Chapter One

General Introduction

1.1. Introduction

This chapter introduces the research work that includes research background, research motivation and rationale, problem statement, research question, and the hypothesis. In addition, this chapter also discusses the aim and objectives of the studies. Methodology, originality, and achievements of the investigation, together with a guide to the dissertation.

1.2. Background

Housing is one of the greatest challenges that face developing countries. The housing problem in Sudan could be attributed to the slow rate of supply in the face of the high rate of demand; lengthy construction time; high construction cost; and in-appropriate solutions. Moreover, conventional construction techniques and poor workmanship greatly compromise quality and results in poorly constructed houses.

Most low-income housing developments in Sudan and elsewhere are built using non-durable conventional cast-in-situ building methods that are inefficient and provides poor quality houses at high costs. Industrialized building systems (IBS) pose a more practical and effective approach to the issue of housing. It is a familiar concept and has proven to be relatively successful for low-cost housing schemes all around the world, especially in some developing countries in Latin America and Asia. Industrialized building systems are now available in various forms techniques and materials, with high production rates and competent prices.

The Sudanese government has always favored site and services housing projects a system by which, governments provide partially serviced plots in planned areas, and people left to develop their houses using conventional methods. A labor-intensive creates a job for cheap and unskilled labor. However, the products of the overall system are characterized as being a degrading factor to the built environment and at a high cost. It is needless to site, the many housing projects that become slums after a short period due to their space inadequacy. In such of situation, and due to the high construction cost, the tendency is to provide minimum built un area. This suggests the urgent need for alternative approaches that provide quality, durable, cost-effective, and culturally appropriate housing schemes. Therefore, no evident study has investigated industrialized building systems as a Strategic approach for low-income housing in Sudan. Industrialized building systems (IBS) housing schemes in many developed countries (Japan, USSR, England, Germany, etc.) came in high-rise apartment blocks as well as single floor houses (Herbert, 1984). This adds relevance and interest to the topic of the popularity of low-rise housing in developing countries. This study will investigate the suitability in terms or technical, economic and environmental feasibility of industrialized building systems for housing in Sudan.

1.3.Research Aim and Objectives

The major goal of the studies is to investigate the technical, economic, environmental, and cultural, viabilities of industrialized building systems (IBS) as an appropriate housing alternative in Sudan. In order to achieve this goal, the research will be designed to accomplish a number of objectives such as:

- Building a comprehensive background of the housing situation in Sudan, the conventional and industrialized building systems with regard to popular/low-income housing projects and sustainable development
- Identifying criteria for comparison between conventional and industrialized building systems.
- Selection and developing of analytical tools to investigate the problem.
- Developing a research model that will assist in identifying and evaluating various industrialized building systems.

- Assessing the performance of both conventional and IBS using the identified investigation tool.

1.4. 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 utilize 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 Sudan.

1.5. Problem Statement

Since Sudan independence in 1956, successive governments failed to product decent housing. The government, however, has promised to produce a large number of housing units to reduce the population crisis, although it has failed to contain the problem. Work, materials and control have proven to be problematic for traditional construction, but how can these factors have consequences for IBS? In order to reduce housing shortages, the rate of production should exceed the housing demand through strict housing policy. However, the traditional construction produced rapidly, the construction is largely poor of quality and as a result, and poorly constructed houses produced. The problem is attributed to several factors, such as:

- **Labor problems:** almost all the labor force that work in the construction industry is uneducated and unskilled.
- **Governmental policies** involve the controlling and management procedures as well as labour, these issues focused on: skills training initiatives, corruption in housing subsidies and tenure, housing policy

implementation, appropriate land use, planning schemes, community-based organizations and corporate social responsibility structures.

- **Technological issues** involve the adoption or new technologies and techniques.
- **Housing finance:** all variables that contribute to construction cost in a way that affects the quality of the product, among these, inflated prices of building material, inflated labor rates, land prices, and housing prices.

Labor, materials, and construction control considered un-manageable factors when dealing with conventional construction techniques. Yet it is important to investigate the effect of these factors when dealing with industrialized building systems. To reduce the existing housing backlog, productivity needs to increase to a level whereby the supply rate exceeds the demand rate.

1.6. Research Question

"Is the industrialized building system (IBS) the appropriate and viable alternative for the production of housing in Sudan?"

This is the initial single question that drives the research. The process of the research development will disseminate the question into various avenues and questions will emerge. One of the main questions that may emerge "What are the real constraints hindering the development of the construction industry in Sudan?" finding answers to these questions provides an answer to the main research question.

1.7. Research Hypothesis

Initiating progressive and economically viable construction industry in Sudan requires the introduction, initiation and implementation of appropriate local strategies, and policies.

The basic foundation for such scope, the road map that guides the work, is not yet set by public institutions and private agencies actively involved in the

Sudanese building industry. The hypothesis of this research poses a single question that should provide a simple answer by either stating the hypothesis is acceptable or not acceptable. Therefore, the hypothesis was taken in the negative form as it provides a stronger form of testing; it stated as: industrialized building systems are not a suitable alternative for popular housing in Sudan.

1.8. Research Methodology

The research methodology consists of both theoretical analysis, and field work designed to realize the goal and objectives of the study. Data from the literature defined and investigated to build a model or a research instrument that to be used to analyze available industrialized building systems and evaluate their viability to the local contexts. The field data will enable the generations of various variables that define the characteristics of the local context.

The literature is an important part of the research as it provides a background and an understanding of the aspects investigated. Furthermore, the literature review provides reasoning and paving the aspects of the analysis. The criteria identification is an important aspect concerning the analysis framework as it provides the basis of the framework, the interviews, and questionnaires. It included investigating the housing situation in Sudan, conventional building systems, industrialized building systems, sustainable development identifying the criteria of each role player.

Figure 1.1 below shows an outline of the research cycle. The research cycle includes three main objectives:

- Literature Review, includes three aspects;
- Study Surveys, includes two aspects; and
- Analyzing & Results, includes two aspects.

These explained and defined as follows:

Firstly, the Literature Review is used set the theatrical basis of the study. The review includes the following aspects;

The housing situation for the Sudan in general and Khartoum state in particular entails social housing, private and public involvement, the civil war conflicts and effects, and housing strategic set by the government. In addition, Khartoum state housing situation, strategic, policies. Also discuss the impact of the migration for the lack of low-cost housing. Furthermore, the lack of housing for the poor financing and construction and reconstruction fund and methodology.

The building system approach; the building construction technologies and techniques for the housing in Sudan. In addition, the structural building systems included 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 Sudan.

The industrialized building systems: a background of the concept of this building system, it’s theory, and application to low-income housing, the potential advantages and disadvantages it can offer in the context of Sudan social housing. Sustainable development for low-income housing; the environmental impact, social sustainability implications, and economic sustainability through job creation.

Also, the comparison between industrialized building systems and conventional building systems and classify for the IBS types that are used and determine the obstructions to implementation of it in Sudan.

Secondly, field work is important as the factors analyzed through their performance of either building system as well as the importance of the system towards the role player of the criteria. Identifying the criteria used for the analysis by listing and substantiating the requirements of each role played in social housing. The criteria identified is for each role played in government-subsidized housing in Sudan and selected in terms of their requirements and the implications IBS would have on their role in government-subsidized housing in Sudan. The Development of the analysis framework will be a crucial component of this research. At this stage, sufficient background knowledge has gathered to understand what type of analysis tool is needed. Applicable decision-making tools are reviewed and a suitable model developed to serve the aim of this study.

The interviews used to weight the importance of each factor of the criteria investigated. The surveys were composed of three aspects; developing the analysis framework, formulating and conducting/issuing both the interviews and the questionnaires. The formulating of the questions for the interviews and the questionnaires based on the framework so that the surveys are collected data for the analysis framework. This objective deals with the formulating and executing the field work. The interviews and questionnaires each play a different role in this study.

The purpose of the interviews is to weigh the importance of the various factors within the criteria identified. These interviews were aimed at the three different role-players involved in the government-subsidized housing, namely the government officials (developers and initiators), the contractors (service provider), and the end-user (resident or homeowner). All three of these groups have a different involvement, perspective, purpose, and motive for low-income housing development, which is why each group interviewed separately for their particular criteria.

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

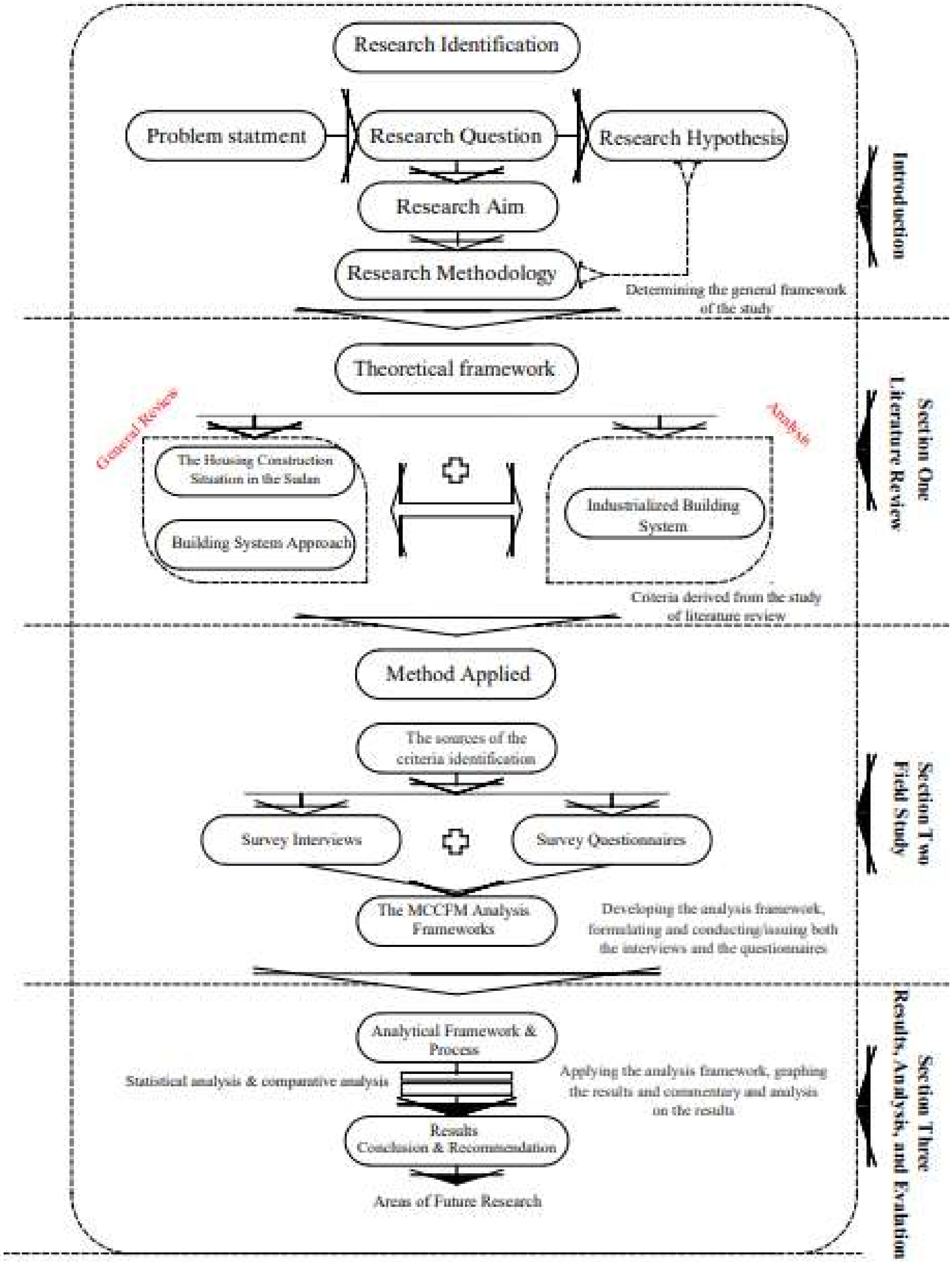


Figure 1.1 Research Methodology Diagram

The process of the data analysis takes the following results of the questionnaires which rate the performance of the criteria provides 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 the difference in performance between industrialized and conventional can be measured and analyzed.

The analysis tool Multi-Criteria Comparative Feasibility Matrix (MCCFM) is the analysis tool used for this investigation. It is based on the Simple Multi Attributable Rating Technique (SMART), which 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. Developing an analytical tool work for this study involves investigating and selecting suitable decision-making tools. Once an appropriate tool has selected, then developed and adapted so to achieve the purpose of this study.

Finally, Analyzing the Results involve the processing, result analysis, evaluation of the data, and discussion obtained. 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 processing the data collected from the interviews and questionnaires and formulating a result. These results used to analyze the feasibility between industrialized 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.

1.9.Research Originality and Achievements

Low-income housing development in Sudan were built using inefficient conventional building methods as the production is too slow and provides poor quality houses at high costs. Industrialized building systems however, could provide more practical and effective approach. IBS is a familiar concept and has been proven relatively successful for low-cost housing schemes in Japan, the Soviet Union, and Germany in terms of production rate and housing supply.

The Sudan government has favored labor-intensive approaches due to job creation and cheap labor, thus neglecting industrialization. So far, no evident study has investigated industrialized building systems as an approach for low-income housing in Sudan. The industrialized low-income housing schemes in Japan, USSR, England, and Germany have developed high-rise apartment blocks, however, industrialized singular houses have generally been unpopular (Herbert, 1984). This adds relevance and interest to the topic as to how will singularly housing is viewed in developing countries. This study will investigate the feasibility of implementing industrialized low-income housing as a new approach for Sudan.

1.10. Dissertation Framework

Chapter 1: Introduction

This chapter presents the work done in this research. It identifies the background of the research, the research motivation and rationale, the problem statement, research question, research hypothesis, research aim and objectives, the relevance of the study, research methodology and research originality and achievements.

Section 1: Literature Review

The literature review demonstrates the local and international literature from previously written works, research, and publications that are relevant to this topic.

Chapter 2: The Housing and Construction Situation in Sudan

This chapter contains the housing and construction situation in Sudan. This involves describing the context in which both industries are performing including the general profile of the country, population and urbanization, civil wars and conflicts and effects. It enumerates the challenges facing the construction industries of Sudan. In addition, this chapter describes the housing of the Khartoum state housing situation. This involves describing the housing strategic, policies, the impact of migrations, the stages of housing development, the lack of housing for the poor, the low-cost public housing, and financing of housing and reconstruction fund methodology.

Chapter 3: Building System Approach

This chapter contains the building system approach; it is providing a general view of the building materials and construction techniques, and structural building system for housing in Sudan.

Chapter 4: Industrialized Building Systems

This chapter describes industrialized building systems, the sequence of construction for the IBS method. Applications, typical classification, the benefit, and the selection of an industrialized system. Also, this chapter attains sustainability in construction and the impact of construction activities on the environment. Also, a comparison between IBS and CBS, and obstructions to the implementation of IBS in Sudan.

Section 2: Field Study

This section describes the research method applied. This involves describing the sources of the criteria identification, developing the analysis tool, developing and conducting the surveys, applying the evaluation tool.

Chapter 5: Method Applied

This chapter summarizes the outlines of the questionnaire and interviews survey investigating the problems facing the Sudan construction industries. The Multi-Criteria Comparative Feasibility Matrix (MCCFM) is the analysis tool that developed to achieve the aim of this research. The appropriate analysis tools investigated and the appropriate one that meets the research requirements chosen. The steps followed to develop the tool as well as the methodology and application procedure described.

Section 3: Results, Analysis and Evaluation

Chapter 6: Results and discussion

This chapter presents the results of data collected from the survey and interview questionnaire. Furthermore, the main results of the analysis framework disclosed. These results quantitatively analyzed by a direct comparison between IBS and CBS that appear swells through charts. The results also qualitatively analyzed through commentary and inference.

Chapter 7: Conclusions and Recommendations

This chapter summarizes the research work done in this research. Its focus based on the overall findings of the analysis and the application of this research in the industry. The recommendations made to the government-housing department, the housing contractors, the homeowners, and researchers.

Chapter Two

Housing Situation in Sudan

2.1 Introduction

This chapter presents an extensive background on the relevant aspects of this research. The information provided in this chapter was collected from existing literature as mentioned in the bibliography and references. The information included in this part represents the whole country before being divided into two nations. The subsections are:

- General Background.
- The Sudan Housing Situation.
- The Khartoum State Housing Situation.

2.2 General Background

A house is important for the human being, it is a 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. 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 (UN Habitat, 2003).

Slums occur from mass urbanization 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. Urbanization 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. 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.

2.3 Sudan Situation

The Republic of the Sudan is the largest country in Africa (the information provided here includes southern Sudan which has become an independent country since 9 July 2011), with a territory covering about 2,505,813 square kilometers of northeast and central Africa. The country lies between latitudes 3° and 22° N and longitudes 21° and 39° E. Nine countries border Sudan; Egypt in the North, the Red Sea, Eritrea and Ethiopia in the East, South of Sudan in the South and the Central African Republic, Chad and Libya in the West. The Sudan is a republic with a federal system of government. There are multiple levels of administration, with 25 States (Wilayaat) subdivided into approximately 120 localities (Mahaliyaat). The northern states cover most of the Sudan and include most of the urban centers. Khartoum - the capital and largest city - is located in the northern half of the country at the junction of the Blue and the White Nile Rivers (**Figure 2.1**).

Sudan has an estimated population of 42 million inhabitants (2008 estimates) with an overall population density of 16.9 people per km2. About 45.2% of the population is urban while 54.8% is rural including nomads (United Nations, 2008a). The national identity of the Sudan evolves multitude and complex elements including ethnic, religious and linguistic characteristics. Sudan was under a condominium rule of Britain and Egypt over the period 1899–1956. Before that period, some parts of Sudan were under a Turko-Egyptian rule (1824–1885). The nation became independent on January 1, 1956.

Figure 2.1: Map of the Sudan

Source: United Nations

2.3.1 Population and Urbanization in the Sudan

The world's total population in 1950 estimated at 2.5 billion, it expected to triple by the year 2010 reaching 6.9 billion. The developing countries alone inhabited by 5.45 billion in 2007 and expected to grow at an average annual rate of 1.19% during the period 2007-2025. The corresponding estimates for developed countries were 1.22 billion associated with a growth rate of 0.16% for the same period (United Nations, 2008a). The growth rate of the world population for the period 1975-1990 estimated at 1.7% per annum on average. According to the Sudan's national census in 2008, the total population of the country calculated at 39.1 million in 2008 with a sex ratio of 1.05 men/women (CBS, 2008) (this population data before the secession of South Sudan in 2011). The trends indicate an overall low population density (**Appendix 1 & Appendix 2**). Sudan is expected to continue its rapid population growth with a large percentage (47.1%) of its people under sixteen years of age. The population has quadrupled in sixty years where the corresponding estimates for 1950 put at 9.1 million (United Nations, 2008a). The northern states, including the three states of Darfur, cover most of the country and include most of the urban centers. The population of northern states estimated at 30.8 million representing about 71.2% of the total population (**Appendix2**). The remaining 28.8% (8.2 million) is the share of the states of the south (CBS, 2008). The three states of Darfur- Southern Darfur, Northern Darfur and Western Darfur – have a population of about 6.4 million (**Appendix 4**). The national census has reported that about 8.5 million (21.7%) out of the total population are originally from Darfur (**Appendix 3**).

The majority of the Sudanese lives by mixed agricultural and pastoralism, yet, as elsewhere in many developing countries, there has been a considerable expansion in the urban population. Urbanization accelerated in recent years by the dual effects of the war in the South and the drought that hit Eastern, Western and Kordufan regions during the 80s (ITDG, 1990; Teklu, Braun, & Zaki, 1991). **Appendix 10** provides information about migrants received by different states of the country.

Anyhow, the urban population of the country, as percentage of total population, increased from 6.8% in 1950 to 40.8% in 2005 and estimated to approach 74% by 2050 (**Appendix 1**). The compounded growth rate of urban population, for the period 2005-2010, estimated at 4.3% (United Nations, 2008a). **Appendix 6** provides a breakdown of the country's population into urban, rural and nomads during 1956-1993. (**Appendix 7 and Appendix 8)** shown the distribution of urban population among different regions and the size of main urban centers of the country during 1956-2008.

The population composition of the Sudan seems to follow the typical trend of many developing countries. **Figure 2.2** demonstrates the trend of population growth in the Sudan in comparison to the world's population growth by the groups of countries during 1950-2050.

The inhabitants of metropolitan Khartoum, the largest city of the country (including Khartoum, Omdurman and Khartoum North) **(Appendix 9**), increased from 0.9 million in 1975 (United Nations, 2008b) to 5.2 million in 2008 (CBS, 2008) and expected to reach 7.9 million by the year 2025. Estimates put the increment of the city population during 2010-2015 to be as high as 3.2%. The share of the city in the total population of the country increased from 2% in 1950 to 13.5% in 2008.

Today, Khartoum accommodates more than one fourth of the urban population of the country (United Nations, 2008a; CBS, 2008). The city alone includes around two million displaced persons from the southern war zone as well as western and eastern drought-affected areas. Most of the population of Darfur and Kordufan who were affected by the drought had settled in camps around Omdurman (Teklu, Braun, & Zaki, 1991). **Appendix 9** shows the population of Khartoum and its share in the total population of the country.

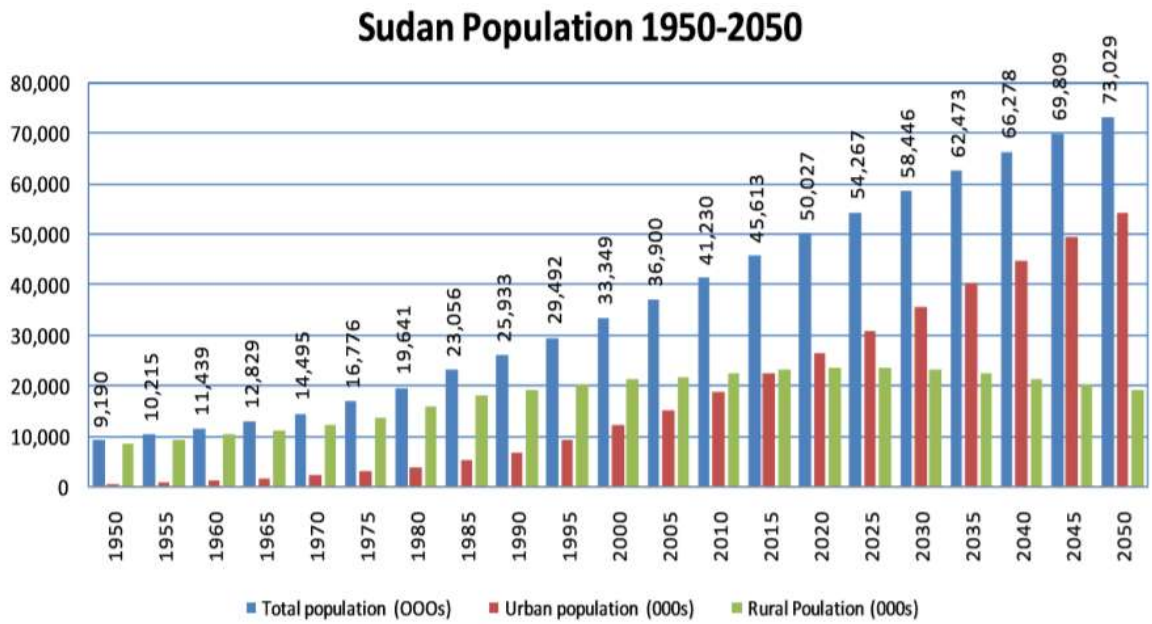


Figure 2.2: Total, urban and rural population of the Sudan 1950-2050

Source: Adapted from United Nations (2008)

2.3.2 Sudan Civil Wars and Conflicts

The Sudan has two hundred of ethnic and tribal divisions and language groups, which makes effective collaboration among them a major problem. Conflicts were inevitable results of this wide range of ethnical diversification. Sudan has been in constant conflicts since its independence in 1956. The two most extensive conflicts have been those between the North and the South, with the first civil war lasting from 1956 to 1972 and the second civil war from 1983 to 2005. The war in southern Sudan was the most critical to the Sudanese society socially, economically and politically. Re-opening the wounds of war, a conflict broke out in Darfur in 2003 and continues until now. Other conflicts emerged in eastern Sudan, the Blue Nile and Southern Kordufan. All these conflicts acknowledged to the marginalization of the public of these regions by the central government. However, the most critical conflict was the one that took place in the South and the ongoing guerrilla conflict in Darfur.

