater impact on the environment of the building site and is more wasteful.

Analysis of End-User Response

Figure (5) illustrates the scoring difference between conventional and industrialised housing for the End-User. The following points are noted for the three most important factors:

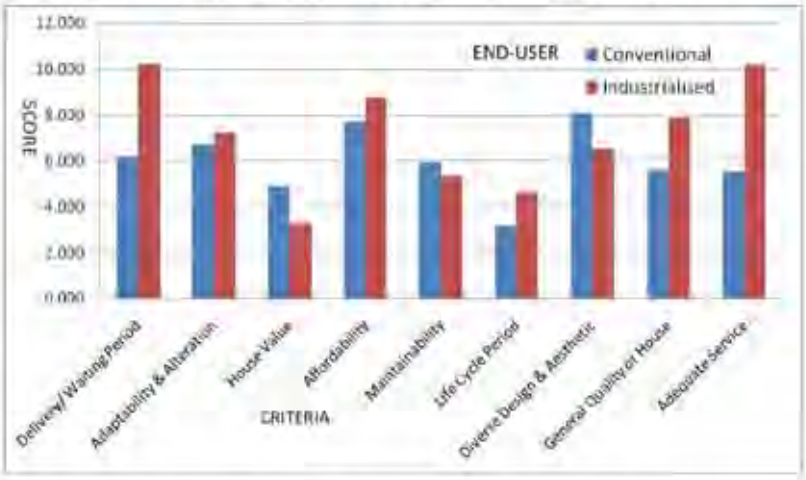


Figure (5) End-Users Scoring for CBS and IBS factors

- **Delivery /Waiting Period** – This is the average waiting period for the housing applicant to receive their government subsidised house. This factor is related with the production rate and delivery rate in the contractor and government sectors respectively. This factor is one the top three rated factors for the end user. Industrialised has scored considerably more than conventional. This is because industrialised is capable of a higher production rate, better manageability and transparency, making the process from production to delivery more efficient.

- **Affordability** – This factor measures the cost aspect of not only the houses but also the cost of alterations and finishes. As the government subsidised houses are built with the intention that the residents will add their own improvements. This is a considerably important factor, because cost is the main concern for the end user. Industrialised has a higher score than conventional but only by a small margin. Industrialised can offer cheaper houses and cheaper extensions on an existing building. This cost advantage is achieved through larger building components and panel building. However, this cost advantage must

be set against the initial capital required, this is why the difference in cost in smaller. Conventional houses are cheap but not as cheap as industrialised could offer. It must be kept in mind that the initial capital outlay for conventional is significantly less than industrialised, which would directly impact on the cost of the houses.

- **Adequate Services (Lights & Water)** – The reason why this factor has been separated from the previous factor (General Quality of House) is because the services in the houses is an aspect which currently is not adequate enough. It on its own is an important factor for the end user, hence it has one of the highest scores. Industrialised has considerably out scored conventional. The main reason for this is because the conventional building method separates the construction of the houses with the provision of the services, which is why the conduits and plumbing lines have to be chased into the walls afterwards. This delays the process and is impractical for mass low income housing. Industrialised, on the other hand, can combine the construction (production) process with the installation of services. This is done by fitting the conduits and plumbing lines into the wall before it is cast or made. Fittings and lines are connected during the assembly process. This ensures that the services are in place, it is also cost effective, practical and shortens construction periods. Most of all it shifts the responsibility to one contractor who doesn't have to rely on subcontractors.

Summary and Discussion

Figure (6) summarises the scoring difference between conventional and industrialised housing for each perspective group.

- **Government** - Generally, regarding all factors of the government industrialised is considered to be the better building method for low income housing. The only set back is that industrialised underperforms through job creation which is an essential requirement for government. If job creation becomes a factor of less importance then industrialised would be fitting for low income housing. Otherwise if an industrialised system could be developed that offers a higher degree of job creation without compromising delivery rates, adequacy and durability, then this system would stand a chance of overcoming the housing shortage. Despite job creation industrialised has generally performed better than conventional and this should be reason enough to consider industrialised building system for government subsidised housing in South Africa.

