KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY.

KUMASI - GHANA

COLLEGE OF ARCHITECTURE AND PLANNING

FACULTY OF ARCHITECTURE AND BUILDING TECHNOLOGY

DEPARTMENT OF BUILDING TECHNOLOGY

IMPROVING BUILDABILITY:

A LOOK AT OFF-SITE PRODUCTION

OTI AMANKWAH

(M.PHIL. BUILDING TECHNOLOGY)

A Project Report Presented to the Department of Building Technology of the Faculty of Architecture and Building Technology in Partial Fulfilment of the Requirement for a Degree of Master of Philosophy in Building Technology

APRIL 2013

DECLARATION

I hereby declare that this work is the result of my own original research and that this thesis has neither in whole or in part been prescribed by another Degree elsewhere. References to other people's research have been duly cited.

…………………………………………………

OTI AMANKWAH

(STUDENT)

……………………………………

………………………………………….

DR. KWAME DANSO

(FIRST SUPERVISOR)

MR AYEREBI DANSO

(SECOND SUPERVISOR)

…………………………………………..

PROF. J. AYAKWA

(HEAD OF DEPARTMENT)

DEDICATION

This work is dedicated to God Almighty, my wife Mrs. Lydia Amankwah for her immense support throughout the period of this study and my children Otiwaa, Agyemang and Duah

ACKNOWLEDGEMENT

My profound gratitude goes to the Almighty God for his guidance throughout this programme especially when the going became tough. I also appreciate the support, correction and understanding nature of my supervisors, Dr. Kwame Danso and Mr. Ayerebi Danso without whose support this research would not have been possible.

I also wish to thank my wife Mrs. Lydia Amankwah for her support and words of encouragement throughout the period of this research work. My sincere gratitude goes to all my siblings especially Prof. Richard Kwasi Amankwah of University of Mines and Technology (UMaT) - Tarkwa for their contribution towards the success of this project. Finally, I cannot forget Architect Seth Tay for his invaluable help during the distribution and collection of the questionnaire.

GOD BLESS YOU ALL

TABLE OF CONTENT

TITLE

PAGE

CHAPTER ONE**: INTRODUCTION**

CHAPTER TWO: **LITERATURE REVIEW**

CHAPTER THREE: **RESEARCH METHODOLOGY**

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The need to control large quantities of waste, complete construction work within time and budget and the issue of construction failure have been a problem in the Ghanaian construction industry for a long time. It is the adoption of new technological advancement in the construction sector that is seen as the way forward to achieving easily buildable works. Off-site production (OSP) has been an area of research interest the world over, as it can help minimise construction waste and improve construction time and ultimately reduce cost of construction schemes. Thus it is worthwhile to study how the adoption of off-site production will impact positively on buildability in the Ghanaian Construction Industry.

In this study the benefits and hindrances as well as the possibilities for the adoption of off-site production by stakeholders of the Ghanaian construction industry such as Architects, Quantity Surveyors, Structural Engineers, Manufacturers and Suppliers of off-site produced building components and Estate developer in Accra and Kumasi was addressed. The survey method included a structured questionnaire and qualitative data collection through semi structured interviews and site visits.

The research result indicates that, in spite of the constraints in the adoption of off-site production, stakeholders of the Ghanaian construction industry believe in the need to explore it's use. It indicated the adoption of off-site production will in the long run help meet the housing deficit in the country and increase the level of growth of the construction industry in the country especially in the field of Real Estate development due to the use of repetitive designs. Off-site production has the capacity to offer increased choice of solutions and to further improve quality and value for money. Other results of the survey are presented.

CHAPTER ONE

INTRODUCTION

1.2 Background

Given the changing nature of the building industry, it is particularly critical for the players in the industry to rethink the way things are done from design through construction in order to respond to the new challenges that are being presented. Mitchell (1996) stated that a good design is one that is appropriate to its use and context". That notwithstanding, that which is good can be made better when constructed at the most reasonable cost. It becomes a plus to the Designer, and economically cost saving to the Client. According to Turner (1995). The design team of building project play the significant role to achieve project satisfaction. The building design presents the synthetic performance between artistic insight and technology knowledge from designers and contractors (Pong, 2009). According to Harvey and Ashworth (1997), construction activities in any economy are concerned with the planning, regulation, design, construction and the maintenance of buildings and other structures. The problem of poor buildability is not found to be limited to the Ghanaian construction industry alone. Chiang et al (2004) stated the incompetence of technology level restricts local construction companies to undertake large scale construction project. Unbuildable designs throughout the construction project imposes hindrance on construction works which leads to additional time spent and extra costs to solve on-site technical problems. Researchers like Ferguson (1989), Griffith and Sidewell (1995, 1997), Glavinich (1995), and Gray and Hughes (2001) all attest to the fact that, designing for buildable projects should take account of the efficient use of available resources which includes labour force on site, general attendance provision from main contractor, specific machinery plants and equipment. External factors should be considered upon the change of geographic site conditions, local political situations and global economic climate (Pong 2009). Besides, as stated by Adams (1989); designers are required to assess the craftsmanship level and the competence of specialist to perform their buildable designs.

The end products of the construction industry are usually large and expensive projects generally spread over large geographical areas. Such construction works are made to fit the needs and specification of clients. Some components of such buildings are manufactured elsewhere by different industries and the products are varied components assembled on site. With this as a background, it became necessary over the years to come up with a construction procedure that will best aid construction by improving product reliability, minimising on -site operation, increasing efficiency, lowering cost, reducing waste on site, minimising on-site duration and minimising number of site personnel (Gibbs and Isack, 2003). This leads to the concept of buildability and off-site production with the sole aim of maximising material usage and cutting down on construction waste.

1.1.1 Buildability:

The interpretation of buildability was developed by Pepper (1994) who asserted the construction-orientated concept input into the project life cycle. Ferguson (2003) also defines Buildability as the ability to construct a building efficiently, economically and to agreed quality level using various material components and sub-assemblies. Holroyd (2003) on the other hand defines Buildability by going further to add that in addition to the above, the construction work be designed in such a way to enable safe and cost effective construction, maintenance, alteration and demolition. ‘‘Buildability is concerned with activities on site and, specifically, with sequences of operations and building methods. It is about the dynamics of building, about the rough and tumble of building work and about the difficulties inherent in putting together a complex jigsaw of materials, components and sub-assemblies, often in bad weather and at all seasons of the year''.

In 1996, The Construction Industry Institute (CII) from Australia revealed that the balance between construction knowledge, environmental constraints and project performance is also important to raise the buildability to an optimum level. Yu and Skibniewski (1999) stated the state-of-art construction technologies from past experiences can boost the buildability level. Buildability as a key element in building production is seen in the efficient and economical production of a building and requires the logical organization of the sequence of assembly. Each activity in that sequence should be made possible by a process which requires that the materials, components and sub-assemblies are delivered on site, handled, stored, converted and prepared ready for assembly into the building. To maximise economy and efficiency, there is the need to ensure continuity of work; good management of labour, plant and equipment is complimented by the process mentioned above. Good buildability, assisted by efficient management, ensures that the assembly sequence is logical, that the building process can easily be followed and that the best flow of materials, components and sub-assemblies can be maintained (Ferguson 1989).