2.3.3 War Effects

During the past two decades the Sudan, claimed (directly or indirectly through famine) as many as two million Sudanese lives as a result of famine. The southern region has a population of around 6.4 million and a predominantly rural, subsistence economy. This region was negatively affected by war for all but 10 years of the independence period (1956), resulting in serious neglect, lack of infrastructure development and major destruction and displacement. More than 2 million people have died and more than 4.5 million internally displaced or become refugees because of the civil war and war-related impacts (United Nations, 2005).

Due to this war, developmental projects were frequently suspended and some projects have started a long time ago without being finished yet. Construction projects suffer from the war as many other developmental projects. Moreover, a great portion of the economy output was devoted towards the military work whereby most of the funds assigned for developmental and constructional projects to the war. Shifting of funds towards war has its observable effects on almost all the markets in the Sudan. Construction and real estate markets, as growing markets, severely suffered from the war. The equilibrium between demand and supply was not subject to market forces; instead, it was at the mercy of the war and the resources available after covering the war costs. The market was reluctant to respond to the gap between demand and supply.

Unorganized migration was inevitable due to the war. As a result, demand and supply were unpredictable making it difficult to create a well-organized and planned market for real estate and its submarkets. Hence, investing in construction and real estate characterized as risky. The role of the private sector in the construction and real estate markets was, thus, unrealizable.

According to Gueli (2007) infrastructure has an important role to play in development and thus the stability in post-conflict environments. Without post-conflict reconstruction, societies emerging from war will struggle to maintain peace and security and promote development. It is obvious that most of the conflicts experienced in the Sudanese context attributed to inequality of development among different regions. Therefore, the post conflict reconstruction is crucial to the sustainability of peace in the country. In other words, the Sudanese Construction Industry is required to develop and improve its capabilities to suit the increasing demand for construction. The government should draw considerable attention to the provision of infrastructure and human needs to avoid further wars and conflicts.

2.3.4 The Housing Situation in Sudan:

The Sudan faces a giant housing backlog, which, despite the government efforts, has increased. The rate of supply is too low and the demand needs to manage in order to meet the backlog. Controlling demand is a difficult subject as it involves demoting urbanization, the main issue of focus will be the supply of housing. An industrialised building system (IBS) for low-cost housing has been proven successful in overcoming housing shortages in certain developed countries.

Sudan 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 Sudan government. This is not a challenge that is easy to over-come by introducing a single lesson or a set recipe, it is only possible to devise a strategy that includes the relevant lessons learnt by similar countries and by intelligent measures that will alleviate the problems that are particular to the situation. Not all new problems solved with conventional ways.

There is a lack of literature directly linking housing situation with public low-income housing in developing countries; this literature review will separate the housing shortage in Sudan from IBS. It 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.

After independence in 1956, Sudan government made a commitment to reduce the housing shortage; it made the comprehensive urban housing policies covered by a number of national plans of economic and social development, the plans gave priority of public investment to what was termed by the economists as the productive sectors, housing seen as resource absorbing was relegated to a low priority with very limited share of the plan public investment. The efforts to face the urban housing problem left to the private sector.

The Plan housing policies were, in effect, a continuation of the ex-colonial practice, consisting of unrelated measures and projects to implement by different ministries and departments.

The Plan Policies can sum up as:

- The construction of housing units for senior government officials.
- The construction of low-cost hire purchase housing to low wage earners.
- The leasing of serviced plots to urban dwellers through open and closed auctions.

The Ten-Year social and economic development plan (1961-70) after independence, being the first National Development Plan following independence in 1956, understandably, catered for housing the balance of government officials required by all provincial capitals and centers. For building low-cost housing units for low wage earners, National Housing Authority determined to build 1000 dwellings out of the stated amount to benefit those working or living in it, supporting a family of minimum 5 persons, this being the first low-cost project.

The Five-Year social and economic development plan (1971-1975) did not stipulate quantitative housing targets, but approved the policy of leasing plots in serviced areas and devoted some public resources for the provision of basic services for some newly developed rented areas. In 1975, the Five-Year Plan extended one year more (1971-76) to cover the policy, among other development sectors requirements, a one-year plan (1976) to alleviate the growing urban housing problem.

This Plan approved by the Council of Ministers in April 1976, for implementation during (1976-1977), with the exception of space and building standards, which were left to the discretion of the provincial councils who were made responsible for stipulated certain quantitative and qualitative housing targets, including:

- The distribution of 28,000 plots through "Site and Services", projects in 13 major urban centers is for various income groups;
- The construction of 600 complete affordable housing units to be rented on a hire purchase basis to workers as an experimental project;
- The improvement of squatter settlements in both Khartoum conurbation and Port Sudan; and
- The encouragement of private investment in housing and real estate development.

The six-year social and economic development plan (1977-1983), for the first-time attention was given to the housing problem and devoted a complete stage on its analysis in terms of backlog deficiencies, demographic needs, demand levels and resources with full understanding of the problems facing the implementation of the previous plans. The current plan contains:

- Provision of 152,000 housing units provided with the necessary services with priorities for the low-income groups.
- Improving 42,000 units of the Squatter Settlements.
- Insuring the provision of adequate economic housing in large scale projects (agro-industrial etc.) for the workers within the project budget.
- Encouraging individuals and cooperative societies to build and make use of possible financing and technical assistance.
- Preparing Structural Plans to guide and control the development of the urban centers and to ensure the construction of the major infrastructural networks.

In 1984, the Minister of Construction and public works approved the document under the heading of "Towards National Housing Polices" and Public Works as a general guide for housing policies but without commitment towards budget. Due to the political changes by 1985 and lack of funds, none of the Plan programs implemented, but fragmentary local housing efforts continued in different urban centers.

The Ten-Year national comprehensive Strategy (1992 -2001) stated very ambitious strategies for both planning and housing in line with Vancouver 1976 international conference principles and recommendations. The overall objective of its housing strategy was a repetition of the previous plans achieved in stages during the Ten Years.

- Phase 1: The first 3 years: preparation of housing plans, improvement of the services in existing housing and the completion of running plan by providing 500.000 new plots.
- Phase 2: 4 years: Provision of 660.000 new plots and re-planning of 450.000 units.
- Phase 3: 3 years: Provision of 440.000 new plots and completion of re-planning 450.000 units.

The process of Khartoum State Housing (1992-2001) leasing plots of land to qualified applicants continued since July 1991 up to 1997 benefit 190,000 applicants. No official commitment offered towards the provision of the essential and basic services. The process of squatter is treatment, re-planning and villages' organization continued. Each beneficiary was likewise to pay the cost of land and administrative charges to affect registration. Certain urban extensions planned as residential communities to accommodate about 6000 plots to reserve for low cost housing projects.

As far as the resulting complexity of the Urban Housing Problem during that period is concerned, **Table 2.1**, shown the four Censuses population sizes by modes of living, assists in establishing crudely the Quantitative Urban Housing problem: Dividing the urban population increase during 1993-2017 by an average household size of six persons ((14,195,253- 11,793,687)/6), then, the number of households in need of housing due to population increase during 24 years, amount to 400,261 households. Since about 240,000 plots were distributed through "Site and Services" projects and doubling this figure to reach 160,000 plots assuming that some local governments were distributing housing plots for those in need, yet the shortage would account to over 150,000 units.

Censuses	Total	Urban	Rural	Nomads
1956	10,262,536	903,586	8,002,712	1,405,951
1973	14,113,590	2,605,896	2,877,984	1,629,710
1983	19,092,684	4,219,826	12,808,028	2,064,830
1998	24,940,683	6,285,052	16,535,673	2,119,958
2008	34,385,963	11,793,687	20,143,997	2,448,279
2017	40,533,330	14,195,253	23,850,626	2,487,451
Annual Growth Rates				
1956-1973	1.9	6.3	1.2	0.9
1956-1983	2.8	5.9	2.1	1.8
1973-1983	3.1	4.9	2.6	2.4
1983-1998	2.6	4.0	1.6	0.6
1998-2008	2.15	34.4	1.8	1.2
2008-2017	2.41	35.5	2.8	1.6

Table 2.1 Censuses Population Sizes, Modes of Living and Annual Rates of Growth.

Source: Urban Housing Situation in Sudan, 2018.

Obviously that huge quantitative shortage in urban housing reflected itself in poor qualitative housing conditions over-crowding, higher room occupancy rates lack provision of essential and basis services, higher rent levels and the spread and expansion of illegal settlements on urban peripheries with all their security and social problems including disguised un-employment, non-scale economies and social malaise.

2.4 Khartoum State Housing strategy:

Khartoum state adopted for strategic plans to include:

- **The First period strategy data:** It was before independence and based on the principle of dividing the land to four degrees. The first was for the colonization of the English colony, the second for the Europe's, the third for the Egyptians and the fourth for the Sudanese citizens who served in the government sector. These grades differ in terms of area, location, conditions, reconstruction and duration of the lease.

- **The Second period strategy:** In the 1957, after the independence, the national government inherited all the buildings and land in the first three grades. It worked to upgrade the lands of the third and fourth levels, to re-plan the random neighborhoods and villages near the city, to provide the completed housing for all state employees.
- **The Third period strategy:** It began after the mid-1970s and was based on two laws; the land law of 1925, And the unregistered land law of 1970. Based on this, all lands became vacant or unexploited property of the state, thus providing support to the housing sector. This strategy based on the method of partnership between the state and the citizen, the policy of location and services, and I consider public housing part of this strategy.
- **The Fourth Housing Strategy:** In the 1990s, the strategy is supposed to focus mainly on the quality of the urban problems of the housing sector and work on solving the problems of quality housing in Sudan in general and in the state of Khartoum in particular. The main features of this strategy are seven axes (methodology, population density, government support, - Land Market and Real Estate Market - Good Urban Management).

2.4.1 Khartoum State Urban Housing policies:

As a continuation of previous policies, its package consisted of:

- Disposal of Leased Plots of Land: Only 77.375 plots of land leased to low-income qualified applicants. No official commitment offered towards the provision of basic and essential services.
- Squatter Settlements uprating Program: This program of improvement of Squatter Settlements, which continued since 1985, covered 205 households, of which about 70.000 dealt with during 2001-2009.

- The process of upgrading and organizing villages was similar to that of Squatter Settlements Treatment. No official commitment towards essential and basic services provision.
- Low-Cost and Economic Housing (2001-2009): Being part of the State Ministry of Physical Planning and Public Utilities Housing Policy package, the responsible administration succeeded in building during the above stated period about 14,500 Low Cost Housing Units and about 4,600 termed as Economic Housing Units.
- The Private Housing Investment: There are 3-types of private investment in process in Greater Khartoum:
    - First Type: constituting piecemeal investment has been in process since independence in 1956 in rather very limited numbers. Private developers purchasing plots or existing buildings within residential areas and developing them into multi-story buildings accommodating flats or apartments for sale or renting.
    - Second Type: came into process during the stated period in a limited number. Private developers purchasing and developing urban land into planned, and fully serviced residential neighborhoods for selling the plots within. Thus, only accessible to some of higher income groups.
    - Third Type: came into process same as second type in a limited number. The Gated Neighborhoods consisted of well-designed villas with own garden within attractive landscaping withal the necessary infrastructure and paved roads and footpaths.

There are no statistics to show the number of housing units of each type, but apparently, the output is small. While the second type is only accessible to higher income group's type, The Third type is only affordable by the very rich minority.

Accordingly, it can be concluded that such private investment in particular the second & third types have no impact on the real housing problem of the masses.

2.4.2 The impact of migrations on the state of Khartoum:

This phenomenon has created more problems and (economic, social, environmental and administrative) challenges. The numbers of the poor have increased because of the lack of an economic base that can accommodate these growing numbers of displaced people and migrants, which has put pressure on ancient urban communities and the management of cities that have been unable to provide housing and services for these numbers.

Unorganized migration was inevitable due to the war. As a result, demand and supply were unpredictable making it difficult to create a well-organized and planned market for real estate and its submarkets. Hence, investing in construction and real estate characterized as risky. The role of the private sector in the construction and real estate markets was, thus, unrealizable.

2.4.3 The stages of housing development in Khartoum State:

The Khartoum state worked to solve the housing problems in the state, number of policies and methods appeared such as:

- Providing ready housing for state employees.
- The program of upgrading and re-planning neighborhoods and resettlement projects.
- Site and services; and,
- Housing and Reconstruction Fund - Khartoum State.

Although the housing plans have contributed significantly to solving the housing problem for long periods since the 1970’s of the last century by distributing a large number of plots of land, but it is accompanied by a number of negatives, the most important lack of delivery of necessary services, which made a large number of plans not long, which led to the emergence of many negative phenomena such as deterioration of environmental health.

2.4.4 Low-cost public housing in Khartoum:

The concept of low-cost public housing emerged in the early 1960’s through project management at the Ministry of Works. The administration has three stages:

- Project Management and Ministry of Works.
- Housing interest.
- Housing and Construction Fund.

The idea of low-cost housing in Khartoum State emerged before independence. The first project is new Emtedad Aldeum project, preceded by a detailed study in the areas of Bari, Abu Hashesh and New Aldeum. The decisions made with respect to the design and selection of building materials and costing according to realistic and close vision.

In the meantime, there were other limited and scattered projects for railway workers' residences and state employees, some of which came under low-cost housing.

At the beginning of the new national era, in 1960 the National People's Project implemented. The role of the Housing Department in the Ministry of Local Government was crucial in tackling the technical and financial problems that faced its beginning. This achieved by increasing the number of houses at the programmed time.

The projects that began in the early 1970’s was in Jabra and Haj Youssef, but they entered the spiral of inflation and the beginning of the financial crisis. The **Table 2.2** below shows the number of units implemented during the different stages of the housing programs development.

The **Table 2.3** below illustrates the efforts of the Khartoum State (Housing Authority), which started to complete the stalled projects and then started the current public housing projects.

Location	The State	No. Of Units	Year
Eastern Aldeum (1,2 west)	Khartoum	120	**1953**
Alshaabiah	Khartoum north	1048	**1960**
Hai Alhajer	Khartoum	120	**1969**
Hai Alhajer	Omdurman	122	**1976**
Jabra	Khartoum- south	324	**1978**
Total	1734		

Table 2.2 the number of units implemented during the different stages of the housing units.

Source: Banaga, Sharaf alddin Ibrahim, the challenge: is to meet the housing needs of the poor, Urban Housing Conference in Sudan, Khartoum. 2008.

Location	The State	No. of Units	Date
Althora Al-hara 20	Omdurman	233	**1975**
Al-Haj Yousef	East Nile	140	**1976 /1977 and completed in 1990**
Dar Al-salam	Umbada	1012	**1992**
Al-kurmota	Jabal Awliaa	2200	**1992**
Hai Al-mustafa	East Nile	700	**1993**
Aljaily	Khartoum North	Starting	**1992**
Total	4285		

Table 2.3 illustrates the efforts of the Khartoum State.

Source: Banaga, Sharaf alddin Ibrahim, the best challenge is to meet the housing needs of the poor, Urban Housing Conference in Sudan, Khartoum. 2008.

2.4.5 Housing and Re-construction Fund - Khartoum State:

In the framework of addressing the housing problems and the implementation of policies aimed at providing direct support to the poor with limited income, as a government commitment to the collective responsibility of the state towards its citizens by adopting a new housing strategy centered on providing a residential environment that meets the minimum requirements for a decent life. Society in a comprehensive vision for real estate development in Khartoum state and then work to alleviate the suffering of low income and poor people in a special vision to promote the city.

Although the idea of public housing is not new, the Housing and Construction Fund, established in 2001, has effectively contributed to the implementation of the new strategy, providing a suitable residential environment for vulnerable segments.

The objectives of the housing and reconstruction fund are:

- Building popular housing and investment in different types and ownership of citizens according to the basis of eligibility for each category.
- To attract and encourage foreign and local capital and others to invest in housing.
- Promote and encourage a wide range of companies to finance and implement collective housing projects.
- Establishing and developing integrated cities with integrated services to create new urban centers that will reduce the burden on existing urban centers.
- Encouraging researches and studies in the field of housing and building materials to reduce cost.

2.4.6 The State Housing and Re-Construction Fund Methodology:

The State Housing and Re-Construction Fund and Urbanization Fund, which was approved by the World Bank at the first World Urban Forum (Habitat 1) in Vancouver, Canada in 1976 and the Second World Urban Forum (Habitat II) in Istanbul, turkey in 1996.

- The cost recovery by recovering funding, and then using it as revolving financing.
- Affordability by targeting each income segment and suitable for residential display, and use this to provide cross-support between different income segments.
- Replicability and sustainability by ensuring continuous supply of housing.

2.4.7 Financing of housing and reconstruction fund projects:

The housing and reconstruction fund projects financed through a financing package that includes:

- Self-financing.
- Monthly installments of residential units.
- Domestic financing (within Sudan) such as banks and banks.
- External resources such as regular loans, soft loans, grants, grants and technical assistance.

The **Figure 2.3** below shows the sources of housing finance:

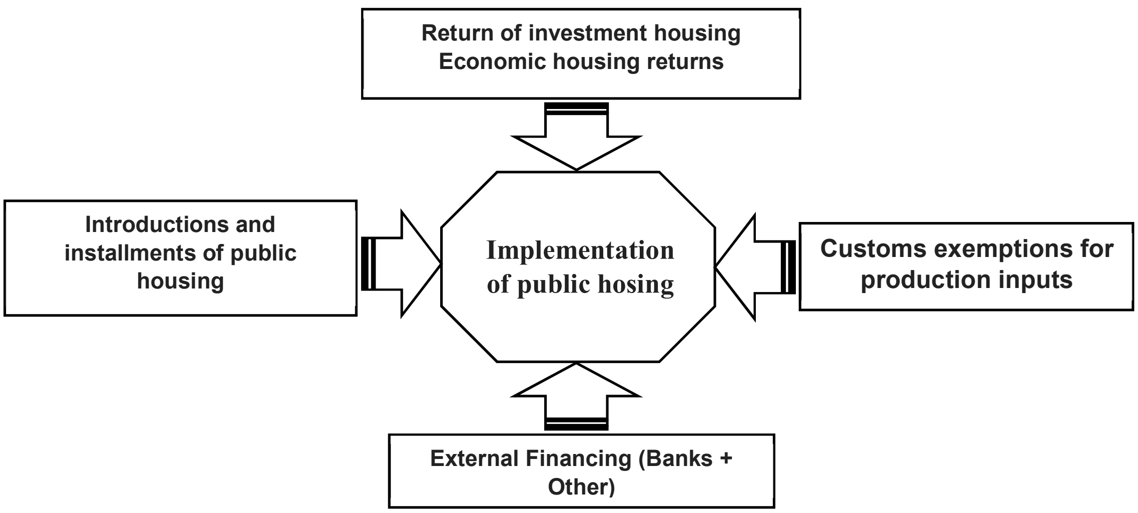


Figure 2.3 The Sources of Housing Finance

Source: The Researcher.

2.4.8 Shortage of housing for the urban poor in the Khartoum state (1993-2017):

The Khartoum total urban population amounted to about 5,991,011 persons by 2008 census and the estimates for 2017 being about 7,687,547 projections. Accordingly dividing by 6 persons per household, the number required to meet the increase in population would have amounted to 282,756 plots were required. Considering, other private sector efforts say the total would have been about 300.000 plots. These conservative estimates results indicate that the supply shortage during 2008 – 2017 amounts to about 300.000 plots, the situation implies that the balance not to mention this period qualitative discrepancies and the huge backlog legacy is absorbed within extended squatter settlements, extended villages and overcrowding.

Low-cost housing: The number available is very small compared to the size of the low-income group. However, these fragmented projects do not provide the solution to the problem of housing for low-income people, as the majority will remain outside the income bracket capable of owning a home.

It noted that there is no data available for urban housing policies adopted since 2009 to date.

2.5 summary:

This chapter provided a general background about the Sudan and Khartoum state situation. The information included in this part represents the whole country before secession to two countries. This part displayed the population growth and the trends of urbanization in the country.

The study emphasized that official statistics and reports tend to limit measurements of construction output to the formal sector and few types of construction activities. Therefore, it is believed that the contribution of the construction sector tends to be underestimated because the lack of information and the exclusion of the informal sector output. Generally, the contribution of the sector to the economy appears poorly reported. Furthermore, most of the development projects are concentrated in the capital city and few big cities, leaving the rest of the nation’s regions highly marginalized and in vulnerable conditions. This, in fact, contributed significantly to the conflicts and wars the country lives with.

Chapter Three

Building System for Low-Cost Housing in Sudan

3.1. Introduction

In this chapter will be investigate the potential of building materials and technologies for Housing in the Sudan. It reviews the buildings in the Sudan were built with local building materials using traditional skills. In addition, it provides base building materials used for low-cost housing. In addition, provide some examples of technology transfer adopted for the application of innovative approaches in the employment of local building materials and technologies, and determine the structural building that used in the Sudan.

3.2. Building Materials and Technologies for Housing in Sudan:

Most of developing countries have recognized the need for establishing building materials industries to manufacture building materials from local resources in order to improve the present situation of their construction industries with focusing on the provision of housing. However, some of these industries were imported from highly industrialized countries. Most of the buildings in the Sudan were built with local building materials using traditional skills. Different building materials were used for construction in the Sudan. Nevertheless, the building materials applied in housing are quite limited especially for low-income assemblies.

Residential areas in Sudanese cities are categorized into first, second- and third-class areas, based on a classification system that dates back to the colonial times. Classes are distinguished by specified criteria, namely income level of its residents, plot sizes, service and construction standards (**Table 3.1**).

A concomitant standard of construction applied whereby houses in first-class areas are required to adopt high construction standards and use permanent building materials, while these high standards are relaxed as one moves down the classification system. Increasing urbanization and proliferating urban growth, the threat to agricultural lands and the high cost of services forced the planning authorities in the 1980s to reduce the average plot sizes to 400, 300 and 200 square meters in first, second and third-class areas respectively. Fourth- class areas introduced in some cities as temporary areas that carry renewable annual leases, mostly to accommodate urgent cases such as squatters, internally displaced persons, etc. The typical plot in those areas is constructed of perishable building materials, such as thatch, mud, etc. In many cases, fourth-class areas dismantled after their leases expire and the land needed for other land uses. The notable example of this was Fallata quarters in Khartoum, which survived for several years before its residents relocated and the area sub-divided into a first-class area.

	Housing Areas		
	First-Class	**Second-class**	**Third-class**
Plot Size—Range (m^2)	**500-800**	**400-600**	**300-400**
Pre-1980s Average Plot Size	**800**	**500**	**400**
Post-1980s Average Plot Size	**400-500**	**300**	**200**
Initial Length of Land Lease	**50**	**30**	**20**
Total Extensions of Land Lease	**30**	**40**	**20**
Applicable Housing Standards	**Permanent building materials (e.g. concrete and bricks), multi- story, high service standards**	**Permanent Building materials (e.g. stone or bricks), medium service standards**	**Average Building materials (e.g. mud), mostly single-story, low service standards**

Table 3.1. Classes are distinguished by specified criteria, namely income level of its residents, plot sizes, service and construction standards.

Source: National Council for Research (2003).

Mostly, housing classes and income groups are segregated in the classified residential areas. Plot sizes differ among different categories of classification. Plots of higher categories are usually larger than those of lower categories.

In the Sudan, the building materials are classified into three types:

- Modern materials: (concrete, red brick with cement mortar, cement bricks and corrugated iron sheets);

- Traditional permanent materials: (red bricks combined with mud bricks for wall construction, mud construction for walls and roofing made from sticks, thatch and mud); and,
- Traditional materials: (thatch used for roofing and for walls).

The residential buildings in first class areas are constructed of red bricks with clay or cement mortar, reinforced concrete ceilings and roofs or corrugated iron sheets for roofing. The materials that are used in the construction of houses in the first and second classes residential areas should be durable materials. However, the houses in the third-class residential areas are constructed of semi-durable materials.

Hence, the building materials (specially the finishing materials) for the first and second class is imported. **Table 3.2** shows the regulations regarding the use of the building materials for different building components for each category of classification. According to National Council for Research, 2003, Statistics show that in 1972 the share of first and second-class residential areas (5.5%) was very small in comparison to the third (43.1%), and 4th classes (20.6%). This structure had slightly changed in 1990 to be 15%, 45%, and 20% for 1st and 2nd classes and 3rd and 4th classes' residential areas respectively. The share of illegal settlements has decreased from 30.8% in 1972 to 20% in 1990.