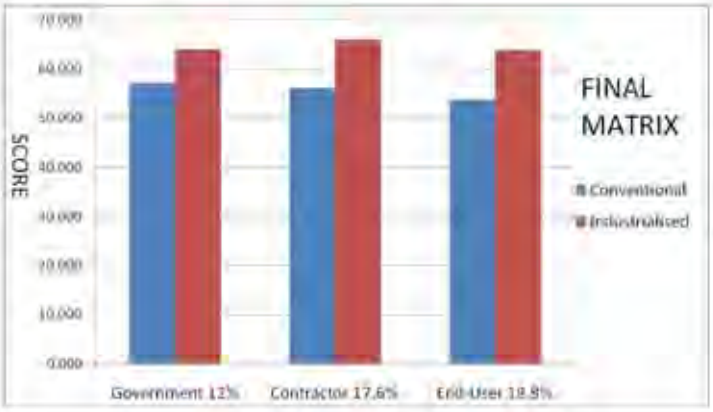


Figure (6) Summary of Scoring for CBS and IBS factors

- **Contractor** - The factors which industrialised can offer a considerable advantage over conventional is manageability, production control, quality control, resource efficiency, product quality, production cost and production rate. These are the factors that make industrialised attractive for housing contractors. However, there are some drawbacks for the contractor, initial capital outlay is the strongest disadvantage for industrialised for the contractors sector. The initial capital outlay is a strong barrier for entry into the industrialised construction industry. A considerable amount of capital is needed to establish all the facilities, machinery and equipment needed to operate an industrialised production line. Design flexibility, labour intensity and skills dependency are factors which are favoured by conventional and may dis-encourage industrialised as a building system. Mechanisation, to a certain extent, is disapproved by government because it denies potential employment especially for a country with high unemployment rates. The other issue is that South Africa has relatively cheap labour which may make labour intensive processes cheaper than mechanised processes.

- **End-User** - Adequate Service Provision is the end users most important factor which is substantially higher for industrialised than for conventional. It seems that industrialised is the better building method for the end user. However, there are some drawbacks. Diverse design and aesthetics is favoured by conventional which can have an implication on the user friendliness of industrialised. In countries where industrialised building systems have been extensively used for low income housing have received complaints and a general negative approach towards this type of building system, although it has managed to house the population. This study speaks for itself as industrialised does indeed provide a better opportunity to eradicate the housing backlog in South Africa. The end user should be pleased with their house if it caters for all their needs.

The Analysis clearly shows that IBS is more feasible than CBS for all three perspectives. The sum of the scores of all the three perspective groups is 166.972 for conventional and 193.850 for industrialised, this is a 16.1% difference. Overall IBS is a more feasible option for government subsidised housing in South Africa. However, this analysis only focuses on the performance of both building systems with respect to the requirements of social housing. If IBS were to be implemented for government subsidised housing in South Africa then more direct considerations need to be taken. Since this analysis only regards the concept of the two building systems, so the actual application of IBS would need to consider a particular design of an industrialised building. This particular design would need to be tailored for the South African environment, must suit the important criteria of the government especially job creation and it must incorporate materials suitable for the South African climate and resource capacity.

Results and Business Impacts

Key Findings

The key findings of this chapter are derived from the data analysis and compared with some aspects of the literature review. The key findings are:

- Generally, IBS is more feasible than CBS as it offers more advantages than CBS for low income housing.
- The main advantages that IBS offers in terms of social housing in South Africa are delivery rate, production control, quality control and adequate services.

- The main advantages that CBS offers in terms of social housing in South Africa are job creation, socio-economic growth and diverse design and aesthetics.
- For the government sector:
  - IBS would be most successful towards delivery rate and durability.
  - IBS would be a hindrance towards job creation.
- For the contractors sector:
  - IBS would be most successful towards production cost and product quality.
  - IBS would be a hindrance towards initial capital outlay and design flexibility.
- For the end-user sector:
  - IBS would be most successful towards adequate services and delivery period
  - IBS would be a hindrance towards diverse design and aesthetics

Business Impacts

As this chapter investigated the feasibility of IBS for housing the poor in South Africa and because it carried out a comparison analysis between IBS and CBS form the perspective of the three main role players within social housing in South Africa, therefore this study can offer beneficial information to each of the three role players.