1.1.2 Off-Site Production:

Off-site production involves the assembly of pieces in a factory, followed by the transportation of the assembled components to its permanent location and the final fit up. Off-site production reduces the hazard level of a task in two ways. Firstly, it allows the work location to be shifted to a lower hazard environment where risk associated with working at heights or in confined spaces are reduced; secondly, off-site production allows the work to be shifted from the construction site to a factory, which allows for the use of safer, automated equipments

(Toole and Gambatese, 2006). Off-site production techniques have been used increasingly in construction as a means of improving quality and increasing efficiency. In order for the concept of off-site production to be widely approved and implemented on site to the benefit of the client as well as the design team, care must be taken by the design team to consider the technique at an early stage of design (CIRIA 2003). Off-site production involves standardisation and pre-Assembly (Prefabrication). Design Standardisation involves the modularisation, simplification and repetition of design detailing (Adams and Ferguson, 1989). The use of standardisation or building rationalisation depends on geometry and requires in-depth explorations on the part of the Designer or Architect. Its main goal is to achieve a harmonic fit of geometric orders in plan as well as in section, while at the same time resolving the problem of structural co-ordination among the various parts of a building without losing sight of its aesthetic appeal. Thus allaying the fear of most clients that the end product will be a dull and boring building without identity or flexibility. A house need not be symmetrical or boxlike in order to be modular (Hersey and Freedman, 1992). Repetitive components when encouraged will lead to the end of the era of material wastage on site due to materials not being the right size and thus the need to cut. Historically, proponents of the concept of standardisation and prefabrication (off-site production) in housing have been many. As far back as the fourteenth century, Palladio, sometimes referred to as the most influential architect in history, in his designs of Palladian and neo-Palladian villas which dominated the renaissance to the present embodied all his designs with geometric rules. He believed that, the design of a house needed numerical rules and analysis, calculations, statistics and measurements and they must be viewed with extraordinary details (Hersey and Freedman, 1992).

The prefabrication of components, elements, or even entire structures off-site as an alternative to working in-situ has been extensively applied in the past, although recently developed approaches have led to a more refined and better developed practical application. Standardisation and pre assembly has been successful in many a prominent project including the Hong Kong Airport. Regardless of the degree of off-site production, it is required that the construction process be broken into stages. The quality of the final product is dependent on both the materials used and attention to details as it does on the construction method. Off-site production can be generic, client specific, supplier led or project specific. It can also take the form of components, sub-assemblies, volumetric preassembly and modular buildings (Holroyd (2003). From an occupancy view point, off-site production in the construction process can add a lot of value to a project, as seen in a balance of lower time; optimum cost and high quality can be achieved based on the assessment of the whole project life span. Off-site production will result in early completion, user satisfaction, ease of maintenance and replacement.. The selection of the appropriate level of off-site production will depend on the specific project and should be clearly driven by the stated value needs of the project. Current building deficits and the need to provide about a million new houses to meet the national housing needs of Ghanaians all point to the fact that such an approach is needed in the country's construction industry. Technological advancement allow concepts like off-site production to address many of the problems facing the house building industry, such as a shortage of labour skills and the need for greater client involvement (CIRIA, 1999). The use of off-site production eliminates or reduces many traditional construction work task with serious risk factors (Simonsson and Rwamamara, 2007). Gibb (2000) further suggests that permanent works designers could reduce the risk by reducing the amount of work done on the construction site, mainly through increased use of some form of preassembly. A major reason posted for the reluctance among clients and contractors in adopting off-site production is that they have difficulty ascertaining the benefits that such an approach would add to a project (Pasquire and Gibb, 2002). The use of off-site production, by many of those involved in the construction process, is poorly understood and based on anecdotal rather than data supported intelligence (CIRIA, 2000). Some view off-site production as too expensive to justify its use, whilst others view off-site production as the panacea to the ills of the construction industry's manifold problems (Groak, 1992; Gibb, 2001). The benefits of off-site production directly or indirectly lead to health and safety of the construction worker and should be considered at the design stage.

1.2 Problem Statement

In recent times, much research has been done in ways of incorporating off-site production into the construction industry with the aim of improving higher quality standards and reducing on site construction duration and cutting down on material waste on site (Gibbs, 2001; Hampson & Brandon, 2004). The building of houses is the contribution made by the construction industry to the advancement of the living standard of the populace. Care must be taken to make sure that things are done the right way. The building process is now associated with the problem of the separation of design and construction as a once accepted method of weaving design and construction into a continuous unified building process. One with several advantages over the traditional way of the designer handing the drawing over to a contractor for execution without much supervision from the designer is the order of the day.

There is also the problem of poor communication between members of the building team and increasing complexity in design (Feld and Carper, 1997). All these factors coupled with external factors such as economic recessions and inflation has led to the need for professionals in the construction industry to adopt concepts like good buildability practices and the prefabrication of components off-site with the aim of managing construction resources for the betterment of the construction industry. Stakeholders of the Ghanaian construction industry most often than not are quick to state that their relatively higher construction process cost is having an adverse effect on their financial performance. The inability of most of these stakeholders to move with the changing tides and introduction of better and more effective and efficient construction methods are making them less competitive. The problems associated with the building process include: Designers not standardising building drawings to make buildings more economical; this could be attributed to the little knowledge most construction professionals have on the moving trends in the construction industry worldwide.

Various forms of waste on site especially those associated with the traditional project delivery system used by stakeholders of the Ghanaian construction industry contributes to the industry's incidence of high construction cost, poor financial performance and decreased value in end product. These are but a few of the effects of waste on site. Final finishes which make up a bulk of the total cost of a building are treated anyhow, waste activities such as over production, multiple handling, defective products, unnecessary waiting are also have their toll on the already grave situation thus affecting the construction industry.

Delay in construction projects completion is also having a negative effect on the credibility of Ghanaian construction industry to deliver optimum value for their customers´ investment. Nicco-Annan (2006) observed time overruns of between 12-24 months from a survey conducted on the construction of some office buildings in Accra. Failure to complete projects at the right time is seen by most clients as a compromise on the value expected to be derived from the projects. Most clients are therefore left dissatisfied seeing their projects not being completed in time.

Untimely delivery of value for money to customers by stakeholder in the Ghanaian construction industry is also a major issue. There have been incidents of customer dissatisfaction resulting from the inability of products and services delivered to aptly meet the needs and expectations of customers. There are reports that in Ghana, clients of the construction industry continue to complain about the industry's performance and its seeming inability to deliver projects on time, within budget and to expected quality standards. The production system employed by stakeholders fails to produce to the exact specification thus decreasing the quality of products (Nicco-Annan, 2006).

Most Ghanaian contractors are used to the traditional system of building construction. Building projects have become very complex, and in most cases design and construction are more or less separated from each other and performed by different companies. This has led to many examples of defective designs, that is, designs that were not possible to perform or that needed redesign before it became buildable, resulting in delays and/or overrun of budgets (Glavinich, 1995; Nima, 1999).

1.3 Research Aim

The aim of the research is to establish how the use of off-site produced building components can improved buildability in the Ghanaian construction industry, especially in the development of Real Estate projects.

1.4 Research Objectives

1. To establish the extent of the practise of the concept of off-site production by stakeholders of the Ghanaian construction industry especially those in Real Estate Development

2. To look into the advantages of the adoption of off-site production in the Ghanaian construction industry

3. A look at the limitations to the practise of off-site production in Ghana

4. To look at effect of construction failure on buildability in the Ghanaian construction industry

5. Examine the cost implications between the use of traditional construction method and off-site production with respect to material waste control in the Ghanaian construction industry.

6. The likely possibilities for the practise of off-site production in the Ghanaian construction industry especially in the field of Real Estate Development.

1.5 Research Questions

i. To what extent is the concept of off-site production being practiced by stakeholders of the Ghanaian construction industry

ii. What are the likely advantages to the practice of off-site production in Ghana

iii. What are the likely limitations to the practice of off-site production in Ghana

iv. What are the effect of construction failure on buildability in the Ghanaian construction industry

v. What are the cost implications in the use of traditional method of construction and off-site production with respect to material waste control

vi. What likely possibilities are there for the practice of off-site production in the Ghanaian construction industry especially in the field of Real Estate construction

1.6 Scope

The scope of the study was limited to key stakeholders in the building industry in the Ghana with particular reference to Architects, Quantity Surveyors, Civil Engineers, Suppliers and Manufacturers of off-site produced building components and Real Estate developers. All findings and fieldwork was limited to Accra and Kumasi.