	Type of Materials		
	Durable Materials	**Semi-durable Materials**	**Non-durable Materials**
General Specifications	- high bearing capacity	- limited bearing capacity	- very low bearing capacity
	- high resistance to weather conditions	- vary in resistance to moisture	- very low resistance to moisture
	- suitable for multi-story buildings	- limited application in multi-story buildings	- inapplicable in multi-story buildings
Examples	reinforced concrete and red brick	plain concrete, red brick with mud mortar, stone with mud mortar and corrugated iron sheets	Jalous, sun-dried brick and baladi roofs
corresponding classes	1st class & 2nd class	3rd class	4th class

Table 3.2: Building materials for different housing areas classes

Source: National Council for Research (2003).

Almost buildings are constructed totally, or partially, of soil depending on location, climate, available skills, cost, building use and local tradition. About 80% of the urban population and 90% of rural population build their houses using earth as a building material (Adam, 2007).

Advantages of earth construction are;

- It is easy to work with,
- Is affordable,
- Has desirable thermal properties (very high thermal insulating value),
- Good resistant to fire and good noise absorbent,
- Does not require much transportation, encourages, and facilitates self-help and community participation in house building.

Therefore, it is a sustainable technology for construction with minimum overcharge on the environment.

Traditional clay buildings in the Sudan called Jalous, after the type of soil used for their construction. Jalous walls are built of mud by hand in tiers rather than in bricks. Walls can also be constructed from sun-dried bricks. Traditional buildings usually founded on strip foundation with a depth depending on the soil conditions.

The common structure of a traditional house is single story, rectangular in form and with flat roof. Building regulations proscribe the construction of Jalous and sun-dried bricks in first- and second-class areas.

Traditional rendering techniques, such as animal dung mixed with soil, cement stabilized soil and sand cement mortar, are commonly used to protect load bearing walls form rain water and climatic changes (Ahmed A. E., 2007).

Bricks known as one of the building materials used for contemporary construction in the Sudan, bricks were used in the Nile valley since ancient times, but the techniques were apparently lost with the coming of the Arabs. The construction of the brick technology has caught the aspiration of most of the urban lower-income population.

Roofs remain the most challenging element of buildings in general and houses in specific. The cost of roofs is the highest in comparison to other building elements and components (National Council for Research, 2002).

The choice of roofing technology governed by:

- Availability of materials;
- Economic feasibility;
- Climatic performance; and
- Ease of construction.

The roofs categorized have used in the Sudan divided to four main groups, namely (Adam & Alagib, 2002).

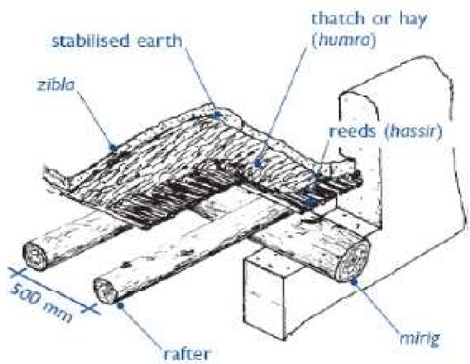
- Flat roofs including traditional earth roof, Shagig roof, and timber board roof;
- Pitched roofs;
- Vaults including vault roofs and jack arch roofs; and
- Domes (thatch or brick).

Flat traditional earth roofs (**Figure 3.1**) are known as baladi roof (baladi means local or traditional, baladi roof is composed of a main timber joist (**mirig**), small pole rafters, reeds (**hassir**), matting or dry thatch, thick layer of mud covered with a mix of animal dung (**zibala**) and soil to protect the penetration of water into the roof layers. A baladi roof has become popular because of their low cost, easy of construction, and high resistance to heat penetration. Despite its good thermal properties, the baladi roof has many disadvantages (i.e., low durability, low resistance to moisture, low structural capacity…etc.). Attempts by local builders and engineers made to improve the structural, thermal, and water resistance properties of traditional roofs by replacing local timber rafters by imported timber and replacing zibala by sand, lime, cement and plaster. Bitumen applied as well for more effective durable protection against rainwater penetration.

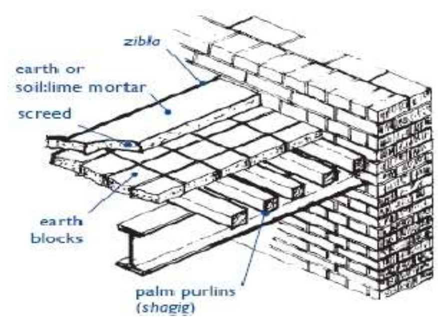
In eastern Sudan palm purlins (**Shagig**) are commonly used for roofing (**Figure3.1**). The Shagig roof is composed of I-section steel beam on which palm purlins laid with earth blocks on the top. Earth or a mixture of soil/lime mortar used to fill the gaps between the earth blocks and applied on the top of blocks. A layer of zibala and white wash applied on the top. Internally, the blocks rendered with a soil/lime mortar and finished with a lime wash. Timber board roofs (**Figure 3.1**) were very popular in most part of the country particularly during the 1940s and 1960s. However, this type of roofing system is very rarely used today as timber costs become much higher. Timber rafters laid on a steel I-section, which spans across the center of the space. Timber boards laid perpendicularly on the rafters and covered by thatch mats on which fire clay bricks laid flat on a layer of earth mortar. The bricks plastered with sand cement and finished smooth to ensure satisfactory rainwater runoff. Alternatively, timber board is covered directly by a damp roofing membrane. However, in this case the thermal performance is not as good as otherwise a bricklayer is incorporated.

In addition, the Pitched roofs (double-pitched or mono-pitched) are capable of shedding rainwater very efficiently off the roof and away from the walls. These roofs have been used in many regions of the Sudan especially in the south where rainfall can be heavy. The efficiency of this roof type depends on the pitch angle and the roof cover, the materials used and the construction method.

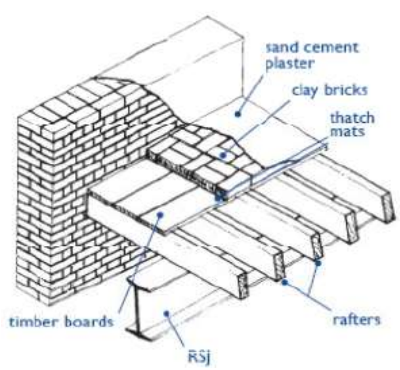
Roof covering materials typically used for pitched roofs in the Sudan are thatch, corrugated iron sheets, corrugated fiber-cement sheets, timber boarding and fired clay tiles. Thatch is a very effective roof cover often used in various parts of the Sudan, especially in southern, western and eastern areas of the country. Semicircular vaulted roofs have been used in the Sudan for low-cost residential buildings. Fired clay bricks and possibly stabilized soil blocks used for the construction of such vaults. The top surface of the vault is covered with a soil or sand cement screed. The Ministry of Housing in Khartoum and the Sudan Armed Forces in the Khartoum area have applied this technology. The performance of constructed units showed good levels of performance in respect to resistance to rainwater penetration and heat insulation capacity the jack-arch (**Figure 3.1**) is another roofing system in the Sudan despite the comparatively high capital costs that result from the excessive use of steel I-sections, which is imported at high costs. This roof type has very good heat insulation properties and good resistance to rainwater penetration. The roof is composed of steel I-sections with a maximum span of 80 cm between members. Fired brick laid on their edge in the area between each I-section and the other in a form of an arch. A special mix known as Khafgi, which is composed of cement, coarse sand, crushed fired bricks and hydrated lime, applied over the jack-arch structure to give a firm cover and good sealant against rainwater. Khafgi improves the insulation properties of the roof as well.



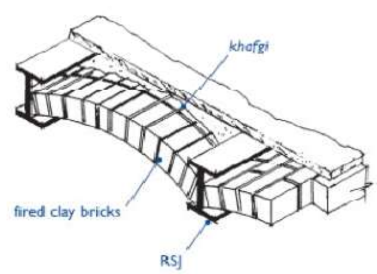
Traditional Earth Roof



Shagig Roof



Timber Board Roof



Jack-Arch Roof

Figure 3.1: Examples of roofing materials and technologies applied for housing in the Sudan.

Source: Adam& Alagib (2002).

Dome roofs still used in some parts of the Sudan, mainly the south and the west. The most common dome roofs are constructed using bamboo or thin wooden members covered with thatch. In some cases, the thatch covered with a layer of earth to provide additional protection against water and heat penetration. In the early 1930s, the Sudanese Railways Authority introduced dome and pyramid structures built entirely of brick with a sand/lime mortar or cement mortar. These huts were mainly used as residences for the railway stationmasters and staff. This type of construction was largely abandoned in the 1970s and rarely used for housing now.

According to Battelle Institute report (1979), more than 65% of wall materials and 71.2% of roofing materials used in buildings in selected urban areas are non-durable. The building methods in the Sudan can be regarded as applied to the whole country as far as techniques and designs are concerned. The only significant difference is in fact in roofing materials, which range from grass roofs, through simple timber and corrugated iron sheets to reinforced concrete roofing slabs. Corrugated iron sheets, timber sheets or boards and jack arch roofs frequently used for roofing in contemporary constructions (Ahmed A. E., 2007). The introduction of corrugated iron sheets and jack arch roofs also attributed to the British.

Modern construction technologies, which are based on steel reinforced concrete frame and floors with brick infill walls, can be found in the capital and main cities in the Sudan. The majority of commercial buildings and first-class residential buildings built in this manner. Generally, these types of constructions are often of professional designs that use expensive materials and complex construction methods, and carried by the formal sector. Thus, the construction methods and materials employed in these constructions change at a relatively high pace. **Table 3.3 and Table 3.4** presents different walling and roofing materials used in towns with population over 20,000 in the Sudan in 1973. Definitely, today the picture is quite different of that of the 70s. However, the same materials and technologies are still applied.

The government through the former Ministry of Housing has planned and implemented a number of housing projects in attempts to avail adequate shelter to special groups. Almost all of these projects were built using bricks or hollow concrete blocks with cement sand mortar and with either corrugated iron sheets or vaulted or domed brick roofs. Most recently, the National Fund for Housing and Reconstruction, established in 2008, developed a limited number of units using stabilized soil blocks. Most of the institutional housing projects developed until now are believed to be qualitatively and quantitatively poor (Ahmed A. E., 2007).

The Comprehensive National Strategy limits the strategic aims for the development of the construction sector only to the search for appropriate indigenous materials and developing designs to be adequate for expansive soil. Therefore, both the Sudanese Construction Industry and the Sudanese Building Materials Industry are marginally considered in the national development plans by the government. Few research studies were undertaken to assess the possibility of introducing innovative materials, improving conventional ones and substituting some of expensive and imported materials by available low-cost indigenous materials technological capacity in the application of appropriate building materials and technologies, especially for housing, remains at a very low level as a result of the absences and/or in-effectiveness of knowledge dissemination channels. Most of the researches performed, regardless to their viability, remain lodged and hidden in the libraries of various ministries and institutions. Therefore, it is quite common to find that specific researches are repeated by two or even more entities because of this phenomenon. Consequently, the practical application of research results and the possibility of adopting their recommendations will be limited.

Province	Total No. of Houses	Grass	Brick	Mud	Stone	Wood	Muds Brick	Others	Not Stated
Bahr Elgazal	16,233	7.9%	7.4%	67.8%	7.8%	1.4%	4.3%	3.4%	0.0%
Blue Nile	55,454	16.7%	43.2%	34.5%	1.6%	0.1%	2.5%	1.4%	0.0%
Darfur	34,904	74.7%	10.6%	3.4%	0.4%	0.0%	7.5%	3.1%	0.3%
Equatorial	11,635	1.4%	7.52%	85.0%	4.2%	0.0%	0.0%	0.9%	0.9%
Kassala	33,860	44.5%	7.6%	29.4%	2.6%	0.3%	0.3%	15.2%	0.1%
Khartoum	132,526	0.5%	27.6%	64.9%	0.3%	0.1%	0.9%	5.8%	0.1%
Kordofan	30,873	23.9%	8.3%	48.2%	1.8%	0.1%	6.3%	10.5%	0.9%
Northern	17,975	0.3%	17.4%	77.7%	0.6%	0.2%	1.9%	2.0%	0.0%
Red Sea	29,148	1.0%	1.9%	0.4%	10.2%	67.5%	0.0%	19.0%	0.0%
Upper Nile	5,066	1.1%	14.1%	81.4%	0.2%	0.0%	0.0%	3.2%	0.0%
Total	367,674	60,242	75,760	170,255	7,643	20,267	8,254	24,635	618
		16.4%	20.6%	46.3%	2.1%	5.5%	2.2%	6.7%	0.2%

Table 3.3: Walling materials used in different states for towns with population over 20,000 in 1973.

Source: Adapted from Battelle Institute (1979)

Province	Total No. of Houses	Baladi	Wood	Corrugated Iron Sheets	Concrete	Others	Not Stated
Bahr Elgazal	16,234	15.1%	0.6%	11.2%	0.4%	72.6%	0.0%
Blue Nile	55,457	53.6%	7.5%	14.0%	%	22.4%	0.0%
Darfur	34,904	10.5%	0.3%	9.1%	0.0%	79.8%	0.3%
Equatorial	11,636	1.3%	0.1%	10.9%	0.3%	86.6%	0.9%
Kassala	33,860	31.2%	0.9%	4.6%	2.5%	60.7%	0.1%
Khartoum	132,526	58.5%	20.0%	10.9%	3.4%	7.1%	0.1%
Kordofan	30,873	27.7%	0.3%	25.8%	0.0%	45.3%	0.9%
Northern	17,976	72.8%	11.6%	8.4%	2.1%	5.1%	0.0%
Red Sea	29,143	0.3%	72.6%	1.8%	7.4%	17.8%	0.0%
Upper Nile	5,066	12.4%	1.1%	27.3%	0.4%	58.8%	0.0%
Total	367,675	146,401	54,554	41,425	9,435	115,235	625
		39.8%	14.8%	11.3%	2.6%	31.3%	0.2%

Table 3.4: Roofing materials used in different states for towns with population over 20,000 in 1973.

Source: Adapted from Battelle Institute (1979).

3.3. Materials and Construction Techniques for Housing in Sudan:

A couple of investigations in search for low-cost building materials for the housing sector have been conducted. Such works included materials and construction techniques. Earth technologies have received the highest attention amongst other building technologies. Recently, traditional earth construction technology has under-gone considerable developments that enhance earth's durability and quality as a construction material for low-cost buildings (**Adam & Alagib, 2001**).

These developments include treatment of earth (ramming), mechanical stabilization (compressing) and/or chemical stabilization (cement, lime, gypsum, bitumen and pozzolana). Following are some of the technologies, including materials production technologies, which have been researched, innovated, or introduced to the Sudan recently.

Besides, the Sudanese construction industry is very poor in terms of adoption, application, and dissemination of appropriate technologies. The sector marginally takes any initiative for the development of traditional appropriate materials. The investment made by the sector in this regard is almost negligible. Local contractors, in order to avoid risk and keep their reputation, are reluctant to apply and adopt new technologies unless these technologies are widespread and turn to be successful. Therefore, most of the performed researches results remain in libraries and cabinets of their institutions.

Furthermore, the owners through their life savings finance most of the construction costs of their houses. Therefore, the owners are usually reluctant to expose themselves to the risk of applying new technologies. In contrary, they prefer applying the traditional technologies they have been practicing for decades or technologies they have tested by themselves even if those technologies turn to inappropriate. This situation creates a gap between research and application where no chances appear to disseminate a technology through application. The weakness or even the non-existence of linkages between the enterprises in the construction industry and various agents further aggravate the situation. Therefore, technological capabilities building takes place on non-durable basis and gets easily lost when successful technologies are not diffused and assimilated. Each of the Sudanese construction industry stakeholders performs on its own without any collaboration, cooperation or coordination with other parties.

The technology has been applied mainly in Khartoum and few other cities around the country. Until now, it cannot be said that the technology has been effectively absorbed and applied.

Technology transfer can be exploited to improve the production of some materials and develop new capacity in others. It is the role of professional institutions to educate the government, professionals, and the public about the possible benefits of technology transfer. It is necessary to establish a national professional body to bring together all the organizations, institutions, corporations, companies as well as individuals. Such a body will help facilitating the exchange of information and experience with the aim of arriving at better alternatives for building materials and technologies. It will help improving standards and specifications and provide training and capacity building programs. The first responsibility of this body is to raise the awareness out benefits of technology transfer and knowledge sharing.

3.4. The building systems in Sudan:

Having described the types of building systems, it is important to statistically compare the conventional building system and IBS in term of labour productivity, construction structural cost, and crew size and cycle time. The focus of this study is on structural work because the demand for labour in structural work is high and employs more foreign workers. It therefore has the highest potential for productivity improvement and reduction in foreign workers. The major operations (in terms of manpower usage) involved in the structural works are formwork carpentry, steel reinforcement and concreting. Among these operations, formwork carpentry requires the most skill while reinforcement work requires skill in taking off and scheduling; bending quite mechanized and steel fixing is an assembly skill for which unskilled foreign workers can be trained. On the other hand, the concrete pouring work skill is simple and easy to acquire.

3.5. Structural building system:

There are four main categories for the building system classification:

- conventional building system;
- cast in-situ formwork system – table or tunnel formwork;
- prefabricated system; and
- composite system as shown in **Figure 3.2**.

The last three building systems are termed as IBS

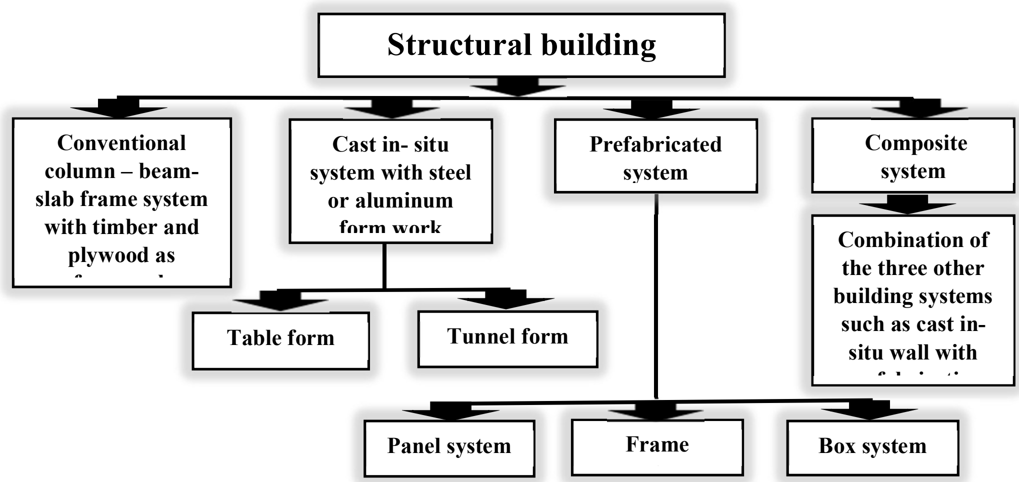


Figure 3.2 Structural building system

Source: The Researcher.

3.5.1. Conventional Construction Method:

The conventional construction approach, is based on the rigid separation of design and construction. The design team prepares detailed drawings, specification and often Bill of Quantity. The tender documents are prepared and the contract will be awarded to the winning bid from the contractors. The contractor will then manage the construction projects by using subcontractors.

The conventional building system divided into two major components. The first component is the structural system, which includes cast in-situ column-beam-slab frames. These frames are constructed through four operations, namely, erection of timber formwork and scaffolding, erection of steel bar, pouring of fresh concrete into form and dismantling of formwork and scaffolding. These operations are labour intensive, tedious and require a lot of on-site coordination. The second component consists of brick and plaster as the non-structural infill material.

Conventional construction method involves construction work being carried-out at site. It involves site preparation by fellow contactors before the laying of the footings. The foundation then built on the footings, to extend above the level of the ground. The building is actually made on the foundation. Usually a floor laid on the foundation. Beams will then be constructed, followed by the construction of columns and slabs. Where it is necessary, staircases will be constructed, before eventually roof beams are constructed, followed closely by the construction of roof trusses. When the roof is to be framed on the site, the top sill plate is nailed on top of the wall sections. Cutting and nailing each piece of wood one at a time takes a lot of time. Not only must each piece be cut but also each piece must be carried up the ladder to the right place.

Waterproof roofing materials will be placed to ensure the roof is waterproof before roof tiles are placed in position. Brick walls will be constructed where necessary, with allocations for the placement of doors and window panels. Painting and aesthetic decoration on walls and floor slabs will follow up and the product will be a complete on-site building. **Figure 3.3** summarizes the sequence activities in conventional construction method.

Certainly, with so much on-going works happening on site, many skilled and unskilled laborers are needed to carry out the works on site. Formworks have to be constructed to specified dimensions and concrete casting will be done when all the formworks and reinforcements have been properly laid on site. Weather is a common factor that affects the working schedule on site, and often, material wastage is a problem faced by contractors.

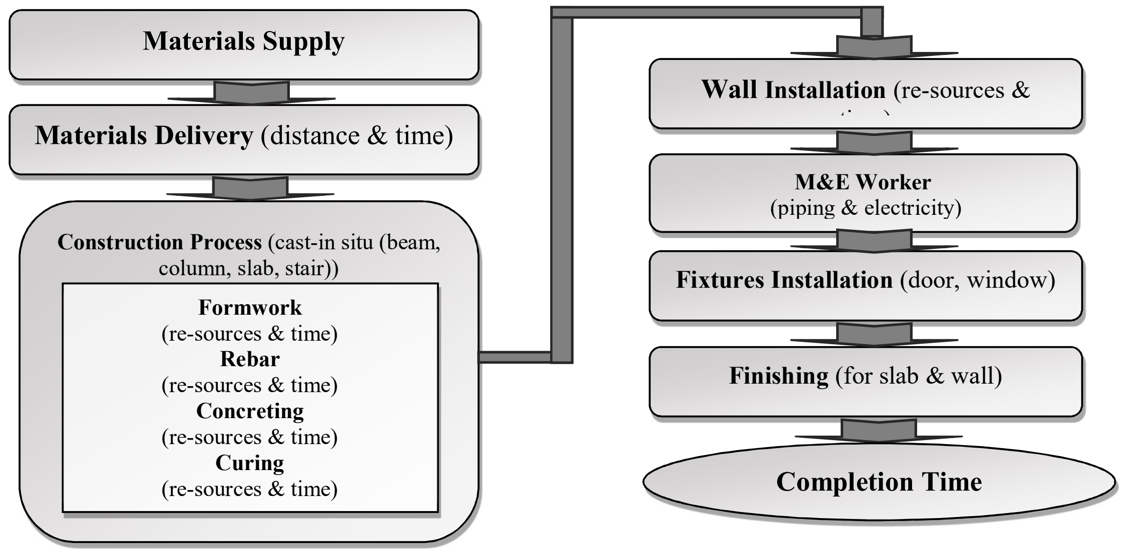


Figure 3.3: Sequence activities of conventional construction method

Source: The Researcher.

Conventional construction method requires proper planning and scheduling to ensure that the work is within the progress schedule. Due to many uncertainty and risk of wastage at site, close watch on the cost of the construction project is essential to minimize any risk of increase in the construction cost of the entire project.

3.5.2. Cast in-situ building systems:

Cast in-situ building systems utilize lightweight prefabricated formwork made of steel, fiberglass or aluminum in order to replace the existing conventional timber formwork. The method is suitable for large numbers of housing units that require repetitive utilization of formwork. The formwork can be reused as many times as possible with minimal wastage. Careful planning of cast in-situ work can improve productivity, speed, and total cost (Ismail, 2001).

3.5.3. prefabricated building systems:

Fully prefabricated building systems can be classified into two main categories, namely on-site prefabricated and off-site prefabricated (factory produced). On-site prefabricated method involves casting structural building elements within site before erecting to actual location. On-site pre-casting provides several advantages over cast in-situ construction. These include mass production of units, cost and time reduction and improved quality of work (CIBD, 1992). Off-site prefabricated method involves transferring building operations from site to factory.

Prefabrication allows a component to be built whenever convenient, so long as it is delivered on time.

3.5.4. The composite construction method:

This system involves casting some elements in the factory while others cast on site. Types of precast elements usually produced are floor slabs, infilled wall, bathrooms, and staircase. These elements are placed for incorporation into main units, column and beams, which are usually, cast in-situ.

3.6. Summary:

This chapter provided a general background about building materials and technologies for housing in the Sudan. It reviews the significance and effectiveness of innovation in the application of local building materials and technologies. It provides some examples of technology transfer adopted for the application of innovative approaches in the employment of local building materials and technologies, and determine the problems of transferring and disseminating knowledge about innovative and appropriate building materials and technologies in the Sudan.