For Government

In terms of the potential implementation of IBS for social housing, out of the three role players, the government is the most important as they are the project initiators and funders of social housing. Thus, if government decided to implement IBS the contractors and end-users will follow suit. The government is a strong role player in the private social housing field. The results of the study do not only show which building systems is more beneficial but also what requirements or criteria conflict and hinder each other's success. A prime example is that the government requires the employment of labour within the community of the housing project with the noble intention of creating jobs and therefore socio-economic upliftment. However, this job creation incentive is a hindrance to the quality and production rate of the houses. Therefore, the results of this study can show what the government criteria is contradictory and can allow the reconsideration of the importance or extent of implementation of certain factors of their criteria.

For Contractors and Other building professionals

This study can be applied to other mass housing industries, form high density apartment developments to high income estate developments. Therefore in this regard the contractor can benefit from the results of this study. This study showed what advantages IBS can offer and in what circumstances it would be most beneficial. This is potentially valuable information to, not only the contractors, but also property developers, building material suppliers and construction professionals, as each of these organisations seek similar criteria within their line of work. Furthermore, the MCCFM analysis framework can be adapted to suit personal requirements, as only relevant criteria can be selected and the MCCFM will derive comparative feasibility analysis.

End-User and Residents

The residents of the houses can utilise this information as grounds for decision making. Since there is talk of a negative perception against prefabricated or industrialised houses the potential

home owner can make justified decision whether an industrialised built home might not be more beneficial than a conventionally built home. This does not only apply to residential buildings but to any other type, be it commercial, industrial or retail. The uses and class of IBS for housing in various countries are of a different nature. For example in Japan a prefabricated industrialised house is highly sought after, where in France industrialised from the bulk of housing (Conrads and Othman, 2008).

Conclusions

Housing the poor is one of the greatest challenges that face the South African Government. It is a broad issue and requires the efforts of every sector to be utilised if this problem to be solved. Since South Africa is a developing country and thus shares similar issues, problems and socio-economic environment with other developing countries, the results of this research can therefore be applied to developing countries in general. The main issue of housing the poor addressed in this chapter is the low delivery rate, the increasing cost of houses, low quality level and being unsustainable.

Data analysis showed that CBS received an unfavourable score for all three perspectives. This building system is associated with a number of problems such as slow delivery rate, poor quality standards and inefficiency. On the other hand, it is has the benefit of creating more jobs, design flexibility and less skill dependency.

The IBS received a better overall score. This showed that this system is the favourable building system. IBS could help produce cheaper mass housing projects, faster delivery rate, at high quality standards and generally more efficient. On the other hand, the shortage of research on the use of IBS for low income housing in developing countries has made it difficult to predict the fate of IBS for housing the poor in South Africa. Factors where CBS would perform better such as Job creation, skills dependency and capital outlay are strong drawbacks towards implementing IBS for a developing country.

In terms of the social housing situation in South Africa, the government set a goal to replace all informal houses with formal houses by 2015. This requires a delivery rate of about 600,000 houses per annum from 2008. Currently the social housing delivery rate averages 250,000 per annum. Clearly the delivery rate would need to be drastically increased in order to reach the goal. The conventionally built houses cannot offer a sufficient delivery rate for housing, where IBS offers a greater delivery rate it would make sense that this building system should be adopted if the government's goal is likely to be achieved.

The South African government requires that the social housing contractors employ a certain number of labourers from the community where the houses are built. The purpose of this is to create more jobs and for socio-economic progression within these communities. The implication of this noble incentive is that it compromises the product quality and delivery rate of the houses as these employed labourers are mostly unskilled and inexperienced. Since these houses are built for the employed people they determine their own quality of the houses. Furthermore, these jobs will only lasts until the housing project is completed, since humans are gifted with perceptibility, the labourers will purposely work slowly so to delay the completion and in turn extend their employment. Clearly this is not sustainable instead a socio-economic progression factors should be implemented through entrepreneurship, self dependent communities and skills development.