1.7 An Overview of Method for the Study

The following approach was adopted for the research:

1. The major method is survey. This included the use of Questionnaires, Interviews and field observations
2. Questionnaires sought the views of professionals in the construction industry such as Architects, Civil Engineers, Quantity Surveyors and Contractors among others.

   *Visit to construction sites to ascertain the extent of the use of off-site produced building components

   *visit to manufactures and suppliers of construction materials and prefabricated components to determine patronage of off-site produced components in construction.
3. Review of relevant literature on buildability and off-site production with the aim of summarising past research and drawing conclusions from various studies that address the related problems.
4. Establish the applicability of the concepts to the construction industry of Ghana.
5. Mathematical review was used to examine the measured methods and operational definitions that were applied to the problem areas of the study.

1.7.1 Relevance of the Study

Off-site production has been an area where researchers from different countries have been looking into over the years especially how it can

1. Help minimise construction waste

2. Improve construction time and

3. Ultimately reduce cost of construction schemes.

The study focused on the need for the Ghanaian construction industry to identify off-site production as a key element for improving the Ghanaian construction industry in the shortest possible time. This will in the long run help meet the housing deficit in the country and also use same to increase the level of growth of the construction industry in the country especially in the field of real estate development where the use of repetitive designs is prevalent. The findings and recommendations of the study would lead to initiatives aiming at solving the problems relating to housing shortage in Ghana.

1.7.2 Research Outline

The first chapter of the research contains the introduction to the research. Sections within this chapter include problem statement, purpose of the study, aims and objectives of the study, research methodology as well as scope of the study.

Chapter two focuses on literature on the elements and activities in the Ghanaian construction industry environment as well as the concept of buildability and off-site production. With an aim of establishing how the housing deficit of the nation can be addressed with the use of off-site production to help aid in the putting up of buildable houses.

The research methodology is described in the third chapter of the work. Details like type of data to collect, data collection tools and data analysis tools have been discussed here.

Chapter four of the research contains data collected and analysis. Information obtained from the analysis of the data collected is discussed in this chapter.

Recommendations and conclusion on the research is contained in chapter five of the research. Proposals for the adoption of off-site production in the Ghanaian construction industry in general and the Real Estate development in particular and recommendations for its future implementation are discussed in this chapter.

CHAPTER TWO

The call for efficiency and productivity improvements in the construction industry suggests that construction has been characterised as adversarial and inefficient; and in need of structural and cultural reform. The reasons for the problems in the respective industries are complex, and require multiple, complimentary initiatives to effect significant improvement (Cole, 2003). The major thematic areas to be considered in the literature review to help address this issue include buildability and its impact on the construction industry worldwide as well as in Ghana and how buildable designs can help reduce the problem of construction failure. The call for improvement through off-site production is not surprising as construction in most countries is still a relatively low technology traditional industry with few changes in its structure and processes over the last century. There will be a closer look at the Ghanaian construction industry to ascertain its problems and look at the way forward to help solve the housing deficit in the country.

BUILDABILITY

2.1 What is Buildability?

The term buildability is specific to the construction industry and its meaning is mainly understood by players in the industry. Some construction industry practitioners are yet to come to the understanding of the whole concept of buildability. Ferguson (1989) defines buildability as the ability to construct a building efficiently, economically and to agreed quality levels from its constituent materials, components and subassemblies. Holroyd (2003) stated that in addition to Ferguson’s definition, there is the need to add that construction work must be designed to enable safe and cost effective construction, maintenance, alteration and demolition to take place. He proposes that everything possible should be done to make construction work easy, as easy work will be cheaper, safer, and quicker to execute than difficult work, thus satisfying clients. Arditi (2002) highlighted that ideally project objectives should be relative to the integrating knowledge and experience from engineering and construction professional.

Chen (1991) sees buildability as a critical factor of project success goals which involves a higher quality of project performance and simplicity in construction method throughout the overall building procurement process. The Construction Industry Research and Information Association (CIRIA) from United Kingdom in 1983 propounded that buildability focus on the completion of overall building facilitates with the uncomplicated construction methods. Southeast Asia Building (1993) developed the idea of buildability to the site operation level to realise buildable designs from desk study to on-site activities. The aim is to eliminate possible difficulty during construction stage. In 1996, The Construction Industry Institute (CII) from Australia revealed that the balance in between construction knowledge, environmental constraints and project performance is also important to raise the buildability to an optimum level. The Construction Industry Review Committee Report 2001 presented the intricate problems have existed long in the local construction industry. The poor performances of building product were frequently found throughout the construction process

2.1.1 Goals of Buildability

The goals of buildability depend on the scope it is intended to cover. Buildability goes beyond the conceptual design and final construction phase to the building performance and maintenance stage (Holroyd, 2003). The goal of buildability is to achieve optimum integration of construction knowledge in the building process and balancing the various projects and environmental constraints to achieve maximisation of projects and environmental constraints to project goals and building performance (Construction Industry Institute, Australia (CIIA) definition). Building projects have become very complex. In most cases design and construction are more or less separated from each other and performed by different companies. This has led to many examples of defective designs, that is, designs that were not possible to perform or that needed redesign before it became buildable, resulting in delays and/or overrun of budgets (Glavinich, 1995), (Glavan & Tucker, 1991) and (Lutz et al., 1989). Nima et al (1999) stated buildability not only requests the early involvement from client but also need the optimum use of construction knowledge and experience from contractors before the tendering award. It is therefore the goals of buildability to bridge the gap between design and construction in order to reduce such perceived problems to the barest minimum.

2.1.2 Principles of Buildability

In the management of buildability, twelve principles of buildability were developed and looked into by the Construction Industry Institute Australia, (CIIA). The principles are as follows.

1. ***Integration***: Buildability must be made an integral part of the project plan
2. ***Construction knowledge:*** Project planning must actively involve construction knowledge and experience.
3. ***Team skill:*** The experience, skill and composition of the project team must be appropriate for the project.
4. ***Corporate objectives***: Buildability is enhanced when the project team gains an understanding of the client's corporate and project objectives.

5. ***Available resources***: The technology of the design solution must be matched with the skills and resources available.
6. ***External factors:*** External factors can affect the cost and/or programme of the project.
7. ***Programme:*** The overall programme for the project must be realistic, construction sensitive and have the commitment of the project team.
8. ***Construction methodology:*** Project design must consider construction methodology.
9. ***Accessibility:*** Buildability will be enhanced if the construction accessibility is considered in the design and construction stages of the project.
10. ***Specification:*** Project buildability is enhanced when construction efficiency is considered in the specification of the development.
11. ***Construction innovation:*** The use of innovative techniques during construction will enhance buildability.
12. ***Feedback:*** Buildability can be enhanced on similar future projects if a post-construction analysis is undertaken by the project team.

The twelve (12) principles of buildability are then mapped onto the procurement process. The CIIA further advocates a structured approach which identifies the following stages in the procurement process.