Chapter Four

Industrialised Building Systems

4.1. Background History of IBS

Industrialised Building System (IBS) is one of the improved building systems that are being introduced to achieve the target of faster completion with mass production of the building elements in places out of its final location in a building.

According to Warszawski (1999), Industrialised building system is defined as a set of interrelated elements that act together to enable the designated performance of a building. "Industrialised system" means to build on-site with elements or components produced by series in plants (Badir, Kadir, and Hashim, 2002).

Rollet (1986) also defined the word industrializing as to build on site with elements or components produced by series in plants. An industrialised organization of building means that these components can be assembled together even though they are produced on different plants as they have then to be compatible. Another definition given by Trikha (1999), expounded that Industrialised Building System (IBS) is a system in which concrete components, prefabricated at site or in factory assembled to form the structure with minimum in-situ construction. Esa and Nuruddin (1998) also defined that an IBS is a continuum beginning from utilizing craftsmen for every aspect of construction to a system that make use of manufacturing production in order to minimize resource wastage and enhance value for end users.

In short, Industrialised Building System (IBS) is a construction method that offers economization of design, site work and materials, provides shorter construction time, saving in labour, better quality control, immunity to weather changes and the most importantly, the cost factor. It has been proven successful in some countries, namely Finland, Denmark, Netherlands, Singapore, England and the United States.

In our country Sudan, the shorter construction time offered by IBS seems to be the panacea for the housing demand in Sudan. It hoped that the widespread understanding on the Industrialised Building System (IBS) can further help to develop and promote IBS as an innovative construction method in Sudan.

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 brought from the effects of the major industries. When coal used to melt 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 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.

Industrialization 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. The first panelized wood house shipped from England in 1624 to provide temporary housing for fishing fleets (Culpin, 1970). 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).

After 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 up-liftmen. Europe and Japan had seen the worst from the war and needed to re-build from the ruins left by the bombing, whole cities as 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 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 favorable 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.

4.2. Application of IBS:

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 un-just 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. Nevertheless, it requires that the creativity to be created and implemented at all stages of development plan to assembly to achieve successful IBS implementation.

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. 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.

4.3. Typical Classification of IBS:

There are various Industrialised Building Systems (IBS) used throughout the world, and they can be classified into several major categories. From the structural classification, there are three IBS main groups identified as being used in this country. The typical classifications are as follow:

- Frame or post and beam system
- Panel system
- Box system

Figure 4.1 shows the concept of the system as classified above. In the evaluation of the systems, various parameters such as the industrialised process used, the transportation and erection problems, architectural features and the social-economic problems must be considered.

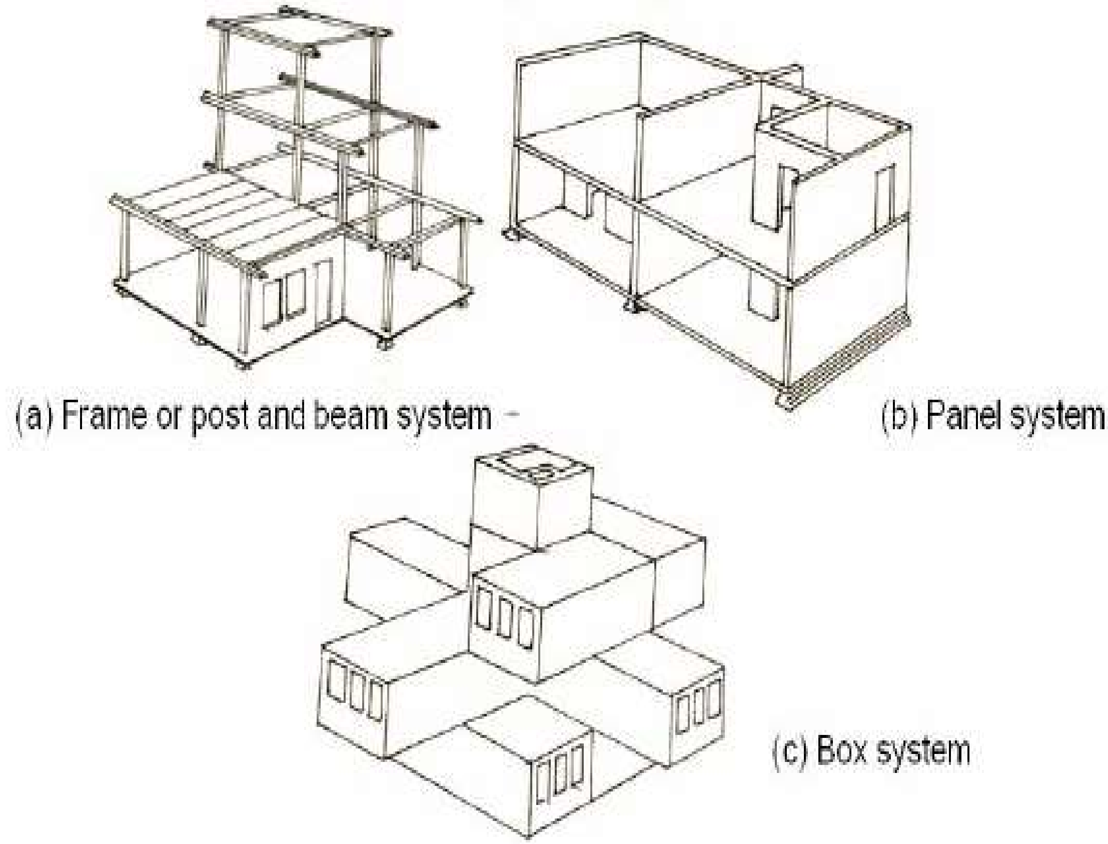


Figure 4.1: Classifications of Industrialised Building Systems (IBS).

Source: Badir, Y.F., M.R.A. Kadir and A.H. Hashim, 2002.

However, commented that the relative weight of components should be used as a basis for building classification. The factor of weight has a huge impact on the transportability of the components and also has influence on the production method of the components and their erection method on site. This classification by weight can help to distinguish between various basic materials used in the production of the components, which by itself help to determine the characteristics of the studied system. **Table 4.1** shows the building system classification according to relative weight of component.

No	General System	System	Production Material
1	Frame system	Light weight frame	Wood, light gage metals
		Medium light weight frame	Metal, reinforced plastics, laminated wood
		Heavy weight frame	Heavy steel, concrete
2	Panel system	Light and medium weight panel	Wood frame, metal frame and composite materials
		Heavy weight panel (factory produced)	Concrete
		Heavy weight panel (tilt up-produced on site)	Concrete
3	Box system (modules)	Medium weight box (mobile)	Wood frame, light gage metal, composite
		Medium weight box (sectional)	Wood frame, light gage metal, composite
		Heavy weight box (factory produced)	Concrete
		Heavy box (tunnel produced on site)	Concrete

Table 4.1: Building system classification according to structural system.

Source: Badir, Y.F., M.R.A. Kadir and A.H. Hashim, 2002.

4.3.1. The Frame System:

Frame system may be defined as those structures that carry the loads through their beams and girders to column and finally to the footing or pile cap. Junid (1986) also stated that, in such a system, the skeletal structures will help to reduce the number and sizes of load carrying members. Their important feature is the capacity to transfer heavy loads over large spans. Therefore, it is used in the construction of bridges, parking lots, warehouses, industrial buildings and sport facilities.

Typical systems of linear components for industrial buildings are composed of structural frames, spaced at equal distances whereby it creates modular linear frame that can be repeated at a desired number of times. Figure 2 shows the example of industrial hall using frame system.

4.3.2. Panel System:

4.3.3. The second system is panel system which also known as planar system. Panel system may be defined as those structures that carry the load through large floor and wall panels (Junid, 1986). This system probably would be the most widely used prefabricated system which employed planar or panel-shaped elements for floor slabs, vertical supports, partitions and exterior wall. Concrete panel systems are extensively used in Europe for high rise building for ease of construction purpose. In Sudan, this system is popularly used in high rise buildings.

Unlike frame system that mainly employed as structural framing, panel systems also fulfill interior and exterior space enclosure functions. They may be prefabricated with a considerable amount of finish with a considerable amount of finishing work such as exterior finish, thermal insulation, electrical conduits and fixtures, plumbing and window frames. Therefore, panel system will significantly reduce the content and number of skilled workers onsite. Hence, this system is widely used in residential buildings, offices, schools, hotels and similar buildings with moderate loads and large amount of finish works. **Figure 4.2** shows the application of panel system in industrial housing.

According to Junid (1986), panel system may be defined as those structures that carry the load through large floor and wall panels. The panels can be made in various forms and materials and are normally prefabricated at factory. Depending on the scale of projects, some panels may be fabricated at site for easy transportation.

Figure 4.2: Industrial Hall using Steel Frame System.

Source: Junid, 1986

Concrete panel systems are extensively used in Europe for high rise building for ease of construction purpose. Other panel systems available are as such wood, plastic, light weight metal and Ferro-cement materials.

4.3.4. Box System

According to Junid (1986), box system may be defined as those systems that use three-dimensional modules (or boxes) for fabrication of habitat units. Box system is useful and preferable because of its compatibility with a high degree of finish in the factory and its lateral resistance (Bruggeling and Huyghe, 1991). The main features of this system are in the internal stability as it can withstand load from various directions.

The box system components either can be cast in box-like moulds or assembled it in the plant. The components may contain a large amount of finishing works such as wall and floor finishing, electrical wiring and fixtures, kitchen cupboard, plumbing pipes and windows. This will definitely speed up the construction time at site. In the case of high-rise construction, the degree of factory prefabrication is reduced for economic reasons of avoiding doubling of wall, ceilings and floors. Depending on how it is used, the boxes can be made to be load bearing or only support its own weight. The boxes can be produced in monolithic form such as concrete boxes or be made in various sections joined together in the factory. **Figure 4.3** shows the assembling of box units into position onsite.

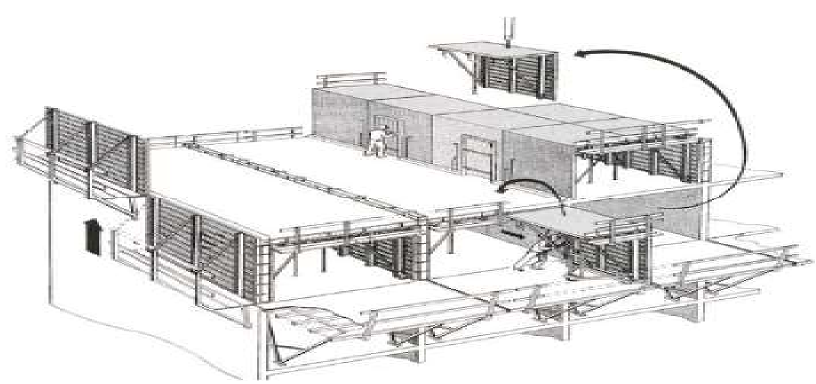


Figure 4.3: Arrangement of box units into position onsite

Source: Bruggeling and Huyghe, 1991

4.4. Benefits of IBS Component

Most of the industry players fail to realize that IBS offers better alternative to the traditional and labour intensive in-situ construction. The main benefits offered by the usage of IBS elements are;

- High Quality and Aesthetical Value of Products
- IBS products are manufactured in a casting area where critical factors including temperature, mix design and stripping time can be closely checked and controlled; and this will ensure that the quality of IBS products are better than cast-in-situ concrete. A huge sum of money will be saved by not having to do rectification work.

Also due to factory- controlled prefabrication environment, many combinations of colors and textures can be applied easily to the architectural or structural pieces. A vast range of sizes and shapes of IBS components can be produced, providing a great deal of flexibility and offer fresher looks to the structures.

4.4.1. Cleaner and Safer Construction Site

Usage of IBS elements eliminates or greatly reduces conventional formworks and props. IBS construction also lessens the problem of site wastages and the related environmental problems. The prefabricated products also provide a safe working platform for workers to work on. Workers and materials are also greatly reduced at the construction sites. Also, as elements are produced in the plant and mostly designed to be repetitive, minimal wastage will be experienced at both factory and construction sites.

4.4.2. Faster Construction

IBS construction will save valuable time and helps to reduce the risk of project delay and possible monetary losses. IBS design and production of elements can be started while the construction site is under survey or earthworks. Production is also unaffected by weather conditions due to preliminary work such as the controlled environment on casting area. Also, the usage of large IBS panels will reduce the time taken to complete the structural works. Therefore, other trades such as painting and electrical wiring can begin work sooner.

4.4.3. Greater Un-Obstructed Span

The usage of pre-stressed precast solutions such as the Hollow Core slabs and Double-T beams offer greater unobstructed span than the conventional reinforced concrete elements. With having the lesser beams and columns in any structure, it will provide flexible working space. It is very ideal for the construction of places of worship, warehouses, halls, car parks, shops and offices.

4.4.4. Lower Total Construction Costs of Ownership

All of the above simplify the construction processes and increase productivity, quality and safety. As a result, the total costs of construction are reduced.

4.4.5. Modular Coordination

The introduction of modular coordination (MC) in the industry is to improve productivity and quality in building construction as well as to act as a tool towards industrialization of the building industry. The proper characteristics of modular coordination are;

- The basic module is small in terms odd size in order to provide design flexibility, yet large enough to promote simplification in the components' variation in sizes.
- Industry friendly features that not only cater for manufacturing but also the transportation and assembly requirements.
- Ergonomically designed to promote efficiency.
- Internationally accepted to support international market.

The introduction of modular coordination in the industry not only provides dimensional basis for the coordination of dimensions and of those buildings incorporating them, but also it acts as a tool towards rationalization and industrialization of the building industry. Modular coordination is essentially based on:

- The use of modules (basic module and multi-modules)
- A reference system to define coordinating spaces and zones for building elements and for the components which form them.
- Rules for locating building elements within the reference system.
- Rules for sizing building components in order to determine their work sizes.
- Rules for defining preferred sizes for building components and coordinating dimensions for buildings.

The use of modular coordination as a dimensional basis for the building industry will pave the way for the creation of open design principles and rules which combine freedom in architectural planning and flexibility in the choice of construction method. It offers designers the possibility of incorporating standardized modular components in building projects effectively due to the following advantages:

- Dimensional coordination for simplification and clarification of the building process. It provides a common language for the building industry players, thus creating better coordination and cooperation between various parties.
- Limitation of variants in dimensions of components, reducing design time especially with the use of standardized modular components.
- Standardisation of building components, thus reducing manufacturing and installation costs.
- Prefabrication of standardized components to minimize wastage of materials, manpower and construction time.
- Industrialization of the building process through the increased usage of modern technologies such as Computer Aided Design and Drafting and Computer Aided Manufacturing.

- Modular coordination is a concept for coordinating dimension and space for which buildings and components are dimensioned and positioned in basic units or modules.

Modular coordination has been introduced in Sudan, but has not been widely implemented in the building industry. The main factors limiting the uses of modular coordination in building industries is lack of knowledge on modular coordination concept and it requires precision dimensioning, proper planning and not by mentioning the production of IBS components.

The principal objective of implementing modular coordination is to improve productivity through the reduction of wastages in the production, installation process, to improve quality in the construction industry and to encourage an open system. With Open System approach, building components could combine in a variety of individual building projects while ensuring the architect freedom in their designs.

Modular coordination is an important factor in application of Industrialised Building System IBS by way of standardization of components and dimensions such as reduce time of production and installation of components, achieving repeatability and able to construct building at lower cost.

4.4.6. Just-In-Time Philosophy

Just-in-time (JIT) is originated from manufacturing industry. It is known as a philosophy of manufacturing based on planned elimination of all waste and on continuous improvement of productivity (Ahmad, 2005). It also has been described as an approach with the objective of producing the right part in the right place at the right time or “just in time”.

The just-in-time philosophy has the potential for managing the movement of precast concrete components from the prefabrication yard to the construction site. Besides, it is also can be used for the logistics management to help raise productivity levels.

JIT should improve profits and return on investment by reducing inventory levels, increasing the inventory turnover rate, reducing variability, improving product quality, reducing production and delivery lead times, and reducing other costs such as those associated with machine setup and equipment breakdown. There are altogether six key principles to illustrate the JIT philosophy. These six principles include;

- elimination of waste,
- total quality control,
- supplier relations,
- single sourcing,
- the un-interrupted work flow and top management commitment; and
- employee involvement.

In the aspect of elimination of waste, waste is regarded as anything that does not add value to the final product. Waste results from any activity that adds cost without adding value, such as the unnecessary moving of materials, the accumulation of excess inventory, or the use of faulty production methods that create products requiring subsequent rework will be eliminated in JIT. Therefore, excess inventory is regarded as waste since it does not add any value to the final product. By stockpiling inventory, it does not bring any benefit. It will just tie down the capital and takes up space. Besides, it also incurs storage cost which includes insurance and security cost. There are also risk of obsolescence and risk damage during the storage time. In this case, JIT concept calls for buffer stocks or zero inventories.

In reality by looking to the construction sector especially on the conventional methods, most of the works are carried out at site. Therefore, construction process and labour work will be severely affected by the weather. If the current situation persists, the construction work will continue to depend on continuous labour force and the production rate will remain at its lowest. Thus, the implementation of JIT principle in the construction sector through the introduction of precast elements is hoped to achieve such success rate that has been long tasted in the manufacturing sector. In this situation, the work process will be done in a controlled and closed environment. The site will only be the installation place, whereas the components produced from the factory will be delivered to the site and ready for installation.

The use of precast elements can help control the usage of formworks, reinforcements and concrete in order to prevent wastage. Proper monitoring and control and the quality assurance of raw materials and the steel modules can ensure the production of high-quality products. In this case, prefabrication can meet the demand of lean production. **Figure 4.4** shows the JIT principle in the construction industry scenario.

In the construction sector, it needs a big space for the storage of materials at site, and this will only reduce the capital budget. The need to prepare a large storage area will not only waste money in allocating a large area for storage purposes, but if the materials are not properly kept at site, it will affect the quality of the materials greatly. Therefore, the implementation of JIT principle can save cost associated with storage, since the materials will be delivered to the site in the right quantities and in a controlled environment, to ensure that the quality of the components are guaranteed.

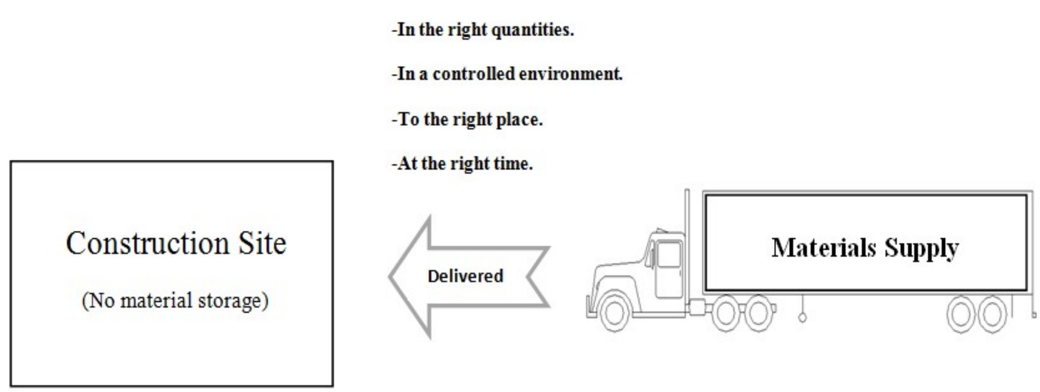


Figure 4.4: Principle of Just in Time.

Source: The Researcher

Since the materials will be delivered to the right place at the right time, this will also reduce cost associated with storage of materials at site.

In this context, it can clearly be seen that the JIT principle has a good potential in developing precast concrete components into eliminating the problem associated with storage of materials at site, and also the heavy traffic problem at site. It is hoped that the JIT principle can be fully implemented in the construction industry in our country, so that the productivity and efficiency of work at site can be improved to a greater height.

4.5. Sequence of Construction for IBS Method

IBS method is different from the conventional construction method. Known for its benefits in terms of shorter construction time, saving in labour, material saving, better quality control, immunity to weather changes and the cost factor, IBS method illustrates a different approach to the construction method commonly used. It offers an alternative to the existing conventional building system.

Among one of the most important characteristics of IBS method is IBS components are prefabricated offsite. Prefabrication system of construction means breaking a whole housing unit into different components such as the floors, walls, columns, beams, roofs, etc. and having these components separately prefabricated or manufactured in modules or standard dimensions in a factory. **Figure 4.5** shows the sequence of activities of IBS construction method.

IBS method emphasizes on prefabrication concept. Firstly, the design stage is carried out where the IBS components are designed according to specifications. Then, the components are prefabricated at factory, where components of IBS are manufactured according to specified dimensions and specifications. Quality-controlled and highly aesthetic end products through the processes of controlled pre-fabrication and simplified installations have maintained and ensured the quality of work in the construction industry.

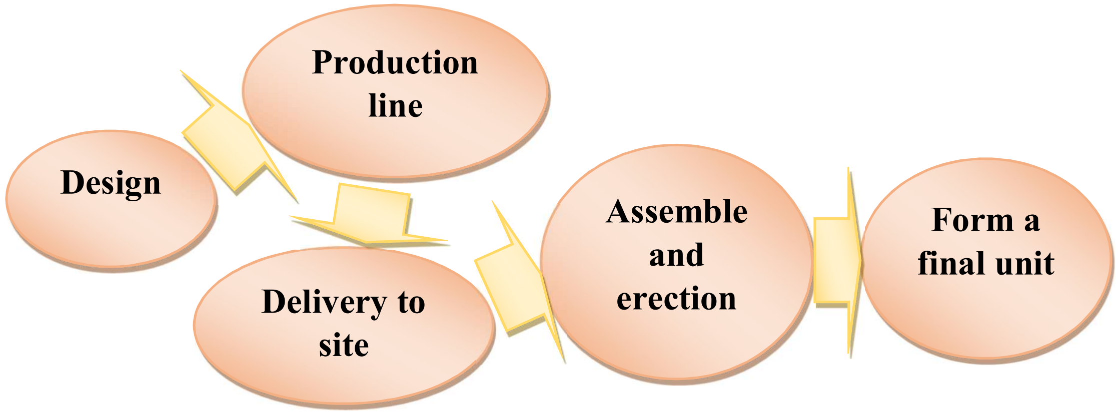


Figure 4.5: Sequence of activities for IBS construction method.

Source: The Researcher

The IBS components are then transported to the site from the factory for assembling process. At site, the IBS components are assembled accordingly with the assistance of a crane. The reduction of construction waste with the usage of the standardized components and less in-site works provides a cleaner site due to lesser construction waste. Finally, the final unit of the building is finally assembled and ready for occupation.

IBS method offers a new concept in terms of speed of construction, and it clearly shows many other benefits as compared to the conventional construction method. According to Chew and Michael (1986), IBS also consists of two types of prefabricated systems in the market, namely; fully prefabricated system and partially prefabricated system.

Fully prefabricated system is referring to the components produced in the factory and later transported to the site for erection. Fully prefabricated system consists of three categories, namely; panel system, frame system and box system. Further description and explanation of the above-mentioned systems has been clarified in the sub-section before.

Partially prefabricated system is a type of system in construction where certain elements that can be standardized are prefabricated in the factory, whereas other components are cast in-situ. In this construction method, certain elements as such wall panels, slab panels and staircase are considered as precast components, while the columns, beams and the foundations are usually cast in-situ due to ease and speed of construction. According to Chew and Michael (1986), this system usually gives more rigid construction and better water tightness characteristic, which are normally a big problem with the usage of panel system and frame system.

4.6. The Selection of an Industrialised System

Before selecting an industrialized system, there are a few aspects to be considered such as economics, marketing, technology, management, physical performance and architectural design. In the aspect of economics, it requires the selection of the most profitable method, suitable location and size of the prefabrication plant. Hence, the forecasting of the demand is required in order to determine the size of the prefabrication plant.

In addition, marketing includes advertising, sales engineering and advertising contracting for projects. As for the technology, it involves the selection of materials, and production technique. It is vital in the selection of the materials, which will determine the quality of the production. Besides, connecting, jointing and finishing techniques needed also to be considered.

Management is always the most important aspect in the industrialised building systems. Planning and coordination production, transportation, erection and quality control are depending on the good management skill. Another aspect needs to be considered is the physical performance which includes strength, stability, fire resistance, thermal and acoustic requirements, maintainability and insulation.

Moreover, architectural design is also important in the considering of implementing an industrialized system. It involves aesthetics, functionality, versatility and flexibility.

4.7. Sustainable Development and Construction

According to 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 jeopardized.' 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. 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).