This analysis is seen as the first stage of developing an optimum building design. The analysis regards the requirements of each perspective group which identifies precisely what the building system would need to achieve. This analysis also but more importantly, distinguishes the direction of which building system would be the most suitable, thus either the industrialised system or the conventional system. Since both of these systems are essentially different it is important to know on what building system the optimum building design should be based on. At this stage the analysis can only recommend a most suitable building system from a technical perspective. Ideally, certain qualities form both IBS and CBS would need to be amalgamated into one hybrid building system that is most suitable to the South African environment. The analysis proves that IBS offers more advantages than CBS for social housing and therefore the optimum building design should adopt greater degree of industrialised and only certain elements of conventional.

Practical Tips

- The poor, worldwide, resort to all sorts of means to house themselves in the face of a housing industry and policies that fail to provide them with affordable options.
- The importance of housing for the poor contrasts sharply with housing conditions and official policies that exist in many developing countries. One billion people, a sixth of the world's populations live in slums, 90 percent of them in developing countries.
- A House is far more than living space and shelter. It is vital for the social and physiological health of a human being. A house is a place to live our lives, to interact with others, to rest, to nurture and feed ourselves, therefore adequate houses are essential for our well being.
- The South African government set a goal to replace all informal houses with formal houses by 2015. This requires 600,000 houses per annum have to be built from 2008. The current delivery rate averages 250,000 per annum. A different approach has to be adopted if the government goals to be achieved.
- The CBS is associated with a number of problems such as slow delivery rate, poor quality standards and inefficiency. On the other hand, it is has the benefit of creating more jobs, design flexibility and less skill dependency.
- The IBS could produce cheaper, fast mass housing projects at high quality standards and generally more efficient. Contrarily, the shortage of research on the use of IBS for low income housing in developing countries has made it difficult to predict its fate in South Africa.
- A new hybrid system that utilise the qualities of both IBS and CBS has to be developed. The new system should adopt greater degree of industrialised and only certain elements of conventional system to suite the South African environment.
- There is a need for more research in the area of adoption and implementations of Industrialised Building System in developing countries.

Acknowledgements

The authors are grateful to the government officials, contractors and end-users who participated in this study.

References

Besterfield, D. H., Michna, C., Besterfield, G. H. and Sacre, M. (1999) Total Quality Management. 2nd ed. New Jersey: Prentice Hall.

Conrads,S.M. and Othman,A.A.E.(2008) Industrialised Building: Investigating its feasibility to house the poor in South Africa: Cato Manor as a case study. Proceedings of the Quantity Surveying Conference, Midrand, South Africa, 10 October 2008, pp. 42-52.

Culpin, C. (1970) Basic Principles of Industrialised Building. *A Paper submitted to the National Congress of Industrialised Concrete Building, Johannesburg, October 1970.*

Department of Housing SA. (1998). Housing Code: Draft1 November 1998.

Department of Housing SA. (2002) Towards Sustainable Settlements: Case studies from South Africa, STE Publishers.

Department of Housing (1994) White Paper: A New Housing Policy and Strategy for South Africa. Pretoria.

Department of Housing SA. (2007) Annual Report 2006- 2007.

Gann, D. M. (1996) Construction as a manufacturing process? Similarities and differences between industrialised housing and car production in Japan. *Construction Management and Economics*, Vol. 14, pp. 437-450.

Gelman, M. (1988) An economic appraisal of industrialised building technique in South Africa.

Hamid, Z. A., Ghani, M. K., Rahim, A. H. A. and Kamar, K. A. M. (2007) Industrialised Building Systems (IBS): Current Shortcomings and the Vital Roles of R&D, *Construction Research Institute of Malaysia (CREAM), Kuala Lumpur.* http://www.cream.com.my/images/news/IBS%20Shortcomings%20and%20Vital%20Roles%20of%20R&D.pdf (accessed 11/04/08).