1. Feasibility
2. Design
3. Construction
4. Post construction

2.1.2.1 Feasibility

Pong (2009) stated, in 1986, the Construction Industry Institute (CII) from United State in and Construction Management Committee (CMC 1991) advocated the collaboration of professional construction knowledge and experience from project team members to underpin the concept of buildability throughout the project life cycle from project feasibility study to construction period and operation stage after handover of completed building. Ferguson (2003) suggested enhancing buildable design with the balance weighting among product quality, building aesthetic, construction time and budget. After further research on the topic, Ferguson (1989) stated that, the feasibility studies should explore both ways of solving architectural problems presented by the design programme as well as alternatives that will optimise buildability. Feasibility requires a study of possible site utilisation, in the form of plot ratio and a study to address all relevant factors must look into possible building methods, including accesses, storage areas and location of major fixed plants even at the initial stage these factors will have a cost implication on the cost of the job which will reflect in the contractor's pricing.

2.1.2.2 Design:

According to Pong (2009), CIRIA (1983) carried out research studies of buildability and reported that many building designers lacked construction knowledge. This was attributed to lack of contribution of contractor's input in early project stage which has led to the poor project performance and inefficient building design production eventually. Ferguson, (1989) further state it is necessary for designers to consider the buildability of their design during the design process. With this in mind, a review of the process whereby materials are converted into components, components into subassemblies and subassemblies into the completed building must be done. The designer should envisage how the conversion will take place and how it can be done with minimum preparation using the most widely used and best equipment predictable. Close attention to buildability in the following areas will pay dividends. In 1996, The Construction Industry Institute (CII) from Australia revealed that the balance in between construction knowledge, environmental constraints and project performance is also important to raise the buildability to an optimum level. Geile (1996), after further studies on the subject, suggested the need for early involvement of client to benefit the communication among contractual parties throughout the project life cycle from the period of feasibility study to the building operation. The possible benefits toward the client business should be considered as well.

2.1.2.3 Construction:

Research by Glavinich (1995) emphasised the need to utilize the available resources effectively and efficiently, as it eventually enables the construction work to be undertaken within the budget and shorter construction time. Low and Abeyegoonasekera (2001) supported Glavinich's research and also pointed out the importance of smooth flow of materials, components and sub-assemblies to delivery resource on site, they moreover stressed on the fact that, logical sequence of operations and construction methods are also significant for buildability. Before that, Yu and Skibniewski (1999) revealed the state-of-art construction technologies from past experiences can boost the buildability level. This lays emphasis on the need to let past experience in construction act as a guiding principle to inform present and future works.

2.1.2.4 Post Construction:

The design of the building should be able to satisfy client's particular purpose as well as project functional requirements. The building provides the spatial space for carrying out occupant's activities at various building zone. The harmonic connection between outside communities is also considered. End user within the building should also have a safe, healthy and comfortable environment (Voordiy & Wegen 2005). According to Ferguson (1989), good post construction or life cycle buildability implies lower cost for routine maintenance and for replacement of a building's constituent materials, components and subassemblies and ultimately the building itself. Maintenance and replacement can be controlled by establishing a hierarchy of items likely to require attention, beginning with those with a short life span to those which will last for the building life cycle. The harder it is to maintain or replace a component or sub-assembly, the better the quality of the original work should be.

2.1.2.5 Buildability as a Key Element in Building Production

Buildability emerged as an area of research, based on the assumption that buildability problems exist because of the comparative isolation of many designers from the practical construction process (Chen and McGeorge, 1994). According to CIRIA, (1983), a widely accepted definition of buildability is: "the extent to which the design of the building facilitates the ease of construction, subject to the overall requirements for the completed building focusing on how to improve the productivity in spite of the complexity of a building project". This definition was criticised for its narrowness in scope. According to Chen and McGeorge (1994) a workable concept of buildability needs to recognise the many factors in a project environment which has an impact on the design process, the construction process, and the link between design and construction. They suggest that buildability might be redefined as: “The extent to which decisions, made during the whole building procurement process, ultimately facilitate the ease of construction and the quality of the completed project”. Wong et al (2005) sided with Chen and McGeorge (1994) as their research also critisised the former definition in that, it essentially confined buildability to the design process. Earlier research by Adams (1989) stated designers are responsible to design the simplest method statement dealing with on site detailed works. The elaborate designs should be able to smooth the progress of construction programme, thus critical path of site operations can be variable in despite of the complexity of task sequencing and the interrelationship between different sub-contractual works; e.g. material on site, material storage, material handling, details positioning and installation. The efficient programme management occupies high mark of construction safety environment. Likewise, site accidents and unwanted expenditure can be diminished (Pong, 2009).

Studies by Ferguson (1989) sided with the research findings of Adams (1989) and later reinforced by Pong (2009). He stated to put up a building in an economic and efficient manner requires a logical organization of the assembly sequence. Each sequence of activity must be made possible by ensuring that materials, components and sub-assemblies are delivered to site, handled, stored, converted and prepared ready for assembly into the building (Figure 1). Labour, plant, and equipment must be well managed to ensure continuity of work through the flow of materials, components, and sub-assemblies into the construction process. Good buildability assisted by efficient management ensures a logical sequence to the assembly to ensure the building process can be easily followed to optimise the building process. Care must be taken that, agreed quality level in terms of ‘function and performance’ and aesthetics in relation to ‘cost and buildability’ is achieved at the end of the building process to ensure project success.

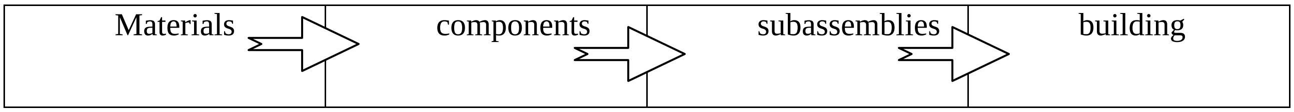


Figure 1 **Assembly sequence on construction site**

Adams (1989) stated good buildability is a main determinant if the constructions of buildings are to be efficient and economical, which depends on the assembling of materials, components and sub-assemblies at the assembly point into the building to optimize efficiency. Logical, accurate and speedy assembly does not only depend on organizational competence but also on the ease of assembly and the competence of the site personnel to achieve a successful project. Nevertheless, the achievement of good buildability depends upon both designers and builders being able to see the whole construction process through each other's eyes.

2.2 Bad Buildability; - Construction Failure

The complexity of the building industry is portrayed in the many specialized disciplines contributing to the project delivery system. The mistakes committed by each of these professionals if discussed well would have led to the avoidance of many errors and construction failures on site; thereby solving the problem of construction failure (Feld and Carper, 1997). According to Ortega (2000), each construction failure provides information that may be used to prevent similar failures. Therefore, the systematic investigation of construction failures should be encouraged. These investigations identify errors to be avoided, and thus contribute to increase the safety of future designs. Each construction failure points to a gap either in theory or practice and thereby fosters innovations. Feld and Carper (1997) stated that even in the ancient days, the first rule in the laws of Hammurabi (approx. 2000 BC) did not promote prevention of failures by learning from mistakes. It stated: "If a builder builds a house for a man and does not make its construction firm and the house which he has built collapses and causes the death of the owner of the house – that builder shall be put to death." This rule certainly prevented sloppy work and poor craftsmanship.