The construction industry, together with the material production industries which support it, is one of the major global exploiters of natural resources. The industry thus contributes very significantly to the current unsustainable development path of the global economy (Spence & Mulligan, 1995). In spite of differing perceptions and awareness about the precise meaning of the term sustainable development, it is now generally agreed that development in the poorer nations must proceed in parallel with a general global application of new technologies that are both less resource-intensive and less environmentally damaging. The development of the industry has become an international issue as indicated by the UN Agenda 21 (1992) and CIB Agenda 21 (1999).

Initially, the concept of sustainable development attempted only to address the conflict between protecting the environment and natural resources, and answering the developmental needs of the human race; however, it was soon realized that sustainable development would not be possible without certain social and economic changes, such as a reduction in poverty levels and greater social equity, both between people and between nations. It was also claimed by Pearce (1996) that sustainable development could be seen as 'a process instead of a fixed destination'.

According to Adebayo (2001), the Amsterdam Treaty's (1997) definition of sustainable development may meet favour within the African region because it embraces the concept of integrated development within a contextual realm. This definition sees sustainable development as:

- Determined to promote economic and social progress for their peoples, considering the principle of sustainable development and within the context of the accomplishment of the internal market and of reinforced cohesion and environment protection, and to implement policies ensuring that advances in economic integration are accompanied by parallel progress in other fields.

The most universally quoted definition for sustainable development is that produced in 1987 by the World Commission on Environment and Development (WCED), otherwise known as the Brundtland Commission (after its Chairperson, Gro Harlem Brundtland, Prime Minister of Norway):

Economic and social development that meets the needs of the current generation without undermining the ability of future generations to meet their own needs.

As Banuri (1999) observes there is professional disagreement about this definition, not on how to put the idea of sustainable development into operation, but to do with the question of definition. Sustainable development has been variously defined as:

- A pattern of social and structural economic transformations, which optimizes the economic and societal benefits available in the present without jeopardizing the likely potential of similar benefits in the future (Goodland and Ledec, 1987);
- Fulfillment of human needs through simultaneous socio-economic and technological progress and conservation of the earth's natural systems (Sage, 1998);
- A development strategy that manages all assets, natural resources and human resources, as well as financial and physical assets, for increasing long-term wealth and well-being (Repetto, 1986);
- Improving the quality of human life while living within the carrying capacity of supporting ecosystems (Caring for the Earth, IUCN/UNEP, 1991);

Development that delivers basic environmental, social and economic services to all evidences of a community without threatening the viability of natural, built and social systems upon which the delivery of those systems depends (International Council for Local Environmental Initiatives, ICLEI/IDRC/UNEP 1996).

The declaration from the World Conservation Strategy (IUCN/UNEP/WWF1, 1980), although frequently criticized for being concerned mainly with ecological sustainability rather than sustainable development precast, appears to be the first actual attempt to define sustainable development:

For development to be sustainable, it must take account of social and ecological factors, as well as economic ones; of the living and non-living resource base; and of the long-term as well as the short-term advantages and disadvantages of alternative action.

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. As shown in Figure 1, Sustainable development involves different categories, those applicable to low-income housing is the Social, Economic and Environmental sustainability, as each is discussed below.

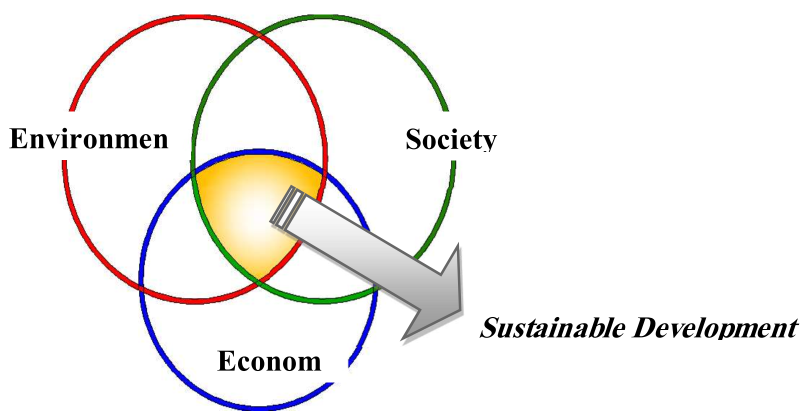


Figure 4.6: Sustainable Development Themes

Source: The Researcher

4.7.1. Environmental Sustainability:

Construction is major supplier to climate change, resource depletion and pollution. 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 re-building. 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 another area. Where conventional construction would need to demolish a building and rebuild it on another site, this is an incredible 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.

This is an unnecessary consumption of energy; it would have worked out cheaper to insulate the houses rather than to cool them. IBS would produce standard insulated wall panels thus saving on cooling costs.

According to Veit Dennert, a German prefabricated housing company, can erect their 104 m2 prefabricated house in just 5 days. This house only consumes 58 kWh/m2/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.

4.7.2. 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. 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, 2001). This is more sustainable as it offers flexibility in neighborhood 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 dis-satisfied 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.

This is providing value to the end-user and the community, and thus practicing sustainability on all three levels.

4.7.3. 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 increases investment on return. The first point is a long-term benefit as increases the GDP by sustainable employment and further wealth distribution. 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 Sudan 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 is as temporary as the employment time. The productivity and quality are 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 returns 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 utilized 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.

4.8. Comparison between IBS and CBS:

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 Sudan.

It must be noted that construction is a heavily interdependent process which makes certain possible theory fallible in reality.

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.

The point is that industrialised building systems can produce the same volume with fewer resources, and if the number of resources used in conventional construction were applied to industrialized buildings, 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).

4.8.1. Costs:

Table 4.2 below is a cost comparison made in Denmark, of selected items. This is based on a three-stories 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 in a factory. This is an advantage as costs are saved by eliminating the need for further touch ups and finishing. This is dependent on the method of industrialised building system and the degree of industrialization, some general advantages in terms of finishes are listed below (Monsted and Percinel, 1982): Power-floated floors are not needed as the floor slabs are precast in a factory with high quality modules.
- 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 planned 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.

	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		59		
Other finishes	254	17	314	18	18.0
Installation & 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	2313	100	7.4
Site & mobilizations costs	173	8	219	9	26.6
Unexpected 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 4.2: Precast vs Traditional

Source: Monsted and Percinel, 1982.

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).

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.

4.8.2. 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 reduce the impact of material price hikes on the cost of the buildings. 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.

4.8.3. 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 utilizes less resources per building and less on-site erection periods which makes plant, labour and equipment more available (Thanoon et al, 2003).

4.8.4. Weather problems:

Industrialised construction is less weather dependent 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. Sweden mostly build with industrialised systems as their winter weather is generally unfavorable for casting and curing of concrete (Glass, 2001).

4.8.5. Modular and Standardisation:

Mass production requires the standardisation of the product, with no exception to industrialised buildings. In order to maximize production efficiency elements of the building product need to be modulated, so machinery and worker’s training can be best absorbed to the characteristics of the product. However, conventionally constructed current low-income houses are completely standardized, 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 colors, tiling etc. As variety, especially for houses, brings a sense of individualism and prides the resident, which is socially beneficial and important for personal morale.

4.8.6. Lean Construction:

Lean production is the philosophy of maximizing production efficiency through eliminating waste and streamlining work flows, it also emphasizes the need to maximize 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. The materials are standardized and supply deliveries are easier to manage, wastage is minimized 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.

4.8.7. 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 are 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.

4.8.8. Re-sell Value:

Industrialised building systems mass produce houses which flood 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.

4.9. Overview of characteristics:

Table 4.3 below 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.

Factors	Answering percentage of respondents (with reference to conventional system)		
	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 4.3: Comparing Industrialised Building System with Conventional System

Source: Badir et al, 2002.

4.10. Classification for Types of IBS Used in Sudan

The Industrialised Building Systems (IBS) is a construction process that utilizes techniques, products, components, or building systems which involve prefabricated components and on-site installation. There are five IBS main groups identified as being used in this country, and these are:

- Precast concrete framing, panel and box systems;

This system includes precast concrete columns, beams, slabs, walls, lightweight precast concrete, as well as permanent concrete formworks.

- Steel formwork systems;

This system includes tunnel forms, tilt-up systems, beams and columns molding forms, and permanent steel formworks.

- Steel framing system;

This system covers steel trusses, columns beams and portal frame systems.

- Prefabricated timber framing systems;

This system prefabricated timber trusses beams and columns.

- Block-work systems

This system includes interlocking concrete masonry units and lightweight concrete blocks.

4.11. Obstructions to the Implementation of IBS in Sudan

IBS is not new in the Sudan construction industry, particularly the usage of steel structures and precast concrete for the construction of bridges, drains and other infrastructure projects. Nevertheless, the usage of IBS in the Sudan building industry is still very low if compared to the conventional methods. The construction industry has been slow in implementation of IBS due to several reasons:

- Wide swings in houses demand, high interest rate and cheap labour cost, make it difficult to justify large capital investment. Contractors prefer to use labour intensive conventional building system because it is far easier to lay off workers during slack period.

- Fully prefabricated construction system requires high construction accuracy. Sudanese labour forces still lack of skilled workers. Many of foreign skilled workers had left the country after the widespread crackdown on illegal foreign workers in recent years. The new batches of foreign workers do not possess the required skill and have to be retrained.
- The construction industry is so fragmented, diverse and involves many parties. Consensus is required in the use of IBS during planning stage. However, the owners, contractors and engineers still lack scientific information about the economic benefits of IBS.
- Lack of research and development in the area of novel building system that uses local materials. Majorities of IBS in Sudan are imported from developed countries, thus driving up the construction cost. Engineering degrees in local universities rarely teach about the design and construction of IBS.
- The economic benefits of IBS are not well documented in Sudan. Past experiences indicated IBS is more expensive due to fierce competition from conventional building system.
- The use of IBS in developed countries is so successful due to high quality and high productivity. But, in Sudan, the scenario is different, most projects constructed with IBS were low quality and high construction cost.
- Lack of incentive and promotion from government in the use of IBS. Many architects and engineers are still unaware of the basic element of IBS such as modular coordination.

4.12. Summary

This section takes into consideration the means available to reduce the economic impacts, through improved technology, design or changed practices and it will suggest ways to promote these changes.

This section defines sustainable development and sustainable construction focusing on the implications this approach has for the construction industry.

It is necessary to identify the key issues and challenges for the implementation of sustainable development and construction in the developing world, as well as the major barriers to practicing sustainable construction. This is necessary to create the clear understanding that is required for the formulation of national strategies and policies.

Chapter Five

Method Applied

5.1 Introduction

For many years, primarily researchers have applied case study research across varied disciplines to understand complex issues or objects. The case study research method is defined as an empirical inquiry that investigates a contemporary phenomenon within its real-life context, when the boundaries between phenomenon and context are not evident, and in which multiple sources of evidence are used.

Although interviews are the most common source of data in case study research, other sources such as questionnaires, documentation, archival records, direct observations, participant observation may also be utilized. Many emphasized that a case study should be regarded as a design, a methodology, a particular data collection procedure, and as a research strategy. Concrete, context-dependent (practical) knowledge with clear methods is, therefore, more valuable. Other researchers in general commonly used research methods emanating from the literature reviews in particular and approaches. Methodology used in this research vary from qualitative to quantitative. Mixing these methodologies used to construct analytical framework and converting the data in to proportional norms that help in estimating scores for respective factors of building systems in Sudan. Developing the analysis framework involves researching and choosing an appropriate analysis tools and developing other tools to suit the needs of this research. Since this study is exploratory in nature and therefore, this chapter will contribute to understanding the consequences of the sources of the criteria identification, methods used and clarify, the purpose and objectives of questionnaires, the questionnaire Structure and the nature and contents of questionnaires and interviews which explain the questionnaire Structure, questionnaire design and Selection the Interview Sample.

This chapter reviews methodology that has been applied in this research, highlighting research (procedures, method development, mechanism and analysis) and survey and sampling methods, which provide justification for the use of suitable methods. Multi Criteria Comparative Feasibility Matrix (MCCFM) is considered as one of the best methods developed and used in this research to investigate the ability of utilizing industrialized building systems for housing the poor in Sudan.

5.2 The sources of the criteria identification:

The criteria 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 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 the role players do currently not consider part of this criteria as it is, 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.

The study purposes to critically compare the two systems the factors thus selected are not just general housing requirements but requirements that relate to the current housing problems in Sudan, 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 given in **Table 5.1** below. This table shows the corresponding references to each of the factors. The identification and substantiation discussed in criteria identification below:

The **Government** requirements 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 is comprised of smaller requirements and reflected as factors in this study, each explained below:

- 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 period. The provision of adequate housing is not only the delivery rate but also the quality of the houses produced. It is useless 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 reflected in various factors for housing quality, durability and service provision.
- Job Creation and Socio-Economic progression: This aim is broad and shared with a few tasks, housing being one of them. Housing is a great monetary 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. 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.
- Financial Implications of housing: 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 that make it feasible for private contractors to enter into the government subsidised housing market. Their main objective is profitability that can be influenced by smaller requirements. These factors 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 recognized by the government and have been our 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 Sudan. 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.

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

Table 5.1 Criteria Identification

5.3 Questionnaires:

A questionnaire is a tool for collecting information to describe, compare or explain knowledge, attitudes or behaviors and/or socio-demographic characteristics of a target group. The main advantage of using questionnaires over other methods of data collection is that a large number of people can be reached relatively easily and economically. Questionnaires are cheap in comparison to other methods of collecting primary data. Yet, they are expensive in terms of design time and interpretation. Furthermore, questionnaires are not always the best way to gather information, especially if there is previous information on a problem. In this case, a questionnaire may only provide limited additional insight. Another setback of questionnaires is the varying responses to questions where respondents may misunderstand or misinterpret questions.

Questionnaires can be used to obtain either quantitative or qualitative data depending on the type of questions. Qualitative data describe a specific aspect in terms of some quality or categorization. On the contrary, quantitative data use numeric values in terms of quantity to precisely provide information about something. They are concerned with describing meaning, rather than with drawing statistical inferences. However, qualitative data have the potential of revealing complex situations, attitudes and perception. Qualitative data are exploratory and provide a more in-depth and rich description. Thus, quantitative data define whereas qualitative data describe. By their very nature, quantitative questions are more exact than qualitative ones. Possibly, data originally obtained as qualitative information about an individual phenomenon may be transformed into quantitative data if they are interpreted by means of counts.

5.3.1 Purpose and Objectives of Questionnaires:

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. The questionnaire is regardless of the three role players, as their function does not involve the performance of conventional and industrialised.

The results of the questionnaires and the interviews combined in the analysis framework, so that an overall analysis regarding the importance and the performance of the criteria could be achieved.

The questionnaires are used to rate the performance of each factor of the criteria for both conventional and industrialised building systems. The questionnaires sent to contractors who are involved or have a background in both industrialised and conventional building systems.

5.3.2 Reasoning for Questionnaires:

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

- Questionnaires required less time and allowed a larger sample size.
- The questionnaire will be relatively simple and easy to perform.
- It is certain that the sample was fully literate.

5.3.3 Design of Questionnaire

It is important to ensure that the questionnaire will gather the information required. A well-designed questionnaire motivates the respondents to provide complete and accurate information. Questionnaires often have standardized answers that make it simple to collect data. Generally, questionnaires are quite flexible in what they can measure, however this depends on the data to be collected and processed. Thus, the design, administration and interpretation of a questionnaire require careful attention. Questionnaires should therefore have very precise designs in order to meet the purpose for which they designed. Baker (2003) noted that in order to avoid squandering all the investment (time, effort and money) on a questionnaire, a researcher should design clear, relevant, meaningful and unambiguous questions for eliciting the desired information from selected respondents. Getting a valid and high rate of response from participants in a survey is a function of their ability and willingness to answer the questions asked. Thus, a questionnaire's contents and phrases must be carefully crafted to avoid ambiguity, imprecision and assumptions.

Marton-Williams (1986) suggests five functions to follow in order to get an efficient questionnaire as a tool for collecting data. These functions are:

A. maintain the respondent's co-operation and involvement;
B. communicating to the respondent;
C. helping the respondent to work out his answers;
D. making the interviewer's task easy; and
E. providing a basis for data processing.

A considerable attention should be drawn to the respondents. The structure of the questionnaire and the logical flow of its questions are key factors in getting the attention and interest of the respondents. Baker (2003) noted that effective communication depends very much on the design and phrasing of the questionnaire. The main obstacles to clear communication are ambiguity, use of unfamiliar words, use of difficult and abstract concepts, overloading the respondent's memory and understanding with too many instructions, using vague concepts and trying to ask two questions at once (Marton-Williams, 1986). The questionnaire designer needs to ensure that the respondents fully understand the questions and are not likely to refuse to answer, lie to the interviewer or try to conceal their attitudes. A good questionnaire is organized and worded to encourage respondents to provide accurate, unbiased and complete information (Crawford, 1997). Baker (2003) recommends that the questionnaire should be easy to read, understand, well organized and without bias.

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 weighted according to its importance and each proposal (conventional or industrialised) then rated according to its performance for each factor. The weighting then multiplied by the rank, which shows the score of each factor, these then added together and the proposal with the highest score is the better proposal. Table 4.1 above shows all 31 factors which need to be ranked according to their performance on a scale from 10 to 100 (10 being least & 100 being most).

For example:

Primary Factor	No	Secondary Factor		Industrialised	Conventional
				10 to 100	
Housing Provision	1	Delivery Rate		75	25

Conventional and industrialised can receive the same rating for a particular factor. The use of extreme rating thus 10 or 100 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 given below; this also defines what direction the rating scale should tend towards.

5.3.4 Questionnaire Structure

A questionnaire provides a tool for information, which can be tabulated and discussed. Accordingly, the questionnaire should be pleasing to the eye and easy to complete (Taylor Powell, 1998). Thus, structuring a questionnaire seen as an art rather than science. Formal standardized questionnaires generally characterized by:

(a) prescribed wording and order of questions, to ensure that each respondent receives the same stimuli;

(b) prescribed definitions or explanations for each question, to ensure interviewers handle questions consistently and can answer respondents' requests for clarification if they occur; and

(c) prescribed response format, to enable rapid completion of the questionnaire during the interviewing process.

Hence, it is important to draw attention to opening questions, the flow and variety of questions and closing questions (Crawford, 1997). How questions will be placed in relation to each other in a questionnaire is an important aspect to consider (Taylor-Powell, 1998). For the purpose of effective communication with the respondents, questions should be put into a meaningful order and format. Taylor-Powell (1998) suggests the following guiding principles for formatting a questionnaire:

- preparing an introductory section that states the purpose of the questionnaire and assures respondents confidentiality;
- Opening questions should be easy without using open-ended questions with lengthy answers.
- addressing important topics early rather than late in the questionnaire;
- arranging the questions to ensure smooth flow and keeping questions on one subject grouped together;
- using the same type of questions and response throughout a series of question on a particular topic;
- printing in an easy-to-read typeface;
- avoid making respondents turn pages in the middle of a question;
- distinguishing the questions from instructions and the answers; and
- pre-coding of answers as many items and response categories are possible to help tabulate and analyze data more quickly

The subject questionnaire structured in accordance to the aforementioned guidelines. A covering letter attached to the questionnaire revealing the purposes behind the survey and highlighting the importance of the topics investigated. The entire questionnaire involves 31 questions, which are structured into three main sections (A, B, C and D), each section contains three subsections, each of which contains a number of specialized questions. The entire questionnaire printed in six pages excluding the covering letter.

Section (A) is designed to provide general information about the respondents including name, entity, job title, sector, scope of work, academic qualification, experience, gender and nationality. This section provides a description for the abbreviations used throughout the questionnaire. Sections B and C are broken down into seven and four subsections respectively.

Section (B) the **Government** requirements 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 are comprised of smaller requirements and reflected as factors in this study, each explained below:

- 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 period. The provision of adequate housing is not only the delivery rate but also the quality of the houses produced. It is useless 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 reflected in various factors for housing quality, durability and service provision.
- Job Creation and Socio-Economic progression: This aim is broad and shared with a few tasks, housing being one of them. Housing is a great monetary 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. 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.
- Financial Implications of housing: Decreasing the cost of the construction of houses means that the government can afford to build more houses every year.

Section (C) the **Contractor’s** requirements are those which make it feasible for private contractors to enter into the government subsidised housing market. Their main objective is profitability that can be influenced by smaller requirements. These factors 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, explained below as these factors also relate to the government and end-user alike.

Section (D) 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 recognized by the government and have been our 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.

5.3.5 Pretesting the Questionnaire

The major problem in questionnaire design is making it clear and understandable to all. Because the draft questionnaire is a product evolved by one or two minds only, it is impossible to say whether a questionnaire is going to accomplish the study objectives without testing. Therefore, it is necessary to pre-test the questionnaire before it is used in a full-scale survey, to identify any mistakes that need correction. The purpose of piloting the questionnaire is to determine the adequacy of structure, clarity and sequence of questions and instructions as well as to determine whether additional or specifying questions needed or whether some questions should be eliminated (Crawford, 1997). Pre-testing has a number of goals, including: to reformulate or eliminate ambiguous or superfluous questions; to provide material to design the answer categories for open questions that need to be closed; to determine whether the questionnaire is balanced in its structure, and to discover whether instructions were properly followed (Siniscalco & Auriat, 2005). Although somewhat time-consuming, this crucial phase is worth the investment and will result in a higher rate of returned surveys and more reliable data (Derrington, 2009). According to Taylor-Powell (1998), pretesting is an indispensable part of questionnaire design, which may result in postponing the study if the resources to pretest the questionnaire are not readily available.

A draft of the questionnaire was prepared after a series of reviews and editing. Then, the questionnaire was handed to **five** persons who were broadly representative of the type of respondents targeted by the main survey. **Three** questionnaires were handed personally whereas **two** were sent by e-mail. The comments and suggestions made by those respondents incorporated into the final version of the questionnaire. Some questions were deleted and some were rephrased. The respondents asked to record the time they needed to fill out the questionnaire. The average time required to fill-out a hard copy was about 20 minutes while filling out a softcopy (on computer) took about 30 minutes. Many respondents commented on the length of the questionnaire noting, however, the relevance of the questions, the easy-flow of the questionnaire and the importance of the topic.

5.4 Interviews:

Interviews 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 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.

5.4.1 Purpose and Objectives of the Interviews:

This framework requires 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. 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 inserted in the appendix.

5.4.2 Reasoning for Interviews:

Interview as the type of survey would be selected because of the following reasons:

- All the necessary sample population 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 would interesting and could be beneficial if this research would be implemented.

5.4.3 Selecting the Interview Sample:

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

5.5 The results of the questionnaires:

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 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 compared and reasoned. The values collected from the interviews and questionnaires applied to the developed analysis tool that 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.

5.6 Development of the MCCFM Analysis Frameworks

Social housing in Sudan 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. There are four different decision-making tools investigated, these are as follows:

- 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 added up and the option with the highest value selected. This tool, however, lacks some of the criteria listed above. Although it directly compares options, it does not involve analyzing 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).

- 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 analyzing the risks and the options involved with a particular course of action. This tool is not appropriate for this study as it lacks analyzing various factors between two options and is difficult to analyze subjective factors. (Mind Tools, 2008).
- 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 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 qualitative factors and compare it to a cost in this analysis; however, it makes it difficult to form an accurate analysis. Furthermore, applying a period to adopting industrialised or conventional is difficult unless a case study 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 Sudan has not yet seen much 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 that is difficult to obtain.
- 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 deemed the most appropriate option. The systematic and fragmented evaluation makes it possible to analyze the various options in details. 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.

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

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 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 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 each perspective group, of which each criterion 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 ability 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 summarizes the results of the other three tables.

The MCCFM works by valuing each factor on a hierarchy basis this 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 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 then multiplied by the weighted factors to derive a score for each factor. These scores then all added up and the score with the highest value 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.

5.6.1 Mechanism of the MCCFM Analysis Tool

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

Step no.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. The **Table 5.2** shows the ‘primary factor’ comprises of related secondary factors, the purpose of the primary factor is to categories 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’.

	MCCFM.	Weighing	CBS		IBS	
			Secondary Factor	Score	Secondary Factor	Score
Primary Factor 1	Secondary Factor 1	W1	R(c)1	S(c)1	R(i)1	S(i)1
	Secondary Factor 2	W2	R(c)2	S(c)2	R(i)2	S(i)2
	Secondary Factor 3	W3	R(c)3	S(c)3	R(i)3	S(i)3
	Secondary Factor 4	W4	R(c)4	S(c)4	R(i)4	S(i)4
	Secondary Factor n	Wn	R(c)n	S(c)n	R(i)n	S(i)n
Total				∑S(c)		∑S(i)

Table 5.2 - MCCFM Example

Where: W1: is the weight of rank for variable R: the range S: score

c: conventional i: industrial

Step no.2: Once all the factors have been established within their primary factor categories, the weighting of these factors begins. First, the Primary Factors 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 then no longer needed. The values 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 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, the 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 second Weighting. These values reflected in the MCCFM table above in the weighting row as W1-4 for each factor. A worked example shown in **Figure 5.1** below.