Hashim, A.H. Abdul Kadir, M.R. and Badir, Y.F. (2002) Industrialized Building Systems Construction in Malaysia. Journal of Architecture and Engineering ASCE Vol. 8, No.1, pp.19-23.

Herbert, G. (1984) The Dream of the Factory Made House, the MIT press, USA.

Hong, O. C. (2006) Analysis of IBS for School Complex , *University of Technology Malaysia.* http://www.efka.utm.my/thesis/IMAGES/3PSM/2006/1JSB/PART6/ongchinhongaa010410d06tht.pdf (accessed: 11/04/08).

Howell, G. and Ballard, G. (1999) What kind of production is Construction?. http://www.leanconstruction.org/pdf/BallardAndHowell.pdf (accessed 17/03/04).

Knight R. (2001). Housing in South Africa. http://richardknight.homestead.com/files/sisahousing.htm (accessed 06/02/08).

Makala, G. (2006) Temprature stability of traditional and low-cost modern housing in the Eastern Cape, South Africa. in *Journal of Building Physics* Vol. 30 No. 1, pp.71-86.

Monkhi, M. (2007) An assessment of low income housing programmes in providing adequate dwellings for the urban poor – A case study of Cato Crest Greenfield, Cato Manor. Honours Dissertation, University of KwaZulu-Natal, Durban, South Africa.

Monsted, J. M. and Percinel, O. (1982) The Technical and Economic Advantages of Industrialized Building Methods. *Construction Methods and Delivery Systems pp. 54-59.*

Neuwirth, R. (2006) Shadow Cities. Routledge

ESSA. (2005) Economic Society of South Africa: An Analysis of the South African Government Low Cost Housing Provision Strategy (2005), [Electronic]. Available: http://www.essa.org.za/download/2005Conference/Radikeledi.pdf (accessed 20/02/08).

Reddy, A.M. (1987) A critical analysis of industrialised building method in South Africa.

Thanoon, W. A., Peng, L. W., Kadir, M. R. A., Jaafar, M. S. and Salit M.S., (2003) The Essential Characteristics of Industrialised Building Systems, *International Conference on Industrialised Building Systems, Kuala Lumpur, Malaysia, 10-11 September, 2003 283*. http://leewp33.tripod.com/sitebuildercontent/sitebuilderfiles/characteristic-ibs.pdf (accessed 04/04/08).

Unger, C. (2006) Industrialised house building – fundamental change or business as usual? *Doctoral Thesis, KTH School of Industrial Engineering and Management*, Stockholm. http://www.diva-portal.org/diva/getDocument?urn_nbn_se_kth_diva-4120-2__fulltext.pdf (accessed 20/02/08).

UN-Habitat. (2003), The Challenge of Slums, Global Report on Human Settlements 2003. UN-Human Settlement Programme. Earthscan Publications

Author Biographies

Dr. Ayman Othman is a Senior Lecturer at the School of Civil Engineering, Surveying & Construction, Faculty of Engineering, University of KwaZulu-Natal, South Africa. He obtained his B.Sc. in Architectural Engineering from Assiut University, Egypt in 1991. Then he worked as an architect and project manager in different national and international architectural design firms and government authorities in Egypt, Saudi Arabia, and the United Arab Emirates. He got his M.Sc. and Ph.D. in Construction Management from Heriot-Watt University and Loughborough University, UK in 1999 and 2004 respectively. Dr. Othman published more than 30 academic papers in refereed journals and conferences. He is a referee and member of advisory board of a number of academic journals. His area of interest includes: value and risk management, dynamic brief development in construction, sustainability, corporate social responsibility, partnership, client satisfaction, information management and technology, and maintenance management.

Mr. Stefan Conrads holds a B.Sc. Honours in Construction Management and a B.Sc. in Property Development from the University of KwaZulu-Natal, South Africa, in 2007 and 2008 respectively. His area of interest includes: Market dynamics, dynamic industrial business models, industrialised building systems and aviation.