Feld and Carper (1997) stated failure comes in two forms. Firstly, it can be defined as a catastrophic structural collapse of which there are few, or secondly, nonconformity with design expectations can also be defined as failure of which there are many if one goes through the problem to measure the shape, position and condition of completed building structures. Most often than not, more than one single cause come together to cause a construction failure. The American Society of Civil Engineers has adopted the definition of failure first advanced by Leonard (1982). "failure is an unacceptable difference between expected and observed performance". Ayininuola and Olalusi, (2004) on the other hand stated there are two types of failures. These are cosmetic failure or structural failure. Cosmetic failure is the failure that occurs when something is added to or subtracted from the building, thus affecting the structures outlook. Structural failure on the other hand affects both the outlook and structural stability of the building. After much research on the subject, Ortega (2000) further stated, nowadays, despite computer-aided design technology and sophisticated scientific theories, construction failures have not ceased to occur. In the past, lack of scientific knowledge was a main factor leading to construction failures. Today, however, carelessness and negligence have risen to greater prominence. Also, political and economic trends are increasing the economic pressure on the construction industry, resulting in failures from careless design and inadequate construction practices. Failure may be as a result of a single error. But it is however more common for failure to result from several interrelated contributing factors. These may be as a result of material performance errors or technical problems. The deficiencies often result from judgmental errors on the part of contractors or designers or from human tendencies towards ignorance, incompetence, greed and negligence. Excessive environmental conditions or unexpected loads not taken into consideration by the designer are also failure factors. It must however be noted that a particular failure may be as a result of a combination of two or more of the factor listed above (Feld & Carper (1997). To help address the problem of construction failure, extensive research by (Feld and Carper, 1997; Gnaedinger, 1987; Kaminetzky, 1991; Ortega, 2000; Petroski, 1994, 1993, and 1992) showed the knowledge gained from studies on the subject should be systematically organized and made available to all interested parties, example, in the form of electronic databases or of Internet pages. Unfortunately, only major failures are reported and therefore broadly discussed. Information from minor, but cumulatively more important, failures is often kept secret, mainly because of legal reasons and of fear for the reputation of the parties involved. Organisations involved in liability suits often do not provide access to information concerning present and past failure cases. The knowledge gained from construction failures is therefore insufficiently organized and at the disposal of a limited number of persons. Independent, state-run institutions, such as universities, are better suited for the scientific investigation of construction failures, not only because of their impartial nature, but also because of the social and economical relevance of the built infrastructure and the high costs of these investigations (Ortega, 2000). On the same subject, Lin and Stotesbury (1988) wrote, architecture and engineering projects should be carried out in a collaborative manner. In most cases, architecture and engineering projects are completed sequentially, with the architectural design, the engineering design and the actual construction undertaken by the architect, the engineer and the contractor, respectively. The sequential design process has severe disadvantages. Besides holding back creativity, it is detrimental to construction projects because engineering and buildability concerns are not addressed early, when project changes are most economically carried out. Collaborative designs should be carried through by architects, engineers and contractors working together from the beginning until the end of the construction project.

Among the errors frequently occurring during the design and construction phases are the following (Bell and Liepins, 1997; Kaminetzky, 1991; Feld and Carper, 1997):

1. Fundamental errors in concept.
2. Site selection and site development errors
3. Programming deficiencies
4. Design errors
5. Construction errors
6. Material deficiencies
7. Operational errors

2.2.1 Fundamental Errors in Concept

Fundamental errors in basic concept according to Feld and Carper (1997) occur when there is an attempt to build something beyond available technology. The scale of such a project may be unique and outside the envelope of past experience. Some projects may be located in an unusual environment where environmental conditions and effects are unreliable and difficult to predict. Some of these failure types are more of economic rather than structural failure. The concept of such projects are later found out to be technically flawed or that the resolution of evolving problems will require far more economic investment than originally anticipated project in this category may be abandoned and will be considered failure by most observer. The first recorded example of a failure due to a concept is Biblical: the collapse of the tower of Babel in Genesis 11. The proposed concept of an unreinforced masonry tower "who's top would reach to heaven" was fundamentally flawed. The result was an inevitable collapse. To check fundamental errors, Bell (1989) and Zallen (1990) writes that, complex, unconventional or large architecture and engineering projects should be reviewed by an independent professional or organization.

2.2.2 Site Selection / Site Development Errors

Many important factors must to be considered while designing and constructing a building. The foremost factor to be analysed is the soil conditions at the site. Soil is a leading cause of building defects. If the soil is not suitably prepared, it can cause severe damage to the complete building, including the ground floor, walls, and the roof (Orfano, 2009). According to Feld and Carper (1997), the natural environment is extremely complex and constantly changing.4 The natural environment is dynamic but not static and different sites and locations are prone to different environmental conditions and natural disasters. The choice of site or location of various construction projects must take the peculiarity of the site selected and the design made to fit it appropriately. Unwise land use or site selection may result in failure. Specific soil conditions make certain sites more vulnerable than others to failure such as expansive soils. Geo-technical studies must be undertaken to determine the characteristics of particular site conditions, to aid site selection and development that reduce the risk of failure.

2.2.3 Programming Deficiencies

The definition of failure as an unacceptable difference between expected and observed performance implies that the designers must understand the expectations of clients realistically (Feld and Carper, 1997). Clients are likely to define a project as a failure when the project expectations are not met; no matter how unachievable or unrealistic it may be, given the economic constraints. Unrealistic and unclear expectations are the root cause of many construction litigations. This type of failure could have been avoided through communication during the programming phase of a project. A programme should clearly define the scope and intent of a project at the outset. So that general agreement can be reached as a way to measure the success of the completed project. In order to achieve this goal, several review meetings should be held starting from the design phase until the actual construction phase (Goodden, 1996). These meetings Ortega (2000) stated have the purpose of reviewing the technical aspects of the architecture and engineering project. Architects, engineers and contractors should participate in these meetings. These reviews should be thoroughly documented. All relevant problems should be discussed as early as possible. It is well known that the cost of carrying out modifications increases as the project progresses.

2.2.4 Design Errors

Analysis of historical construction failures by (Levy and Salvadori, 1994; Petroski, 1994, 1993, and 1992) suggest that unconventional designs may disclose new types of failure, which remain latent in conventional designs. Designs with geometrical dimensions or other characteristics outside the experience envelope may behave unexpectedly and reveal new or surprising failure mechanisms. In many cases, such mechanisms cannot be predicted despite advanced computer programs, because the available computer programs do not simulate the relevant physical phenomena. Further study on the subject led Rice (1994), to state, designers must never forget that we do not build our designs ourselves. Designers must therefore anticipate and avoid any mistakes, but if an error does occur it must be evident from the very beginning that we will be there to take our share of the responsibility and that we will always be available to see our work correctly completed. ... It may be difficult to persuade the client to pay for one's presence, particularly if the contractor perceives this as unnecessary. But persevere we must because with any other scenario disaster looms." Construction projects are complex because of the division of tasks and responsibilities between architects, engineers, and contractors. According to Orfano (2009) the design developed by an architect or an engineer may be aesthetically good, but it could be functionally ineffective. Therefore, the builder and the architect should work jointly to ensure that the design is perfect and will not cause structural failures.

For the time being, research by Feld and Carper (1997) pointed to the fact that, during the expected life span of a building failure may occur at any time. Deficiency in the basic design of a structure including incorrect amount of reinforcement at points of maximum moment, incorrect dimensions of concrete or steel sections to provide sufficient resistances for normal loading, is a rare cause of failure. Most failure cases can be attributed to design errors. These include: error in design concept, calculation errors, failure to consider a load or a combination of loads, deficient connection details, detailing problems, including selection of incompatible materials or assemblies that are not constructible, Misuse of computer software, Failure to consider maintenance requirements or durability, Inadequate or inconsistent specifications for materials or expected quality of work and Unclear communication of design intent.

2.2.5 Construction Errors

Studies on the problem of construction error by Carper (1987) stated that particular attention must be given to the construction phase. According to him, the loading cases relevant to each step comprising the construction phase should be carefully analysed. The adequacy of the selected temporary structures and the value of the chosen safety factors should be justified. He further recommended the Inspection of construction site by designers. Architects and engineers should carry out site inspections of the construction process to ensure that structures are built safely and according to plan. After further studies on the subject, Feld and Carper (1997) stated Construction is a risky occupation. Many failures of cast-in-place concrete structures occur during construction due to inadequate temporary support, premature removal of shoring and premature loading of concrete. Other construction error failures include excavation accidents, construction equipment failure, and improper construction sequencing which is absolutely critical for some construction types such as post-tensioned pre-stressed concrete. Design assumptions of sequencing if not properly followed can have catastrophic results. Inadequate temporary support, excessive construction loads and nonconformity to design intent such as dissimilarities between design documents and the as-built.