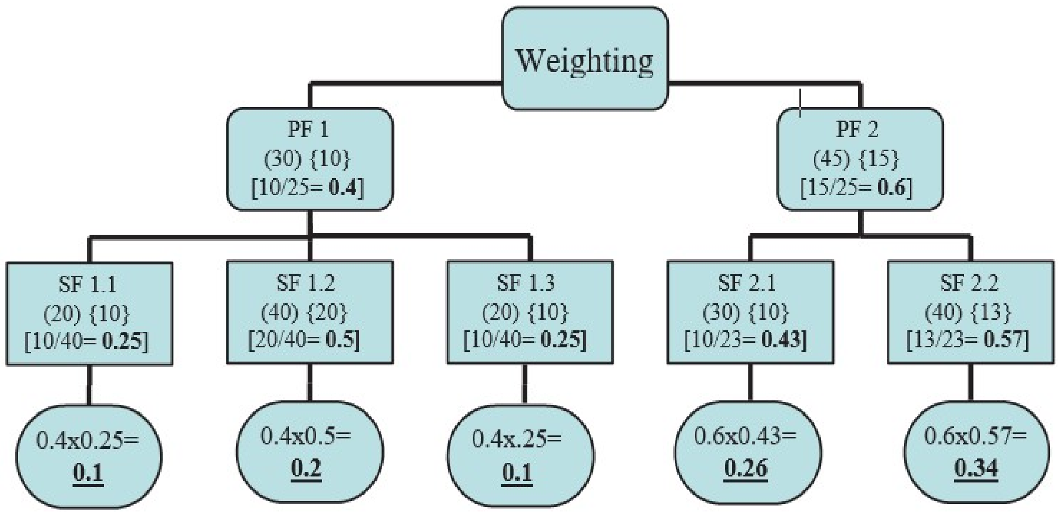


Figure 5.1: MCCFM Weighting

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 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 no. 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 Sudan 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 no.4: Once the performance of each building type has been provided then the values are scored. The weighted values of each factor from step **two** 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) ∑ and industrialised = S (i) ∑. The values of these two scores compared and the higher one is the more feasible option.

Step no.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 then placed in a fourth and final Summary Table that 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.

5.6.2 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 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 explained as follows:

The results of the questionnaire are 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.

The results of the interviews are analysed as it provides the study with data that reflects the importance of each factor of the criteria analysed. This data illustrated in a table and in bar graphs that 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.

The final scores for each factor of the MCCFM analysis combines the data of performance and the data of importance. This step analyses 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 Sudan. The data of the final scores of the MCCFM shown in bar graphs for each factor. At a stage each perspective group must still be analysed separately as their criteria is related to their perspective. This is why three separate bar graphs, one for each group, would be analysed separately.

The fourth table of the MCCFM is the Final Matrix; these 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 analyze 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.

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

5.7 Summary

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 questionnaire was directed at contractors who are involved in both IBS and CBS and who have an understanding for government-subsidised housing.

The MCCFM is a tailored analysis framework tool that suits the requirements of this study. It is able to analyze each perspective group separately yet is also able to draw a direct comparison between each perspective group so that a 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 analyzing 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 Six
Analytical Framework and Process

6.1. 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.

6.2. Response Rate

The main aim of collecting data is to maximize the amount and accuracy of transfer of meaning (convergence) from the data provider to the researcher (Fellows & Liu, 2008). In general, survey techniques, such as questionnaires and interviews, yield low response rate mainly because they are highly labor intensive on the part of the respondents and particularly on the part of the researcher. Thus, the useable response rate can be as low as 25-35% (Fellows & Liu, 2008).

The circulation of questionnaires of the subject study and collecting them back took a period of about 3 months (February-April 2018). The respondents represent 80 entities from which 53 entities (66.25%) have responded to the questionnaire. These entities include consultancy and contracting companies, building materials manufacture and supply companies, universities, research institutes, professional institutions, governmental authorities, finance institutions, industrial companies, … etc.

The questionnaires were distributed to the targeted entities mainly through personal contact (58.2%) and e-mails (21.4%). About 20.4% of the questionnaires to these entities were delivered or returned both personally and by e-mail.

The response rate was very high, thus quite acceptable. The high rate of response is attributed to the variety of methods used for circulating and collecting the questionnaire. Furthermore, most of the respondents had been given a notice two weeks before circulating the questionnaire. Besides, the respondents were offered the flexibility in deciding the means of returning the questionnaires. Indeed, such flexibility contributed significantly to acquiring such a high response rate. About 33% of the respondents (26 respondents) have provided further comments and recommendations related to the problems investigated.

6.3. The Profile of Respondents

The questionnaire covered a wide spectrum of respondents of different academic and professional backgrounds related to the Sudanese construction Industries and Sudanese building material Industries. The majority of the respondents work for the private sector and work for the public sector and public-private owned companies respectively.

The information provided by the respondents reveals that 132 (73.5%) of the respondents work in a single field with the majority of them work as consultants, contractors, academic and research and building materials manufacturer and/or suppliers. About 48 (27.5%) of the entire population responded to the questionnaire work in two or more fields simultaneously. Consultants who also work in the academic and research field followed by contractors who also work as materials manufacturers and/or suppliers dominate participating in two fields or more. This implies that consultants are oriented towards the knowledge base field while contractors are attracted to the business sector.

The majority of respondents hold university degrees (40 participant (50%) B.Sc., 28 participant (35%) M.Sc. and 12 participant (15%) PhD). Consultancy services attract more professionals acquiring PhD and M.Sc. degrees than contracting services. Once again, the relationship between the consultancy services and academia observed. The survey indicates that most of the participants (75%) obtain experience above 10 years where 25% of respondents acquire experience for more than 20 years.

6.4. Methods of Analysis

The MCCFM analysis data collected from questionnaires and interviews. From the **Table 6.1** the survey questionnaire sent to 250 participants of which 180 participants have responded this is a 72% response rate. Out of 25 Interviews had been planned where 15 had been conducted.

	Planned	response	% diff	Within1st month	Within 2nd month	Within3rd month
questionnaire	250	180	72%	45	95	40
interviews	25	15	60%	3	6	6

Table 6.1 Response Rate

From the **table 6.1** above the first month, sending the questionnaires and only 45 participants had responded, in the second month, only 95 participants had responded and in the third month, 40 more had responded. Four participants replied via email while 15 participants replied in questionnaire form. Fifteen of the interviews intended were actually conducted which is a 60% margin. Two potential interviewees failed to arrange an interview date within the time needed and contact was lost the one. Three of the ten interviews were conducted within the first month of arrangement and six out of the twenty-five conducted within the second and third month of arrangement.

6.5. Interviews Analysis

6.5.1. Analysis of Government Interviews

The graph **Figure 6.1** blow shows the weighting of the importance of each factor of the government's criteria based on the data in **Table 6.2**.

Note: 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.

Sec	Primary Facto	No.	Secondary Factor	Data
GOVERNMENT	Housing Provision	1	Delivery Rate	0.123
		2	Adequacy & Housing Quality	0.127
		3	Durability & Structural Quality	0.141
	Affordability &Job Creation	4	Cost per House	0.117
		5	Initial Capital	0.097
		6	Job Creation	0.127
	Sustainable Development	7	Socio-economic Growth	0.112
		8	Building Reuse & Adaptability	0.075
		9	Green & Resource Efficiency	0.080

Table 6.2 Interview Government

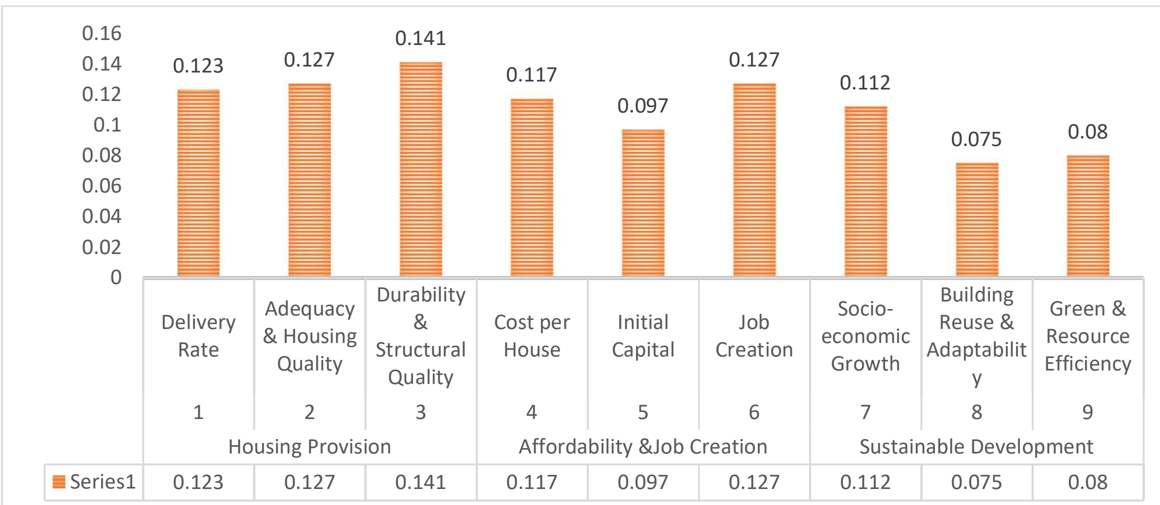


Figure 6.1 Interview Government

- **Delivery Rate:** The delivery rate of the houses is an important factor. The current delivery rate is very high the government must control.
- **Adequate Housing & Quality:** This factor is rated as the second most important for government housing. Therefore, the houses that delivered must be of adequate standard otherwise the houses would be as good as a shack.
- **Durability & Structural Quality:** This factor is the most important factor for government. This is because the buildings must be useable for the next generation. There would be little point in building houses that when the housing demand has finally been supplied then the government will have to start replacing their previous houses.

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

6.5.2. Analysis of Contractor Interviews

The graph Figure 6.2 shows the weighting of the importance of each factor of the contractor's criteria.

Note: 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**: It is the most important factor for the contractor, as has the highest weighting. The cost of construction or the production of the houses affects the profitability of the contractor. The lower the costs the higher the profit. 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.

Sec	Primary Factor	No.	Secondary Factor	Data
CONTRACTOR	Production	10	Production Cost	0.115
		11	Initial Capital Outlay	0.099
		12	Production Rate	0.070
		13	Product Quality	0.103
	Management	14	Manageability	0.071
		15	Production Control	0.075
		16	Quality Control	0.085
		17	Skills Dependency	0.051
		18	Labour Intensity	0.066
	Physical Implications & Sustainability	19	Design Flexibility	0.059
		20	Construction Complexity	0.050
		21	Carbon Footprint	0.097
		22	Resource Efficiency	0.060

Table 6.3 Interviews Contractor

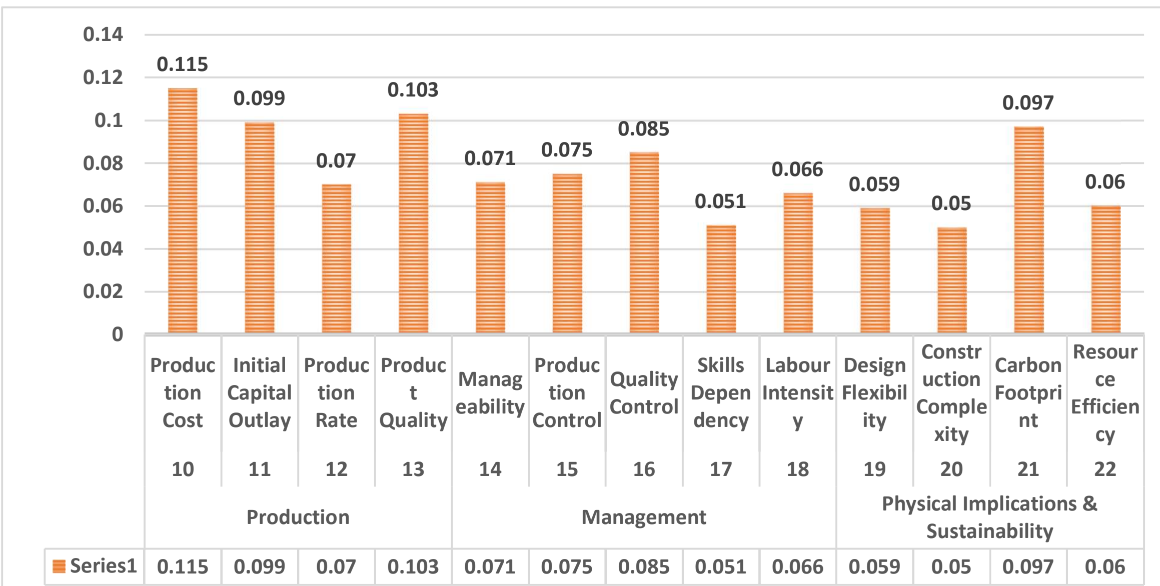


Figure 6.2 Interview Contractor

- **Initial Capital Outlay:** This factor is rated as the third most important factor for the contractor. To establish any type of business a certain amount of capital needed to purchase assets that will run the business. Industrialised 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 is 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.

- **Product Quality:** This factor rated as the second most important factor for the contractor. 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.
- **Production Control**: The contractor must ensure that it can deliver the number of houses within the time required, and that the production or construction of the houses is at a rate that will ensure timeous completion. Otherwise, the contractor is liable to face penalties for late completion.
- **Quality Control:** The contractor must ensure that the houses are of reasonable standard. The earlier the defect found the easier and cheaper it is to remedy. This requires continuous quality assessment to ensure defects found and remedied early. To remedy a defect after completion is costlier 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.

- **Carbon Footprint:** As per the graph above, this factor weighted as the fourth most important. This is a corporate incentive requirement. The general carbon emissions and usage of the contractor's company measured as a carbon footprint rating. Since these low-income housing projects are government funded this factor might become a stronger requirement in the future.

6.5.3. Analysis of End-User Interviews

The graph **Figure 6.3** shows weighting of the importance of each factor of the end user's criteria.

Note: 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**: This is the third most important factor for the end user. The end-user registers for a house after which he must wait for period before the house built and delivered. This waiting period can be years.

Sec	Primary Factor	No.	Secondary Factor	Data
END-USER	Time & Future Value	23	Delivery & Waiting Period	0.131
		24	Adaptability & Alteration	0.132
		25	House Value	0.085
	Cost	26	Affordability	0.126
		27	Maintainability	0.095
		28	Life Cycle Period	0.091
	Quality	29	Diverse Design & Aesthetic	0.097
		30	General Quality of House	0.105
		31	Adequate Service Provision	0.137

Table 6.4 Interviews End-User

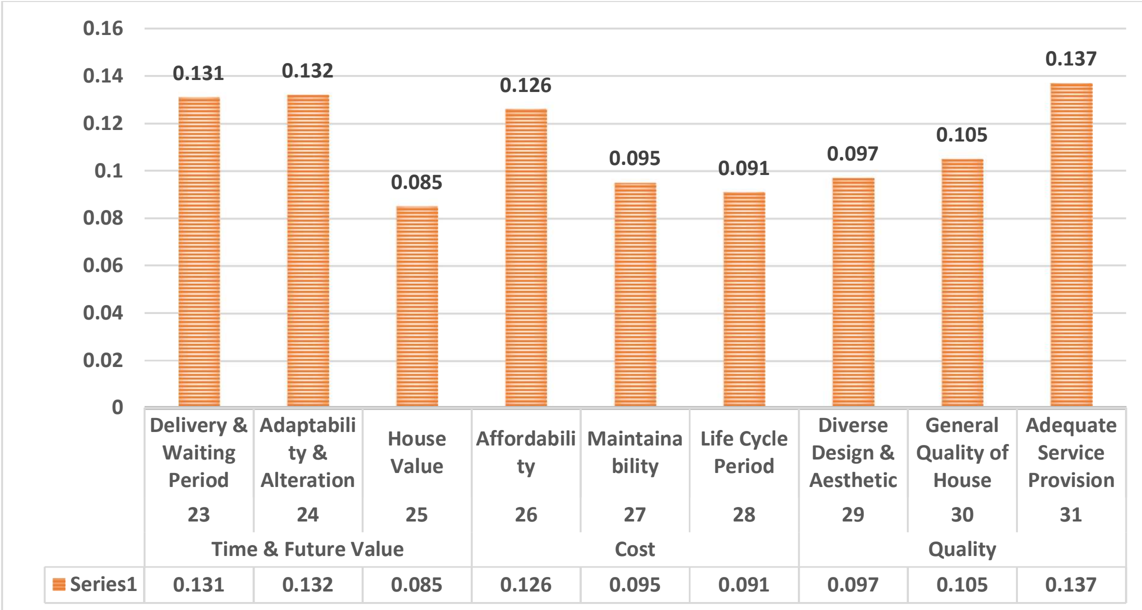


Figure 6.3 Interview End-User

- **Adaptability & Alteration**: This is the second most important factor for the end user. 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.
- **Affordability:** This is the fourth most important factor. Since the houses are built for the poor who regard cost as an important factor. 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.
- **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, good

structural, finishes, thermal qualities, durability standard, and its services (lights and water).

- **Adequate Service Provision:** This factor 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 deemed adequate and formal, it must include the provision of such services water. The aim of the government is to replace all informal housing with formal houses; therefore, each house must include adequate services.

6.6. Questionnaires Analysis

6.6.1. Analysis of Government Questionnaires

The results of the questionnaire are shown in table 5.5 below. The graph Figure 5.4 below shows the rating of the factors from the questionnaire. These factors were taken from the government criteria. Each factor is analyzed as follows:

Sec	Primary Factor	No.	Secondary Factor	CBS	IBS
GOVERNMENT	Housing Provision	1	Delivery Rate	44	72
		2	Adequacy & Housing Quality	54	73
		3	Durability & Structural Quality	51	75
	Affordability &Job Creation	4	Cost per House	62	68
		5	Initial Capital	56	51
		6	Job Creation	68	46
	Sustainable Development	7	Socio-economic Growth	55	29
		8	Building Reuse & Adaptability	44	56
		9	Green & Resource Efficiency	45	71

Table 6.5 Government Questionnaire

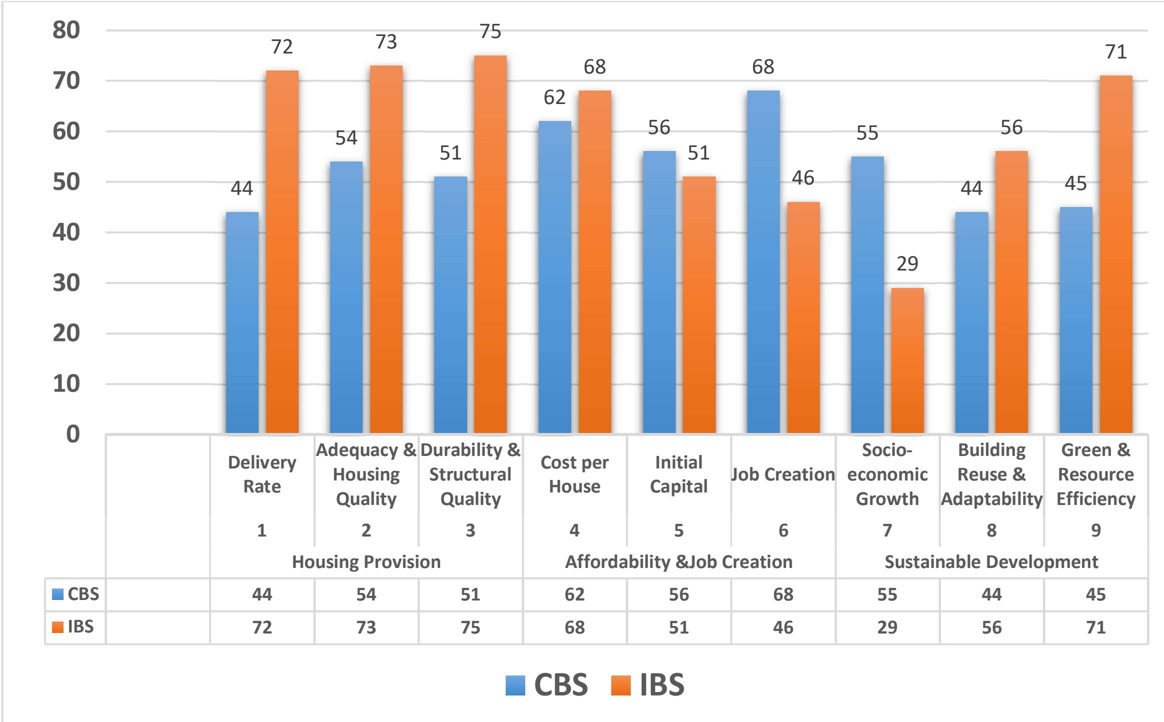


Figure 6.4 Questionnaire Government

- **Delivery Rate:** It expected that delivery rate would be the highest scored out of other factors; surprisingly adequacy and housing quality has received slightly higher score. Conventional construction is only as fast as the bricks and mortar allow. IBS makes use of assembly line production process where rapid production is one of the main advantages.
- **Adequacy & Housing Quality:** This factor is the second highest scored factor and it not expected to be this factor. Both systems could offer similar standard of finishes, services and layout designs, the difference is that industrialized can offer better quality control of meeting standards where conventional has less on-site control of such standards. Besides, industrialized can fix its conduits and plumbing lines into the walls before the assembly or construction of the house which secures the standard immediately.
- **Durability & Structural Quality:** This factor is the highest scored factor. The previous Adequacy and Housing Quality deals with

finishes, services and layout, but, the Durability and Structural Quality deals with the structural standard and the durability, relate to the graph industrialized has achieved a higher performance than conventional. This is due to the quality control measures and production process of industrialized building systems. Conventional is more dependent on the skill of the labors, the materials used and the quality control measures.

- **Cost per House:** The government subsidizes the cost of the houses and in most municipalities, the full cost is subsidized. Therefore, the cheaper the cost of the house the further the subsidy can cover the more can be built. Conventional may be cheaper depending on the wage rate and material prices. Industrialised has scored higher but only at a smaller margin and it can offer cost savings through resource efficiency and mass production.
- **Initial Capital:** This is factor is rated inversely to the amount of capital needed as initial capital is a barrier of entry in the housing market. 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. However, Conventional 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, because industrialised utilizes mechanized production therefore less labour.
- **Socio-Economic Growth:** This is an important factor for social housing. The performance is relatively low for both building systems, 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 that would add benefit that is more social.

- **Building Reuse & Adaptability**: The ability for a house to change and adapt to a different use. Industrialized 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 re-built in another place, similar to a tent. Conventional building system is more able and flexible towards extensions due to the bricks and mortar type of building.
- **Green & Resource Efficiency**: The environmental impact of housing must be considered by the government, even though it is for a direct 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 low. Conventional is dominantly on site and has bigger impact on the environment of the site. Additionally, the greater consumption of cement and the wastage therefore, also has a considerable impact on the environment.

6.6.2. Analysis of Contractors Questionnaires

The **table 6.6** and graph **Figure 6.5** below show the rating of the factors from the questionnaire. These factors are taken from the contractor's criteria. Each factor is analyzed as follows:

Sec	Primary Factor	No.	Secondary Factor	CBS	IBS
CONTRACTOR	Production	10	Production Cost	62	74
		11	Initial Capital Outlay	62	40
		12	Production Rate	48	78
		13	Product Quality	58	78
	Management	14	Manageability	44	66
		15	Production Control	40	75
		16	Quality Control	40	74
		17	Skills Dependency	68	56
		18	Labour Intensity	72	64
	Physical Implications & Sustainability	19	Design Flexibility	85	64
		20	Construction Complexity	54	52
		21	Carbon Footprint	64	68
		22	Resource Efficiency	46	72

Table 6.6 Questionnaires Contractor.