2.2.6 Material Deficiencies

There is the saying that materials do not fail; people fail. Though it is true that most problems with materials are human errors involving lack of understanding about certain materials or the ignorant juxtaposition of incompatible materials, there are certain failures that can be attributed to unforeseen material inconsistencies. Manufacturing or fabrication defects may exist in the most reliable structural materials (Feld and Carper, 1997). Ortega (2000) stated, the use of unconventional materials without a thorough understanding of their behaviour in the intended environment should not be attempted. It is recommended to consult an independent expert on the material in question. Researching on the problem of the use of defective materials, Yates (2009) wrote construction projects are on contractual basis so low cost materials are bought to save in financial terms. Low quality cement is cheap but it causes a huge decline in the standard of the constructed building. The time for wear and tear is reduced and the building texture becomes more vulnerable to factors like dust and rain. As a result the outside texture of constructed building starts to erode at a very quick rate and with the passage of time; the overall structure becomes weaker and weaker. Hence ultimately the building falls resulting in irrecoverable human loss.

2.2.7 Operational Errors

Failures can occur after occupancy of a facility as a result of operator/ owner error. These include alterations made to the structure, change in use, operational judgment errors, negligent overloading, and inadequate maintenance. Operational failures can occur when maintenance or operation personnel do not have the requisite knowledge or skill to operate the facility properly. Designers and contractors also share the responsibility of durability of constructed projects, through appropriate selection of materials, design for maintainability and quality of construction- Feld and Carper (1997). According to Ortega (2000) exceptional or unconventional structures should be monitored not only during the construction process but also during the operative phase. A monitoring strategy should be developed during the design stage, before construction has started. In this manner, the behaviour of structures can be studied. To help address the problem of construction failure, the close cooperation of the designers or builders of a failed structure will help determine early, accurately and economically the failure's cause (Ortega, 2000). Although failures will probably not cease to happen, certain strategies can be implemented in order to reduce their frequency. Besides presenting successful design examples, education at universities should point to errors to be avoided (Gnaedinger, 1987). There must also be ongoing research as failures refer to gaps in scientific knowledge and therefore, scientific investigations of construction failures should be carried through and the lessons learnt from failures should be disseminated as quickly as possible. Ortega (2000) further stated failures also point to gaps in building practice. Building codes need to be updated to take account of the conclusions reached from failure analysis.

To help check all these problems of construction failure there is the need to train the local construction workforce in new trends and advancement in construction and if possible shift a bulk of the construction activities from the worksite to factories where components can be manufactured off-site under strict supervision.

2.3 Off-Site Production

Off-site production is the process of prefabricating building components /or preassembly of building components off-site. The use of off-site production (OSP), by many of those involved in the construction process is poorly understood (CIRIA, 2000). Some view off-site production as too expensive to justify its use, whilst others view it as the panacea to the ills of the construction industry's manifold problems (Gibbs, 2001). Neither of these views is holistically correct. The benefits of off-site production are largely dependent on project – specific conditions, and the combination of building methods used on a project. The UK and Australian construction industries have identified off-site production as a key vision to improving the industry over the next decade (Hampson and Brandon, 2004; Latham, 1994; Egan, 1998). According to Cole (2003), the Australian construction industry has been characterised as adversarial and inefficient; and in need of structural and cultural reform. The reasons for the problems in the respective industries are complex, and require multiple, complimentary initiatives to effect significant improvement. However, calls for efficiency and productivity improvements across these industries suggest that off-site production has a major role to play. In the UK, government commissions view off-site production as an important contributor to progress in the construction industry (Egan, 1998; Barker, 2004; Gibb, 1999). According to Blismas and Wakefield (2009), the call for improvement through off-site production is not surprising as construction in most developed countries is still a relatively low technology traditional industry with few changes in its structure and processes over the last century. By contrast, substantial advances have been made in manufacturing, logistics and service industries over the same period. Howell (1999) explains the peculiarity of the construction industry from the manufacturing sector as ‘‘manufacturers make parts that go into projects but the design and construction of unique and complex projects in highly uncertain environments under great time and schedule pressure is different from making tin cans’’. A pilot study by Pasquire and Gibbs (2002) demonstrated that the decisions to use off-site production are still largely based on anecdotal evidence rather than rigorous data, as no documented measurement procedures are available. In the study, evidence is presented demonstrating that current evaluation methods for comparing traditional and off-site produced building solutions do not adequately account for all the main factors that affect cost. Research in UK has generally concentrated on case studies and anecdotal evidence, with a limited number of industry surveys or applied process mapping and improvement studies. These largely industry-level studies have produced an abundant array of benefits and barriers to off-site production, with the hope that these would spur activity. Despite these well documented benefits, acceptance of off-site production has been limited (Neale *et al.*, 1993; Bottom *et al.*, 1994; CIRIA, 1999,2000; Gibb and Isack, 2003; Goodier and Gibb, 2004a,2004b). Pan *et al.* (2007) also reported that the use of off-site production in the UK housing sector was very low, with most top 100 house builders rarely using any off-site production. Major research efforts have focused on presenting positive examples of off-site production within the construction environment. Gibb (2001) included a series of case studies with some historical and contemporary examples of off-site production ranging across all building types. Examples and case studies, however serve no more purpose than to stimulate those not experienced in off-site production to investigate the options on a project. The problem, as noted earlier, is an ability to then objectively assess the benefits offered by off-site production for a particular project. Another school of research has attempted to identify the value-adding aspects of off-site production, so that the benefits could be better assessed and realised within projects considering adopting off-site production. Blismas and Wakefield (2009) stated that, the Construction Industry Research and Information Association (CIRIA) conducted a research project entitled "Adding value to construction projects through Standardisation and Pre-Assembly" in 1999 in which the value gained from the application of off-site production was reviewed. The reports concluded that a deliberate and systematic use of off-site production, which commenced early in the process of the project, would increase predictability and efficiency, and ultimately add value to the process (Gibb, 2001). Further associated studies developed interactive tools for ascertaining the value-added benefits of off-site production. Blismas *et al.* (2003) developed a tool enabling a comparison between traditional methods and off-site production options, highlighting that a holistic evaluation would provide a more comprehensive assessment of value than is commonly used in the industry, which is centred on simple cost comparisons.

Table 1. **Clients' perception of the benefits of off- site production.**

Benefits	Description (indicates high incidence)
Time	Less time on site – speed of construction
	Speed of delivery of product
	Guaranteed delivery, more certainty over programmes
	Reduce management time
Quality	Higher quality on-site and factory
	Product tried and tested in factory
	Greater consistency – more reproducible
	More control of quality, consistent standards
Cost	Lower preliminary and overall cost
	Increased certainty, less risk
	Increased added value
	Lower overheads, less on-site damage
	Less wastage
Productivity	Includes less snagging
	More success at interfaces
	Less site disruptions
	Reducing the use of wet trades
	Removing difficult operations off- site
	Work continues on site independent of off-site production
People	Fewer people on-site
	People know how to use products
	Lack of skilled labour
	Production off-site is independent of local labour issues
Process	Programme driven centrally
	Simplifies construction process
	Allows system to be measured.