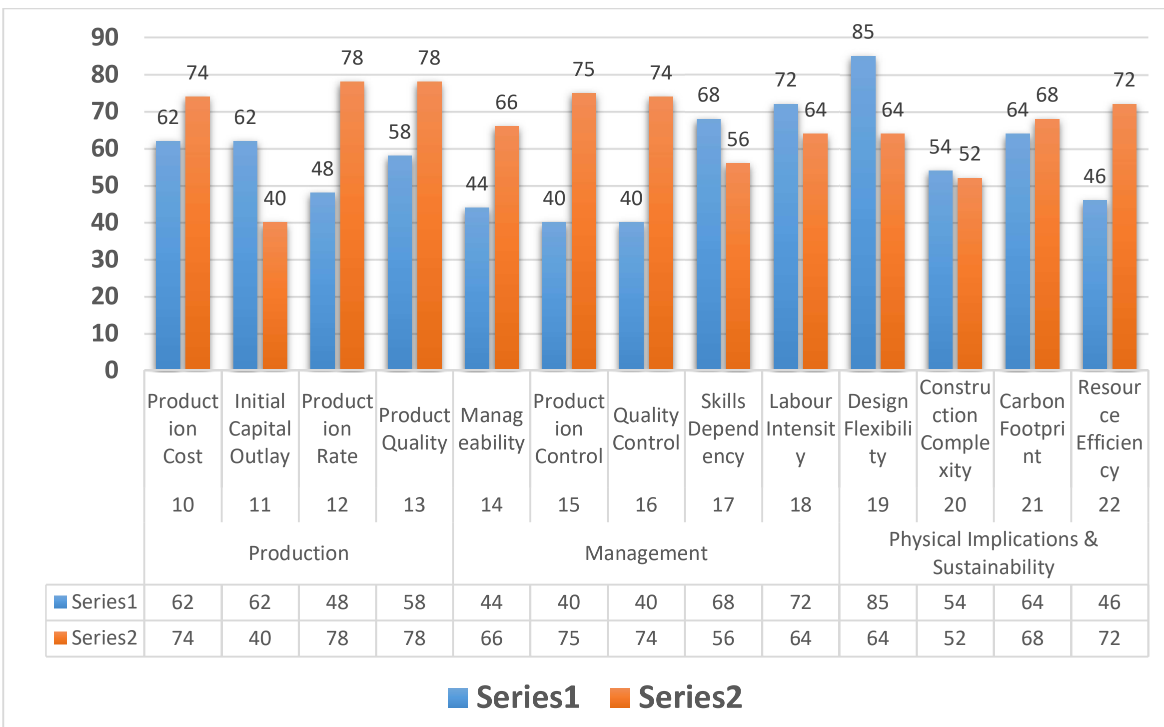


Figure 6.5 Questionnaire Contractor

- **Production Cost**: Cost is an important factor for low-cost housing, which is why both systems perform relatively well for production cost. Industrialised can offer savings through their efficient production process and on labour.

- **Initial Capital Outlay**: The graph shows that conventional needs much less capital than industrialised. The performance rated inversely to the amount of capital required. Conventional rated fairly highly for this factor, which shows that its ability to establish such a business on little capital is possible. Establishing an industrialised building process requires a considerable amount of capital to fund the equipment, machinery and factory needed for production and construction.
- **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 labourers and is able to systematically control the production of its product. Conventional is more dependent on the skill of their labourers which in Sudan 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 its lower level of manageability.

- **Production Control**: This factor has the largest difference in performance between the two building systems that shows how much the production control process differs between the two systems. It 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.
- **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 is more difficult to implement quality checks due to its onsite construction process.
- **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 are 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 subsidized housing requires the employment of a certain number of laborers from the community. Therefore, the labour intensity is also an advantage in this regard. Conventional rated at higher performance than that of industrialised. The performance of both systems is high as construction does employ a large number of laborers.
- **Design Flexibility:** This factor rated the highest of all the others, which is not expected. Conventional rated substantially higher than industrialised because conventional is abler to adjust the building plans after construction has started, providing 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, it is 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 rated.
- **Carbon Footprint:** This factor is a 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 re-building 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 are more resource efficient, as the substantial rating shows on the graph.

6.6.3. Analysis of End-User Questionnaires

The **table 6.**7 and graph **Figure 6.6** below show the rating of the factors from the questionnaire. These factors taken from the contractor's 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 rating of this factor is relatively average. The margin between the two systems is negligible. The reason why this factor rated so close to each other is that both systems would have a similar performance in adaptability and alteration.
- **House Value**: 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 low which is because it is negative stigma and its standardization.

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

Table 6.7 Questionnaires End-User

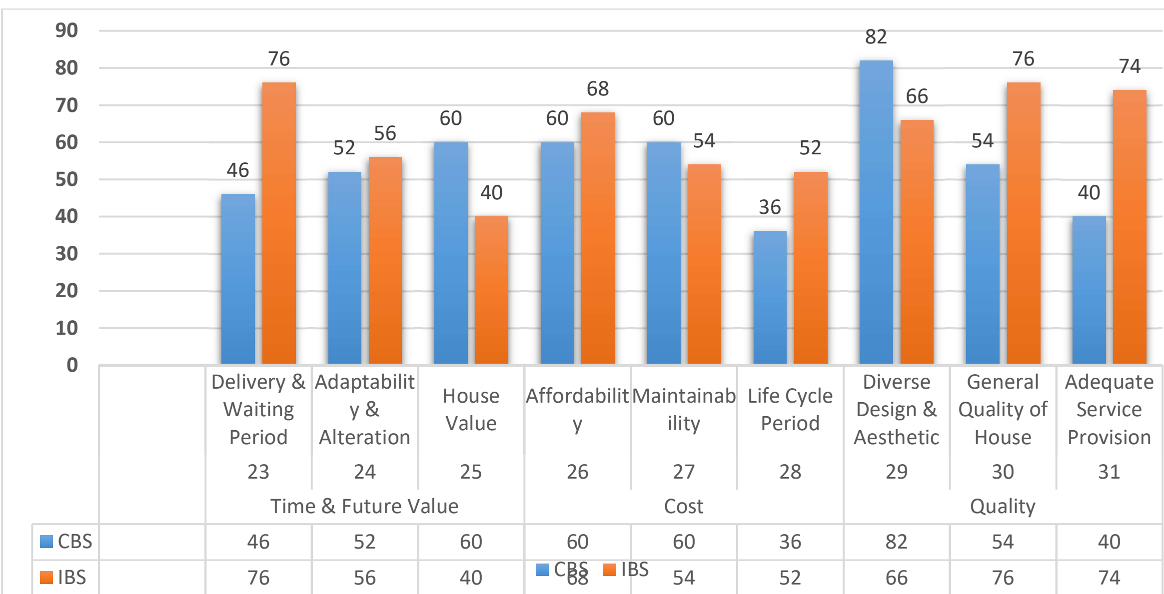


Figure 6.6 Questionnaire End-User

- **Affordability**: The reason why this factor is rated fairly high is that low-income housing must be affordable. Industrialised is rated slightly higher than conventional, this is because of the cost of production and the cost of alterations and extensions.
- **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 than 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 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 factor is rated as one lowest in performance for both factors because in 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. 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.
- **Diverse Design & Aesthetic**: It is not sure why this factor has been rated so highly, it does not 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, largely, dependent 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.

6.7. MCCFM Analysis

6.7.1. Analysis of Government MCCFM

The **Figure 6.7** below shows the scoring difference between conventional and industrialised for the government sector based on the **table 6.8**. The following points are noted:

- **Delivery Rate**: This factor shows the difference between Industrialised and conventional. Industrialised houses have got a second higher score as the construction of industrialised built houses 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.
- **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, expect only adequacy and not luxury. However, this standard of services and finishes must still serve its functional use well enough to last a generation. The other issue is the time taken for the services 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 optimizes 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, and water and layout design. This factor has a considerable difference in favour of industrialised. The reason for this is that currently in Sudan conventional building system 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 standardized materials and 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 subsidizes the construction of the houses the cheaper the house the more houses, they are able to build and subsidies. 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 Sudan the terms differ. This is because Sudan has cheap labour which is usually a saving for industrialised in high wage rate countries. 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 a capital outlay that is a barrier for entry. The extent of this factor is difficult to measure as there are certain degrees of capital required.
- **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 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 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 affects the community.

Sec	Primary Factor	no	MCCFM.	Weighting	CBS		IBS	
					Secondary Factor	Score	Secondary Factor	Score
GOVERNMENT	Housing Provision	1	Delivery Rate	0.123	44	5.41	72	8.86
		2	Adequacy & Housing Quality	0.127	54	6.86	73	9.27
		3	Durability & Structural Quality	0.141	51	7.19	75	10.58
	Affordability &Job Creation	4	Cost per House	0.117	62	7.25	68	7.96
		5	Initial Capital	0.097	56	5.43	51	4.95
		6	Job Creation	0.127	68	8.64	46	5.84
	Sustainable Development	7	Socio-economic Growth	0.112	55	6.16	29	3.25
		8	Building Reuse & Adaptability	0.073	44	3.30	56	4.20
		9	Green & Resource Efficiency	0.080	45	3.60	71	5.68
	Score			1.000	479	53.84	541	60.58

Table 6.8 MCCFM Government

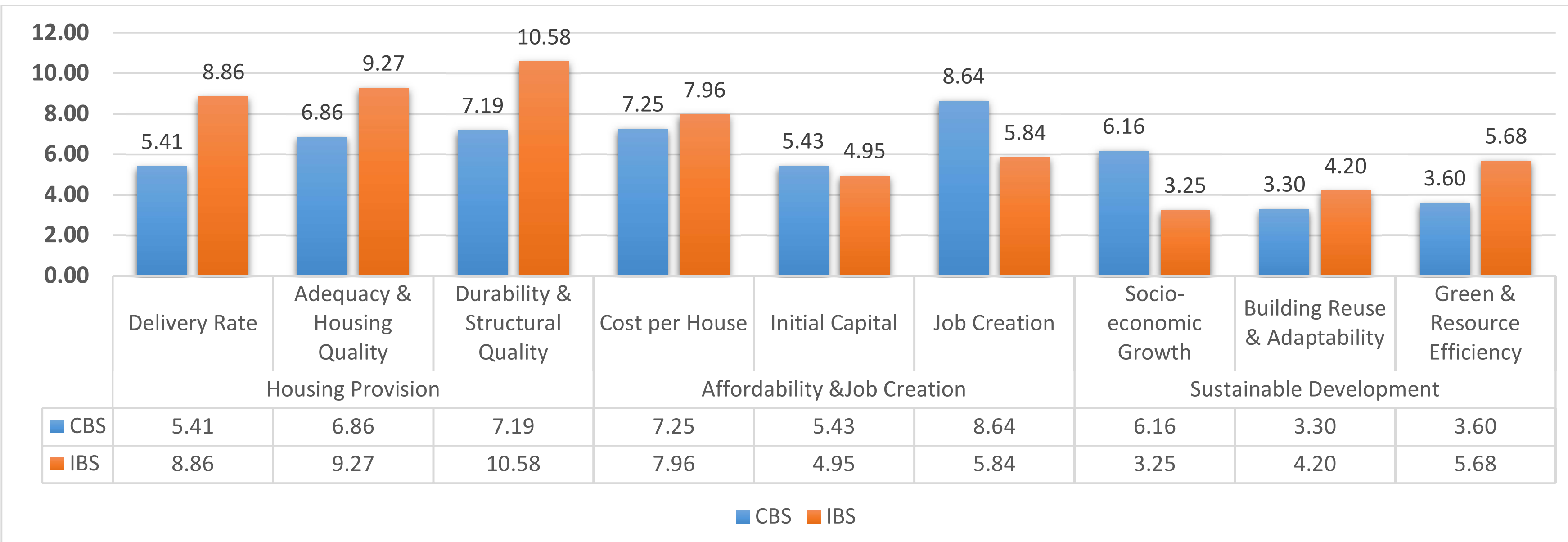


Figure 6.7 MCCFM Government

- **Job Creation:** This is an important requirement for government. The contractors who build government subsidised houses 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 maximize 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 mechanization it decreases the need for employment that is in direct contrast with conventional.
- **Building Reuse & Adaptability:** This is the extent to which a building can be recycled and its adaptability for other uses, thus, its ability 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 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 placed below other factors that directly deal with the housing problem. It is believed that this factor would become more pressing in the future. Industrialised is regarded

a 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.

6.7.2. Analysis of contractor MCCFM

The **Figure 6.8** below shows the scoring difference between conventional and industrialised for the contractor sector based on the **table 6.9**. The following points are noted:

- **Production Cost:** This is an important factor to consider, as the cost of producing house 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 utilizing cheap materials, cheap labour and minimizing 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 its low score than it is for contractors, as it can see end user. 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, largely, identical. Standardization and less onsite construction provide 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.

Sec	Primary Factor	no	MCCFM.	Weighing	CBS		IBS	
					Secondary Factor	Score	Secondary Factor	Score
CONTRACTOR	Production	10	Production Cost	0.115	62	7.13	74	8.51
		11	Initial Capital Outlay	0.099	62	6.14	40	3.96
		12	Production Rate	0.07	48	3.36	78	5.46
		13	Product Quality	0.103	58	5.97	78	8.03
	Management	14	Manageability	0.071	44	3.12	66	4.69
		15	Production Control	0.075	40	3.00	75	5.63
		16	Quality Control	0.085	40	3.40	74	6.29
		17	Skills Dependency	0.051	68	3.47	56	2.86
		18	Labour Intensity	0.066	72	4.75	64	4.22
	Physical Implications & Sustainability	19	Design Flexibility	0.059	85	5.02	64	3.78
		20	Construction Complexity	0.050	54	2.70	52	2.60
		21	Carbon Footprint	0.097	64	6.21	68	6.60
		22	Resource Efficiency	0.060	46	2.76	72	4.32
	Score			1.001	743	34.43	861	40.97

Table 6.9 MCCFM Contractor

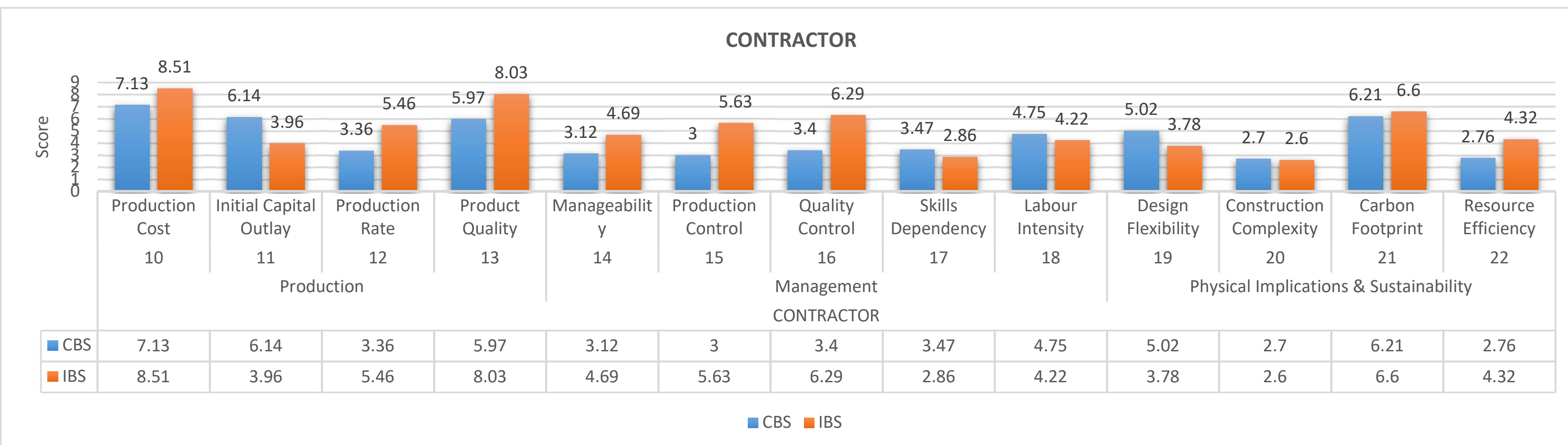


Figure 6.8 MCCFM Contractor

- **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 is 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 checkpoints 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 fewer professional staff per house produced than conventional, because of the production method. Although less professionals 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 number 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 organizations. 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 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 efficient resource 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 (e.g.: 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.

6.7.3 Analysis of End-User MCCFM

The **Figure 6.9** below shows the scoring difference between conventional and industrialised for the contractor sector based on the **table 6.10** 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.

Sec	Primary Factor	no	MCCFM.	Weighing	CBS		IBS	
					Secondary Factor	Score	Secondary Factor	Score
END-USER	Time & Future Value	23	Delivery & Waiting Period	0.131	46	6.03	76	9.96
		24	Adaptability & Alteration	0.132	52	6.86	56	7.39
		25	House Value	0.085	60	5.10	40	3.40
	Cost	26	Affordability	0.126	60	7.56	68	8.57
		27	Maintainability	0.095	60	5.70	54	5.13
		28	Life Cycle Period	0.091	36	3.28	52	4.73
	Quality	29	Diverse Design & Aesthetic	0.097	82	7.95	66	6.40
		30	General Quality of House	0.105	54	5.67	76	7.98
		31	Adequate Service Provision	0.137	40	5.48	74	10.14
	Score			0.999	490	53.63	562	63.70

Table 6.10 MCCFM End-User

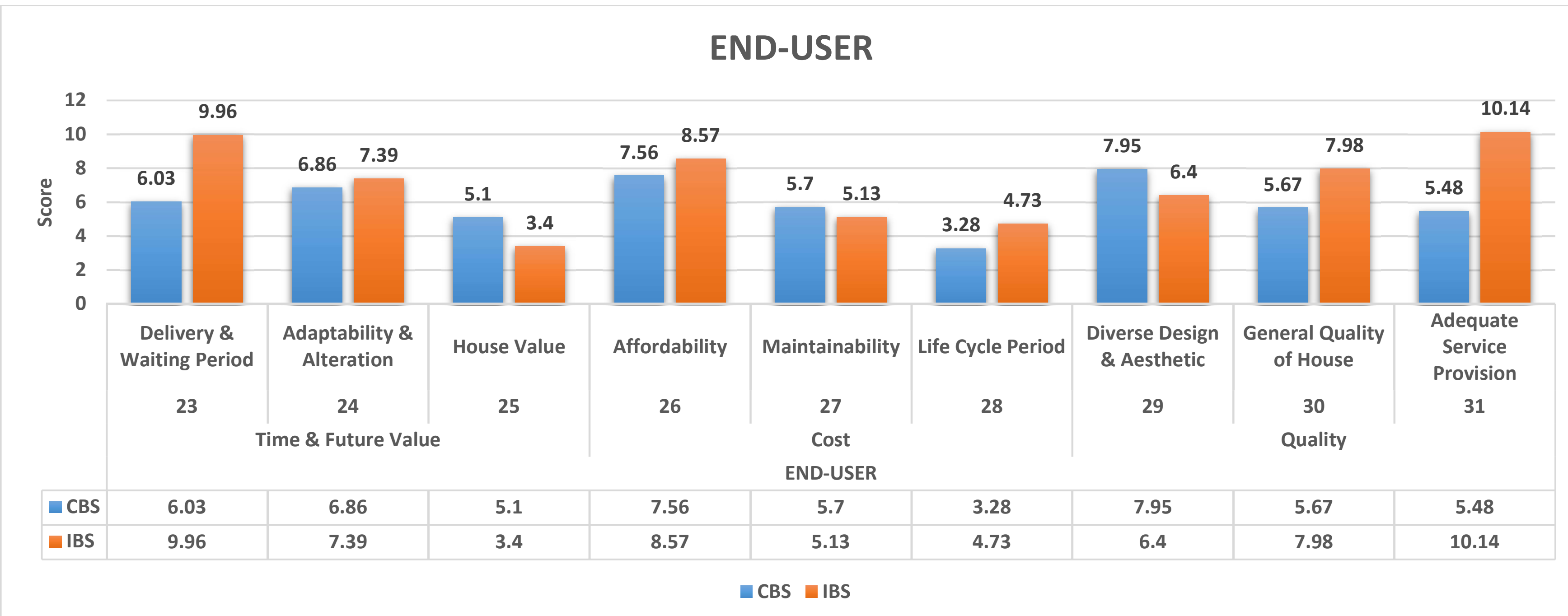


Figure 6.9 MCCFM End-User

- **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 is 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 its 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 is obvious to have scored higher for this factor. However, the reason why this factor was chosen is because studies criticized 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 is an important factor for the end user; hence it has one of the highest scores. Industrialised has considerably outscored 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 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.

6.8. Conclusions from Questionnaires and Interviews

Results of the questionnaires and interviews have been placed in the MCCFM analysis tables. **Table 6.11 below** shows the th14ree 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.

Group	No.	Most Important Factors	Performance	
			IBS	CBS
Government	1	Durability & Structural Quality	51	75
	2	Job Creation	68	46
	3	Delivery Rate	44	72
	4	Adequacy & Housing Quality	54	73
Contractor	5	Production Cost	62	74
	6	Product Quality	58	78
	7	Carbon Footprint	64	68
End-User	8	Adequate Service Provision	40	74
	9	Delivery/Waiting Period	46	76
	10	Affordability	60	68

Table 6.11 Important Factors with Performance Rating

The four major requirements factor for the government are the government aims to achieve through their housing process. The least 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 favorable towards IBS where Job Creation is favored 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 favorable option. The reason for the top three factors is as follows:

- Durability and Structural Quality: the government maintains that houses should last long enough for the next generation.
- Job Creation: the government is using the housing process to create jobs for socio-economic up-liftmen.
- Delivery Rate: the houses must be developed fast enough to supply the need and overcome the housing backlog.

- Adequacy & Housing Quality: the houses that are built must be of reasonable standard and must be live-able.

The product cost and product quality are the most important requirements for the contractors. The Production cost and product quality are both strongly favored by IBS. Carbon Footprint is only slightly favored 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 favorable option for contractors. The reasoning of the top three factors is as follows:

- Production Cost: the cheaper the contractor can construct houses the greater the profits.
- Product Quality: the quality of the houses must be good enough to ensure future contracts
- 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 favored 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:

- Adequate Service Provision: essentially the end user requires running water and electricity in their houses.

- Delivery/Waiting Period: the waiting period sometimes takes a few years before the house is built, during which the community must place in transit housing while their shacks are replaced with formal houses.
- 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 Sudan such as labour intensity, job creation, and less skills dependency. Adopting either system will have to compromise between the advantages offered by either building system. Therefore, the suitable building system must be selected by least cost in advantages and not only by what one system can offer.

6.9. MCCFM Result

The **Table 6.12 below** 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.

Final Matrix	Government	Contractor	End-User	Total
Conventional CBS	479	743	490	1712
Rating	53.84	34.43	53.63	141.90
Industrialised IBS	541	861	562	1964
Rating	60.58	40.97	63.70	165.25

Table 6.12 MCCFM Final Result

Government: From the figure 5.10 graph and the MCCFM table 6.12 it is evident that the difference margin between industrialised and conventional is less for government (6.74%) than for contractor (6.54%) and end user (10.07%). A major requirement for government is job creation which has considerably scored higher for conventional. Socio-economic growth is another similar factor which is favored by conventional. The other important factors for the government such as delivery rate, adequacy and durability have been considerably favored by industrialised.

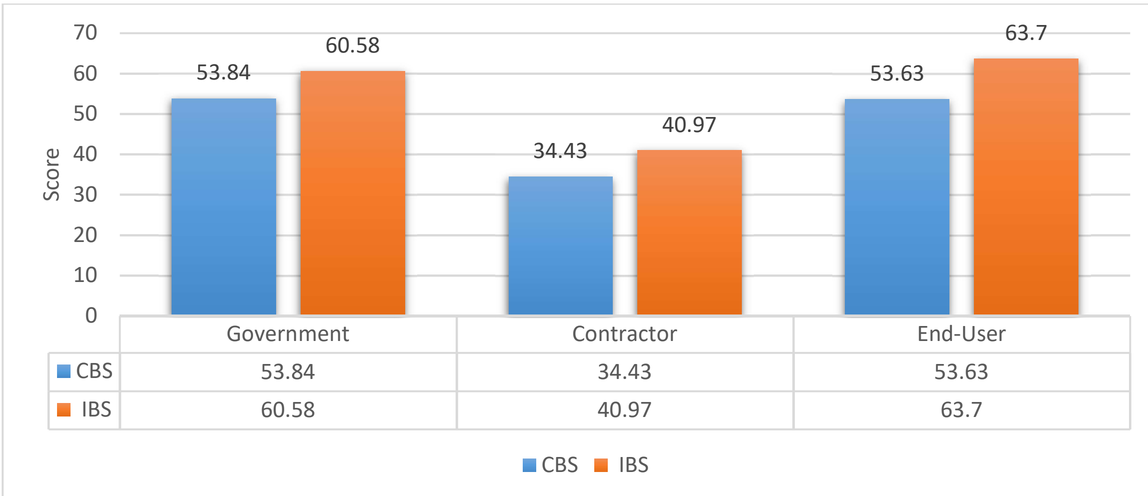


Figure 6.10 MCCFM Final Result

Out of the four most important factors considered by government only one, job creation, is in favour of conventional the other three are considerably favored by industrialised. Another important criterion 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 out of the 9 factors were considerably favored by industrialised, only 2 out of the 9 were favored substantially by conventional and the remaining 3 out 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 Sudan.