Source: Gibb and Isack (2003)

A lack of understanding of the construction process and its associated costs is arguably the single most significant barrier to the use of off-site production in construction. With this historically entrenched approach to costing, off-site production will invariably appear more expensive than traditional methods. According to a large interview based survey to determine construction clients' view on the benefits of off-site production (OSP), Gibb and Isack (2003), describes the benefits of off-site production as being mainly time and quality based. Table 1 summarizes their findings in descending order of benefits. Further interviewees of Gibbs and Isack (2003) were asked to rank a list of key benefits from the initial interviews and literature, bearing in mind both the importance of the benefits and the likelihood of realising the benefit. The main benefits are from indirect cost savings and non cost value adding items. Based on the findings, the table below shows the rating of benefits of off-site production from highest to lowest according to importance and likelihood (Gibbs and Isack, 2003).

BENEFITS FROM MOST HIGHLY RATED TO LOWEST RATING.

1. Minimise on-site operation
2. Reduces congested work area and multi trade interfaces
3. Minimises on-site duration
4. Improve health and safety by reduction and better control of site activities
5. Produces high quality or very predictable quality finishes
6. Minimises number of site personnel
7. Benefits when only limited, or very expensive on-site labour
8. Enables existing business continuity
9. Can cope with restricted site storage area
10. Enables inspection and control off-site work

11. Provides certainty of project cost and outcome
12. Provides certainty of project completion date
13. Less environmental impact by reduction and better control of site activities.

A similar study by Gorgolewski (2003) on the other hand summarizes the benefits of off-site production as follows

1. Reduced local benefits.
2. Reduced levels of defects
3. Less waste in manufacture
4. Health and safety
5. Improved environmental performance of final product
6. Social benefits from improved working conditions
7. Greater efficiency in the use of resources, both materials and labour
8. Transport

2.3.1 Reduced Local Impact

With the key feature of off-site production being that most of the work is removed from site to a controlled factory condition, there is a reduction in the time spent on site which leads to reduced impact on the locality. Experience has shown that most off-site manufactured buildings can be assembled and be ready for use in about half the time needed traditional buildings of the same type. This means that the locality around the site is disrupted for a shorter period of time reducing noise, pollution emission and local traffic disruption in the case of built-up areas. Furthermore, the lightweight nature of the construction may offer potential for smaller foundations and lead to less ground works, reduction in local disruption from moving soil away from the site, and bringing concrete in to use for foundation. On the other hand, the large deliveries of the volumetric and panel units to the site must be managed well, so as not to cause disruptions to local activities (Gorgolewski, 2003). In conclusion, a shorter construction period will lead to quicker return on investment to the client and reduced overheads (Blismas and Wakefield, 2009).

2.3.2 Reduced Level of Defects

A building site exposed to adverse climatic conditions does not offer a good working condition for high quality workmanship and quality construction. They are not attractive working conditions for the workforce. In other industries, such as car manufacture or electronics, zero faults are expected yet in the construction industry, defects in buildings are common at handover, and often take a long time and are costly to rectify. Factory based activities allow better and safer working conditions and being protected from the climate, are more likely to use to better quality. In a factory, it is easier to set up quality control procedures, with testing, prototyping and checking. This in the end ensures the best quality of products. It is a significant cost and efficient benefit to the builder and leads to satisfied customers. Efficiency is also improved in the use of resources and reduced waste. Manufacture in a factory provides much better working conditions than a building site (Gorgolewski, 2003 & Blismas and Wakefield, 2009).

2.3.3 Less Waste in Manufacture

Manufacture in a factory allows for better management of the waste stream. Materials can be used more efficiently, exact amounts of materials can be ordered and materials can be stored more carefully. In addition, any waste that occurs in a factory can be easily collected for reuse or recycled. There is further potential for reducing waste when using off-site fabrication if the designer is prepared to co-ordinate sizes so that materials such as timber and tiles among others are used in their standard sizes without generating many off cuts. Prefabricated components assembled on site should generate little waste as components come to the site pre-engineered to assemble together (Gorgolewski, 2003 & Gibb and Isack, 2003).

2.3.4 Health and Safety

On site construction work can be a dangerous activity and can lead to a significant number of casualties and even fatalities. The demands for health and safety requirements on construction sites are pushing many builders to consider different ways of building. This includes off-site manufacturing techniques. This technique allows much of the process to be carried out in a factory where conditions are more controlled and comfortable, and where safety requirements can be easily met and monitored, and healthy and comfortable working conditions can be maintained more easily. On the other hand, the use of cranes to assemble prefabricated components on site requires careful planning and management (Gorgolewski, 2003; Neale *et al.*, 1993; Bottom *et al.*, 1994).

2.3.5 Improved Environmental Performance of the Final Product

Correct installation of the building components, especially insulation materials and air barriers are important to the performance of a building in use. Factory manufacture allows operatives to be better trained and supervised in these tasks and allows regular checking and testing of performance. Since manufacturers will be producing such components en-mass for different sites, there is the potential for manufacturers to take more time with the selection of environmentally friendly materials and establish local supply chains in the area of the factory (Gorgolewski, 2003 & Gibb and Isack, 2003).

2.3.6 Social Benefits from Improved Working Conditions

A factory manufacturing prefabricated building components offer stable skill and long term employment than site employment which is intrinsically transient. Due to this, factory based employers are more willing to invest in training their workforce. Also, high level of skill and flexibility is necessary to make off-site fabrication function efficiently. This demands greater training by employers. Building sites are usually temporary employment locations with little commitment to the local communities whereas manufacturers in factories often have close links to the community, employing many local people, thus providing long term economic and often social services to the community (Gorgolewski, 2003 &Gibb and Isack (2003).

2.3.7 Greater Efficiency in the Use of Resources, both Materials and Labour

Building sites have a problem of maximising the use of labour and materials. Site use of labour is considerably less efficient, about (50%) in some cases as compared to factory based activities, with a considerable percentage of materials delivered on site also going to waste. For example, volumetric construction using prefabricated modules allows buildings to be dismantled and relocated (Gorgolewski, 2003; Neale *et al.*, 1993; Bottom *et al.*, 1994).

2.3.8 Transport

Monitoring of transport to a construction site is a complex and difficult issue. The deliveries of off-site fabrication need large vehicles often travelling considerable distances from the factory. The nature of the work also means that less labour is required on site for a shorter period. In short, a well managed site using off-site fabrication can significantly reduce the amount of traffic generated. On the other hand, transport movement to the factory should be considered, whilst material deliveries to a factory can be planned so that full loads can be delivered (Gorgolewski, 2003). Off-site production addresses the new construction agenda of improving efficiency in construction through waste minimisation, process integration, a commitment to people and a quality driven agenda. However most of the benefits outlined are not yet being fully realized, and the construction industry is yet to come to grasp of the full potential of this technology. It is also possible that this technology can lead to the loss of some traditional site skills and move away from the local supply of labour to sites. Strong adherence to the tenets of off-site production will eventually lead to the era of project success from the point of view of designers, contractors and clients.

2.4 Buildability, Off-site Production and Project Success

A successful project is difficult to define. According to Pitagorski (1998) it is one that satisfies the client and sponsors with an outcome that achieves project within time and cost constraints, produces quality products, ends when appropriate, maintains and promotes harmonious relationships among project stakeholders and contributes lessons learned to the organisation. Latham (1994) notes that, a successful project must have value for money, be pleasing to look at, be largely free from defects, timely delivered, fit for the intended purpose, guarantee reasonable running cost, durable and the end result must be customer delight. As outlined in the Table 1.1, owners are interested in their project on time and on budget. Contractors and designers both expect a certain profit and fee goals. However all the three parties' priorities timely project completion on time. The problems with these criteria according to Sanvido et al (1992) are:

a. All factors are deemed to be equally important whereas in practice some are more important than others.

b. It is impossible to satisfy all these criteria on a single project, thus the need to prioritize them.

c. Measurement is a problem as some of these criteria can be measured quantitatively (objectively), whereas others can be measured qualitatively (subjectively). There is a difficulty in agreeing to a criterion for measurement.