Contractor: for the contractor industrialised had scored 6.54% more than conventional. Industrialised offers many advantages for the contractor as the contractor aims to profit from the construction of the houses. The contractor's criteria are comprised of 13 factors. 6 out of the 13 are strongly favored by industrialised, 4 out of the 13 are considerably favored by conventional and 3 out of the 13 are only marginally different. All of the contractors three most important factors are favored 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 contractor's 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 favored by conventional and may discourage industrialised as a building system. Labour intensity is only favored 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. Mechanization, 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 Sudan has relatively cheap labour which may make labour intensive processes cheaper than mechanized 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 are comprised of nine factors. Five out of the nine favor industrialised, two out of the nine favor conventional and two out of the nine are marginal. The end-user group had the highest difference between industrialised and conventional at 10.07% this is a considerable margin considering that government had received a 6.74% 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 are favored 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 Sudan. The end user should be pleased with their house if it caters for all their needs.

6.10. Summary

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 **141.90** for conventional and **165.25** for industrialised, this is a 14.13% difference. Overall IBS is a more feasible option for government subsidised housing in Sudan. 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 or government subsidised housing in Sudan, 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 Sudan environment, must suit the important criteria of the government especially job creation and it must incorporate materials suitable for the Sudan 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 Sudan 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 Seven

Conclusions and Recommendations

7.1. Conclusions

The construction industry in Sudan is under pressure to change its approach in order to meet future demands for sustainable and economic development. The analysis discovered that IBS suits the demands for low-income housing better than CBS, yet the core question of practicality and implementation still remains. This chapter discussions the question in the face of IBS for low-income housing in Sudan. 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.

7.2. Research Process Conclusion

This research purposes to investigate the ability of industrialised building systems for housing the poor in Sudan. The main aim is comprised of three objectives, thus; literature review, study surveys and data analysis. The literature review involves the following: housing situation in Sudan, conventional building systems, industrialised building, 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. Moreover, 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 are 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 players, 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.

7.3.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 possible 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 Sudan are delivery rate, production control, quality control and adequate services.
- The main advantages that CBS offers in terms of social housing in Sudan are job creation, socio-economic growth and diverse design and aesthetics.

1. For the **government** sector:
    - o IBS would be most successful towards: Delivery Rate and Durability.
    - o IBS would be a hindrance towards: Job Creation.
2. For the **contractor** sector:
    - o IBS would be most successful towards: Production Cost and Product Quality
    - o IBS would be a hindrance towards: Initial Capital Outlay and Design

Flexibility

3. For the **end-user** sector:
   - o IBS would be most successful towards: Adequate Services and Delivery Period.
   - o IBS would be a hindrance towards: Diverse Design and Aesthetics.

7.4. The Value to Industry

This study investigates the ability of industrialised building systems for housing the poor in Sudan. This is done by analyzing a comparative study between IBS and CBS for each major role player within social housing in Sudan. 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.

a. 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. 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.

The main example is that the government requires the employment of labour within the community of the housing project to 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.

b. Contractors and Others

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 organizations 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.

c. End-User and Residents

The residents of the houses can utilize 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.

7.5. RECOMMENDATIONS

7.5.1. Research recommendations

This research provides a recommendation to the government housing department, housing contractors, homeowners, and eager research. Each group's recommendation is as follows:

a. Government housing department

This research suggests that the Housing Department should review its standards and ensure that the requirements are not inconsistent and that a level of importance should be assigned to each of these requirements so that optimal standards are established that will not hinder development.

The main recommendation of this research to the government is that you should consider using and implementing certain aspects of industrial building systems so that the current building system can offer faster delivery, cheaper costs, and better standards without compromising their requirements.

b. Housing contractors

Advantages and disadvantages offered by IBS and CBS for government housing in Sudan. This research also recommends aspects of the contractor's criteria that can be useful for collective construction in general and not just for low-cost housing.

The MCCFM is an analytical framework specifically designed for housing and comparison between IBS and CBS. The contractor can adapt this analysis framework to its own needs for the inclusion of relevant criteria and the processing of accounts. MCCFM can provide no decision-making between IBS and CBS building grades.

c. Homeowners and end-user

This research recommends the homeowner when choosing between an industrial building house and a traditionally built house. As this research demonstrates the advantages and disadvantages of each end-user factor, it will help to create a thoughtful decision as to what type of building to choose in terms of its use, type and future plans.

With regard to government-supported housing in Sudan, the end user can use IBS for his full benefit as a degree of knowledge is gained through the construction system.

7.5.2. Other research recommendations

- Developing the design of industrial buildings suitable for low-income housing in Sudan.
- Proposing the most appropriate method for the IBS program for

housing the poor in Sudan.

- Investigate the feasibility of industrial building systems for real estate development.
- Improve construction efficiency by building precast concrete panels.
- Standardized quantitative evaluation techniques for quality.

7.5.3. Recommendations for Further Research

This research would suggest two further dependents studies that would propose a solution in overcoming the housing problem in Sudan:

- 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-user’s role which would be needed to allow the successful implementation of the proposed building design.

Development of quality control procedures through the management of the working group.

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Appendix

Appendix 1: Total population (thousands) 1950-2050

Year	Total population (000s)	Urban population (000s)	Rural Population (000s)	Percentage urban (%)
1950	9,190	627	8,563	6.8
1955	10,215	877	9,338	8.6
1960	11,439	1,229	10,210	10.7
1965	12,829	1,716	11,113	13.4
1970	14,495	2,395	12,100	16.5
1975	16,776	3,178	13,598	18.9
1980	19,641	3,920	15,721	20
1985	23,056	5,157	17,899	22.4
1990	25,933	6,903	19,030	26.6
1995	29,492	9,233	20,259	31.3
2000	33,349	12,034	21,315	36.1
2005	36,900	15,043	21,857	40.8
2010	41,230	18,646	22,584	45.2
2015	45,613	22,513	23,100	49.4
2020	50,027	26,612	23,415	53.2
2025	54,267	30,921	23,346	57
2030	58,446	35,468	22,978	60.7
2035	62,473	40,152	22,321	64.3
2040	66,278	44,872	21,406	67.7
2045	69,809	49,534	20,275	71
2050	73,029	54,046	18,983	74

Source: United Nations (2008a; 2008b)

Appendix 2: Population distribution by main geographical areas

Main Geographical Areas	Total	Area (Million km2)	%	Density (Inhab. Per km2)
All Sudan	**39,154,490**	**2.5**		
Northern Sudan	30,894,000	1.78	71.2%	17.4
Southern Sudan	8,260,490	0.72	28.8%	11.5

Source: (Area figures) Salih (2003, p. 437)

Appendix 3: Population Distribution by Region of Origin (Former 9 Regions)

Regions	Total	%
All Regions	**39,154,490**	
Northern	3,112,334	7.9%
Eastern	3,999,322	10.2%
Khartoum	1,405,772	3.6%
Central	7,466,567	19.1%
Kordufan	5,686,337	14.5%
Darfur	8,505,564	21.7%
Upper Nile	2,990,840	7.6%
Bahr El Ghazal	2,879,482	7.4%
Equatorial	2,563,779	6.5%
Not Sudan	177,042	0.5%
No Response	4,359	0.0%
Not Reported	363,092	0.9%

Source: Adapted from CBS (2008)

Appendix 4: Population distribution by state of enumeration

State	Total	%	Area (km2)	Density (Inhabit per km2)
All States	**39,154,490**		**2,505,813**	**15.6**
Northern	699,065	1.8%	348,765	2.0
River Nile	1,120,441	2.9%	122,123	9.2
Red Sea	1,396,110	3.6%	218,887	6.4
Kassala	1,789,806	4.6%	36,710	48.8
Al-Gadarif	1,348,378	3.4%	75,263	17.9
Khartoum	5,274,321	13.5%	22,122	238.4
Al-Gezira	3,575,280	9.1%	27,549	129.8
White Nile	1,730,588	4.4%	30,411	56.9
Sinnar	1,285,058	3.3%	37,844	34.0
Blue Nile	832,112	2.1%	45,844	18.2
Northern Kordufan	2,920,992	7.5%	185,302	15.8
Southern Kordufan	1,406,404	3.6%	158,355	8.9
Northern Darfur	2,113,626	5.4%	296,420	7.1
Western Darfur	1,308,225	3.3%	79,460	16.5
Southern Darfur	4,093,594	10.5%	127,300	32.2
Upper Nile	964,353	2.5%	77,773	12.4
Jonglei	1,358,602	3.5%	122,479	11.1
Unity	585,801	1.5%	35,956	16.3
Warrap	972,928	2.5%	31,027	31.4
Northern Bahr-El-Ghazal	720,898	1.8%	33,558	21.5
Western Bahr-El-Ghazal	333,431	0.9%	93,900	3.6
Lakes	695,730	1.8%	40,235	17.3
Western Equatorial	619,029	1.6%	79,319	7.8
Central Equatorial	1,103,592	2.8%	22,956	48.1
Eastern Equatorial	906,126	2.3%	82,542	11.0

Source: Adapted from CBS (2008)

Appendix 5: Ranking of states size by population

State	Total	%	Ranking
All States	**39,154,490**		
Khartoum	5,274,321	13.5%	1
Southern Darfur	4,093,594	10.5%	2
Al-Gezira	3,575,280	9.1%	3
Northern Kordufan	2,920,992	7.5%	4
Northern Darfur	2,113,626	5.4%	5
Kassala	1,789,806	4.6%	6
White Nile	1,730,588	4.4%	7
Southern Kordufan	1,406,404	3.6%	8
Red Sea	1,396,110	3.6%	9
Jonglei	1,358,602	3.5%	10
Al-Gadarif	1,348,378	3.4%	11
Western Darfur	1,308,225	3.3%	12
Sinnar	1,285,058	3.3%	13
River Nile	1,120,441	2.9%	14
Central Equatoria	1,103,592	2.8%	15
Warrap	972,928	2.5%	16
Upper Nile	964,353	2.5%	17
Eastern Equatoria	906,126	2.3%	18
Blue Nile	832,112	2.1%	19
Northern Bahr-El-Ghazal	720,898	1.8%	20
Northern	699,065	1.8%	21
Lakes	695,730	1.8%	22
Western Equtoria	619,029	1.6%	23
Unity	585,801	1.5%	24
Western Bahr-El-Ghazal	333,431	0.9%	25

Source: Adapted from CBS (2008)

Appendix 6: Population in the Sudan by Type 1956, 1973, 1983 and 1993

State	1955/56	1973	1983	1993
Total Population	10.3	14.1	20.6	24.9
Urban	9.0	18.5	20.5	25.2
Rural	78.0	70.0	68.5	66.3
Nomads	13.0	11.5	11.0	8.5

Source: Elhoweris and Hassan, (2003, p. 103)

Appendix 7: Urban population in the Sudan by region 1956, 1973 and 1983

State	1955/56	%	1973	%	1983	%
Total Urban Population	886,476		2,605,896		4,219,826	
Nothern Sudan	829,465	93.6%	2,317,980	89.0%	3,772,174	89.4%
Southern Sudan	56,011	6.3%	287,916	11.0%	447,652	10.6%

Source: Alfadil (2003, p. 467)

Appendix 8: Size of urban centers in the Sudan for years 1956, 1973, 1983, 1993 and 2008

State	1955/56	1973	1983	1993	2008
Khartoum	152.6	808.8	1,343.3	2,919.8	5,274,321
Algezira	NA	NA	9.7	64.4	906,216
Southern Darfur	12.3	62.8	112.0	227.2	629,971
Northern Darfur	26.2	54.5	84.3	141.9	504,080
Al-Gezira	47.6	118.0	144.8	211.4	423,863
White Nile	22.7	60.6	89.6	173.3	404,763
Central Equatoria	10.7	56.7	81.9	125.0	372,413
Nothern Kordufan	52.4	92.2	138.0	229.4	340,940
Kassala	40.6	100.5	140.5	234.6	298,529
Sinnar	8.1	32.6	41.6	72.2	296,871
White Nile	12.3	26.8	34.8	56.5	295,695
Southern Darfur	NA	NA	31.9	73.3	295,167
River Nile	5.4	17.7	26.8	51.0	284,148
Red Sea	47.6	153.1	205.0	308.2	283,953
River Nile	11.0	24.1	34.3	NA	269,446
Algedarif	17.5	66.2	115.8	191.2	269,395
Nothern Kordufan	16.5	27.6	31.1	54.6	256,482
Western Darfur	11.8	38.6	55.5	92.8	252,744
White Nile	NA	NA	24.6	59.3	239,665
Jongeli	NA	16.0	17.6	NA	221,106
Blue Nile	NA	12.2	28.1	71.8	212,712
Kassala	8.7	24.3	37.6	54.1	211,864
Lakes	4.0	17.7	19.7	NA	153,550
Western Bahr El Ghazal	80.0	53.4	91.0	NA	151,320
Nothern	13.3	5.6	9.3	NA	150,161
River Nile	36.3	64.3	72.9	87.9	134,586
Upper Nile	9.7	37.1	31.7	NA	126,483
Southern Kordufan	4.7	18.4	34.7	62.1	105,252
Western Equatoria	1.3	9.6	9.4	NA	82,461
White Nile	11.4	22.3	19.8	NA	NA

Source: Adam (2003, p. 34) and CBS (2008)

Appendix 9: Population of the city of Khartoum 1950-2050

Year	Population (000s)	Percentage of the total urban population (%)	percentage of the total population (%)
1950	183	29.1	2.0
1955	252	28.7	2.5
1960	347	28.2	3.0
1965	477	27.8	3.7
1970	657	27.5	4.5
1975	886	27.9	5.3
1980	1,164	29.7	5.9
1985	1,611	31.2	7.0
1990	2,360	34.2	9.1
1995	3,242	35.1	11.0
2000	3,949	32.8	11.8
2005	4,518	30.0	12.2
2010	5,185	27.8	12.6
2015	6,077	27.0	13.3
2020	7,017	26.4	14.0
2025	7,937	25.7	14.6

Source: United Nations (2008a; 2008b)

Appendix 10: Numbers of IDPs received by different states

State	Number of IDPs	%
Khartoum	845,000	26.3%
Nothern States	116,102	3.6%
Eastern States	231,000	7.2%
Central States	631,000	19.6%
Kordofan States	365,000	11.3%
Darfur States	443,058	13.8%
Upper Nile States	336,334	10.5%
Bahr Elgazal States	172,000	5.3%
Equatoria States	78,000	2.4%
Total	**3,217,494**	**100.0%**

Source: Salih (2003, p. 439)

Appendix 11: The Questionnaire

PARTICIPANT LETTER

Dear participant,

Thank you for your interest in my research to develop a strategy for the construction industry in Sudan. I value the unique contribution that you can make to my study.

You have been selected as a member of a panel of experts to participate in a single round questionnaire on the Sudan Construction Industry. The research methodology I am using is a qualitative one through which I am seeking comprehensive description of your experience in the construction industry. In this way I hope to answer my research question:

"Is industrialized building system (IBS) the appropriate and viable alternative for housing development in Sudan? "

this is the initial single question that will drive the research. In the process, the research development will disseminate the question into various avenues and sub-questions will emerge.

"What are the real constrains hindering the development of the construction industry in Sudan?"

finding answers to sub-questions will provide an answer to the main research question.

Through your participation and professional experience, I hope to formulate a strategy and a set of recommendations. You will be asked for opinions based on experience gained within your professional life to best approach the problem I am investigating. I am seeking solutions and strategies you think will be appropriate for the developing economy of Sudan.

I value your participation and thank you for the commitment of time, energy and effort. If you have any further questions, I can be reached at the address below.

Sincerely,

Omer Saad Ali

PhD candidate

Sudan University of Science & Technology,

E-mail: omersaad72@yahoo.com

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Questionnaire

This research investigates the feasibility of industrialised building systems as an alternative housing for the low-incomes in Sudan. a Simple Multi Attributable Rating Technique (SMART) is a decision-making housing tool concept that analyze a feasibility of system by comparing industrialised housing against conventional housing by measuring certain factors. Each factor is weighted according to its importance and each proposal (conventional system or industrialised) is then rated according to its performance for each factor. This weighting is then multiplied by a rank which give a score (numerical value) for each factor, these are then added together and the proposal that highest score is the better proposal. Table 1 below shows all 31 factors which need to be ranked according to their performance on a scale from 10 to 100 (10 being least & 100 being most).

For example:

Primary Factor	No.	Secondary Factor		Industrialised	Conventional
				10 to 100	
Rate of Housing Provision	1	Delivery Rate		75	25

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 or should have a complete and perfect performance. A set of definitions and operational for each factor is given below, this would also indicate the direction of the rating scale should tend towards. 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 utilizing mass production techniques for construction by prefabricating larger standard building components in a factory, on or off site, and minimizing 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 Sudan.

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 impacts 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 consider 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 dependent the better).

18. Labour Intensity: To what extent does either system utilize 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, considering

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: 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).

Appendix 12: The Interview

Contractor Interview .1

Date :

Name :

Company :

Position :

Tel : Cell :

E-Mail :

1 Weighting. Factors 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	
		1.3 Product Quality	

2.Managemant		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 Construction	
		3.2 Complexity	
		3.3 Carbon Footprint	
		3.4 Resource Efficiency	

2. Any Further Factors That May Be Necessary?

1. __________
2. __________
3. __________
4. __________
5. __________

Thank You for Your Time.

Government Interview

Date :

Name :

Company :

Position :

Tel : Fax :

E-Mail :

1. Weighting Factors Questions:

Primary Factor	10 To 50 Primary Rating	Secondary Factor	10 To 50 Secondary Rating
1. Rate of Housing Provision		1.1 Delivery Rate	
		1.2 Adequate Housing & Quality	
		1.3 Durability & Structural Quality	
2.Affordability &Job Creation		2.1 Cost Per House/ Unit	
		2.2 Initial Capital	
		2.3 Job Creation	
3.Sustainable Development		3.1 Socio-Economic Growth	
		3.2 Reuse of Building & Adaptability	
		3.3 Green & Resource Efficiency	

2. Any Further Factors That May Be Necessary?

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________

Thank You for Your Time.

End-User Interview .1

Date :

Name :

Company :

Position :

Tel : Cell :

E-Mail :

1. Weighting Factors Questions:

Primary Factor	10 To 50 Primary Rating	Secondary Factor	10 To 50 Secondary Rating
1. Time & Future Value		1.1 Delivery/ Waiting Period	
		1.2 Adaptability & Alteration	
		1.3 House Value	

2.Cost		2.1 Affordability	
		2.2 Maintainability	
		2.3 Life Cycle Period	

3.Quality		3.1 Diverse Design & Aesthetic	
		3.2 General Quality Of House	
		3.3 Adequate Service Provision	

2. Any Further Factors That May Be Necessary?

1.
2.
3.
4.
5.

Thank You for Your Time.

Appendix 13: Questionnaire Table

Sec	Primary Factor	No.	Secondary Factor		Industrialised	Conventional
					10 to 100	
GOVERNMENT	Rate of Housing Provision	1	Delivery Rate			
		2	Adequacy & Housing Quality			
		3	Durability & Structural Quality			
	Affordability &Job Creation	4	Cost per House/ Unit			
		5	Initial Capital			
		6	Job Creation			
	Sustainable Development	7	Socio-economic Growth			
		8	Reuse of Building & 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			

Appendix 14: Analysis of interviews responses

Sec	Primary Factor	No.	Secondary Factor	Data
GOVERNMENT	Housing Provision	1	Delivery Rate	0.123
		2	Adequacy & Housing Quality	0.127
		3	Durability & Structural Quality	0.141
	Affordability &Job Creation	4	Cost per House	0.117
		5	Initial Capital	0.097
		6	Job Creation	0.127
	Sustainable Development	7	Socio-economic Growth	0.112
		8	Building Reuse & Adaptability	0.075
		9	Green & Resource Efficiency	0.08
CONTRACTOR	Production	10	Production Cost	0.115
		11	Initial Capital Outlay	0.099
		12	Production Rate	0.07
		13	Product Quality	0.103
	Management	14	Manageability	0.071
		15	Production Control	0.075
		16	Quality Control	0.085
		17	Skills Dependency	0.051
		18	Labour Intensity	0.066
	Physical Implications & Sustainability	19	Design Flexibility	0.059
		20	Construction Complexity	0.05
		21	Carbon Footprint	0.097
		22	Resource Efficiency	0.06
END-USER	Time & Future Value	23	Delivery & Waiting Period	0.131
		24	Adaptability & Alteration	0.132
		25	House Value	0.085
	Cost	26	Affordability	0.126
		27	Maintainability	0.095
		28	Life Cycle Period	0.091
	Quality	29	Diverse Design & Aesthetic	0.097
		30	General Quality of House	0.105
		31	Adequate Service Provision	0.137

Appendix 15: Analysis of survey questionnaires responses

Sec	Primary Factor	No.	Secondary Factor	CBS	IBS
GOVERNMENT	Housing Provision	1	Delivery Rate	44	72
		2	Adequacy & Housing Quality	54	73
		3	Durability & Structural Quality	51	75
	Affordability &Job Creation	4	Cost per House	62	68
		5	Initial Capital	56	51
		6	Job Creation	68	46
	Sustainable Development	7	Socio-economic Growth	55	29
		8	Building Reuse & Adaptability	44	56
		9	Green & Resource Efficiency	45	71
CONTRACTOR	Production	10	Production Cost	62	74
		11	Initial Capital Outlay	62	40
		12	Production Rate	48	78
		13	Product Quality	58	78
	Management	14	Manageability	44	66
		15	Production Control	40	75
		16	Quality Control	40	74
		17	Skills Dependency	68	56
		18	Labour Intensity	72	64
	Physical Implications & Sustainability	19	Design Flexibility	85	64
		20	Construction Complexity	54	52
		21	Carbon Footprint	64	68
		22	Resource Efficiency	46	72
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

Appendix 16: MCCFM summary matrix

Sec	Primary Factor	MCCFM.	Weighing	CBS		IBS	
GOVERNMENT	Housing Provision	Delivery Rate	0.123	44	5.41	72	8.86
		Adequacy & Housing Quality	0.127	54	6.86	73	9.27
		Durability & Structural Quality	0.141	51	7.19	75	10.58
	Affordability &Job Creation	Cost per House	0.117	62	7.25	68	7.96
		Initial Capital	0.097	56	5.43	51	4.95
		Job Creation	0.127	68	8.64	46	5.84
	Sustainable Development	Socio-economic Growth	0.112	55	6.16	29	3.25
		Building Reuse & Adaptability	0.075	44	3.30	56	4.20
		Green & Resource Efficiency	0.08	45	3.60	71	5.68
	Score		0.999	479	53.84	541	60.58
CONTRACTOR	Production	Production Cost	0.115	62	7.13	74	8.51
		Initial Capital Outlay	0.099	62	6.14	40	3.96
		Production Rate	0.07	48	3.36	78	5.46
		Product Quality	0.103	58	5.97	78	8.03
	Management	Manageability	0.071	44	3.12	66	4.69
		Production Control	0.075	40	3.00	75	5.63
		Quality Control	0.085	40	3.40	74	6.29
		Skills Dependency	0.051	68	3.47	56	2.86
		Labour Intensity	0.066	72	4.75	64	4.22
	Physical Implications & Sustainability	Design Flexibility	0.059	85	5.02	64	3.78
		Construction Complexity	0.05	54	2.70	52	2.60
		Carbon Footprint	0.097	64	6.21	68	6.60
		Resource Efficiency	0.06	46	2.76	72	4.32
	Score		1.001	743	34.43	861	40.97
END-USER	Time & Future Value	Delivery & Waiting Period	0.131	46	6.03	76	9.96
		Adaptability & Alteration	0.132	52	6.86	56	7.39
		House Value	0.085	60	5.10	40	3.40
	Cost	Affordability	0.126	60	7.56	68	8.57
		Maintainability	0.095	60	5.70	54	5.13
		Life Cycle Period	0.091	36	3.28	52	4.73
	Quality	Diverse Design & Aesthetic	0.097	82	7.95	66	6.40
		General Quality of House	0.105	54	5.67	76	7.98
		Adequate Service Provision	0.137	40	5.48	74	10.14
	Score		0.999	490	53.63	562	63.70