Table 1.1 **Criteria for measuring project success from owner, designer and contractor view points.**

OWNER'S CRITERIA	DESIGNER'S CRITERIA	CONTRACTOR'S CRITERIA
On schedule	Satisfied client	Met schedule
Within budget	Quality architectural product	profitability
Functions for intended use	Met design fee & profit goal	Under budget
End result as envisioned	Professional staff fulfilment	Quality specification met / exceeded
Quality workmanship, product	Met project budget and schedule	No claims for liability
Aesthetically pleasing	Marketable product / process	safety
Return on investment	Minimal problem	Client's satisfaction
Marketable building	Building function as intended	Good customer buy-out
Minimal aggravation in producing building	Socially accepted	Good direct communication
	Client pays	Minimal or no surprises during the project
	Well defined scope of work	

Source – Sanvido et al (1992)

Project success is therefore a subjective issue though certain basic criterion must be met. Therefore to avoid any subjectivity, before the commencement of any project, the project team must come up with a set of criterion to determine the success of a project.

2.4.1 Factors for Measuring Project Success

Sanvido et al (1992) defined critical success factors as those factors predicting success on projects. Munns and Bjeirmi (1996) noted the factors that affect the success of a project to be; a realistic goal, competition, client satisfaction, definite goal probability, third parties, market availability, implementation process and the perceived value of the project. The following steps in Table 1.2 are also suggested to ensure the successful completion of a project.

Table 1.2 **Steps to ensure project success.**

Planning with a commitment to complete the project
Careful appointment of a skilled project manager
Spending time to define the project adequately
Correctly planning the activities in the project
Ensuring correct and adequate information flow
Changing activities to accommodate frequent changes
Accommodating employee’s personal goals with performance and rewards
Making a fresh start when mistakes in implementation have been identified.

Source – Sanvido et al (1992)

For a successful project to be achieved, it is important that certain principles are followed. One of these is the project procurement system which seeks to help achieve buildability and project success in construction project. Chen (1991) outlined that, buildability as a critical factor to the project success goals involved the higher quality of project performance and simplicity construction method throughout the overall building procurement process. After further research on the subject, Russell (1994) figured out the overall project programme should involve systematic procurement methods and experienced construction knowledge from project team members. In 1983, CIRIA in the UK carried out research studies of buildability and reported that building designers were lack of construction knowledge and lack of contribution of contractor's input in early project stage led to the poor project performance and inefficient building design production eventually. Besides the CIRIA study, Griffith (1984) suggested to invite construction disciplines to participate at the initial design period and to procure the pertinent contractual arrangement on different kind of projects to enhance buildability improvement. The effective project management supplemented by proper procurement method could enhance the buildability performance.

2.5 Buildability, Off-site production and the Project Procurement Systems

Walker (1996) defined the procurement system as project organisation adopted by the client for the management of the design and construction of building projects. He further stated the procurement system is a management system adopted by the client to secure the design and construction services required for the execution of the proposed project to the required cost and quality within the required duration.

Walker (1996) classifies Procurement systems with respect to the level of integration of design and construction process as:

a. Conventional/Traditional
b. Integrated
    i. Design and Build
    ii. Package deal and Turnkey
c. Management Oriented
    i. Management Contracting
    ii. Construction Management
    iii. Project Management
d. Contemporary Systems

a. Conventional / Traditional Procurement System

The schedule of design and construction in this system, as shown in Figure 2.1 are separated because of the distinct responsibilities of design consultants and contractors respectively. Under this system, design and construction are managed separately as different stages of the project execution process. Walker, (1996) stated this approach to procurement involves discrete design development, tender, and construction delivery phases. The separation of design and production function, it is stated, will lead to design without concern for buildability or production economies, lack of feedback to the design team, and perpetuation of mistakes from project to project. The traditional procurement system separates the design from construction (Masterman, 2002). Thus, a more practicable approach should be undertaken by independent parties to carry out detailed buildability review of designs before tender issue (Wong, et al, 2005). The traditional procurement system is absolutely hostile to the tenets of off-site as the concept strives to achieve more integration between the design and construction phases of the project delivery process.

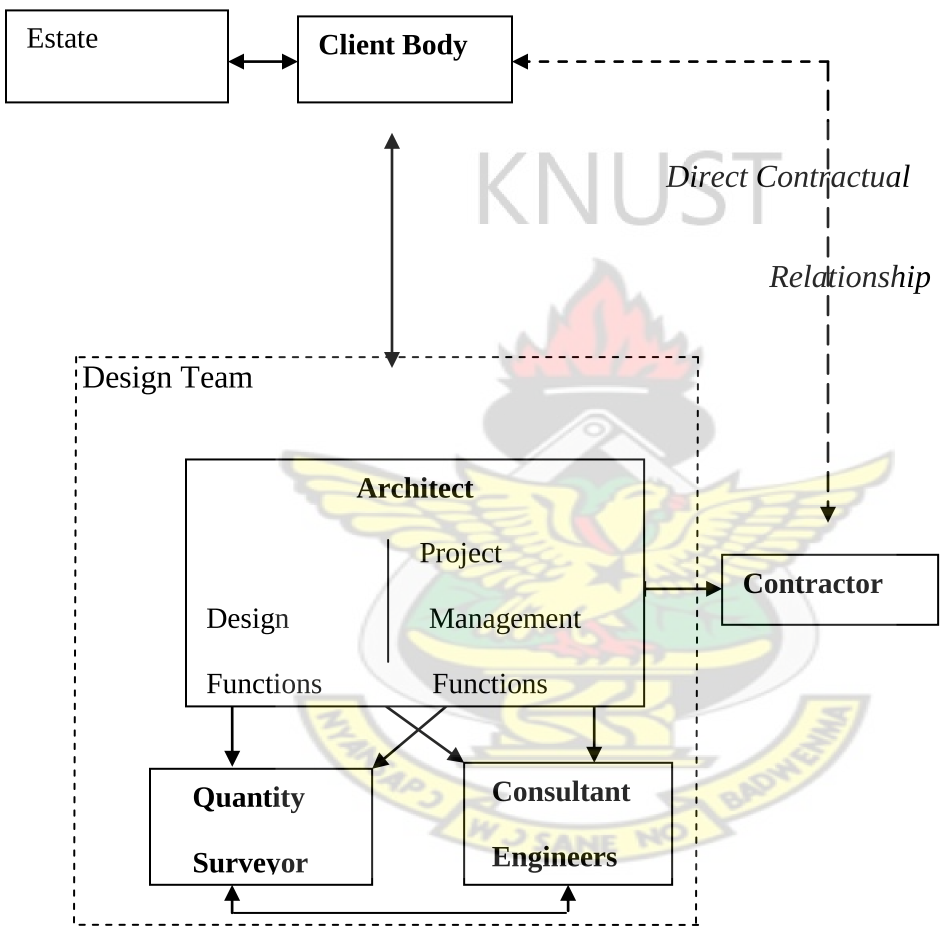


Figure 2.1: **Structure of traditional procurement system** (Walker 1996)

Off-site production aims at minimising waste and maximising value to clients by ensuring a high concern for buildability and production economies, continuous feedback to design team, and the elimination of mistakes throughout the entire project delivery process.

b. Integrated Procurement System:

Under this system, design and construction becomes the responsibility of one contractor and the client deals with him alone. As projects increase in size and complexity without a corresponding increase in design time, it becomes difficult to allow all alternatives to be fully studied and considered, thus increasing uncertainties.

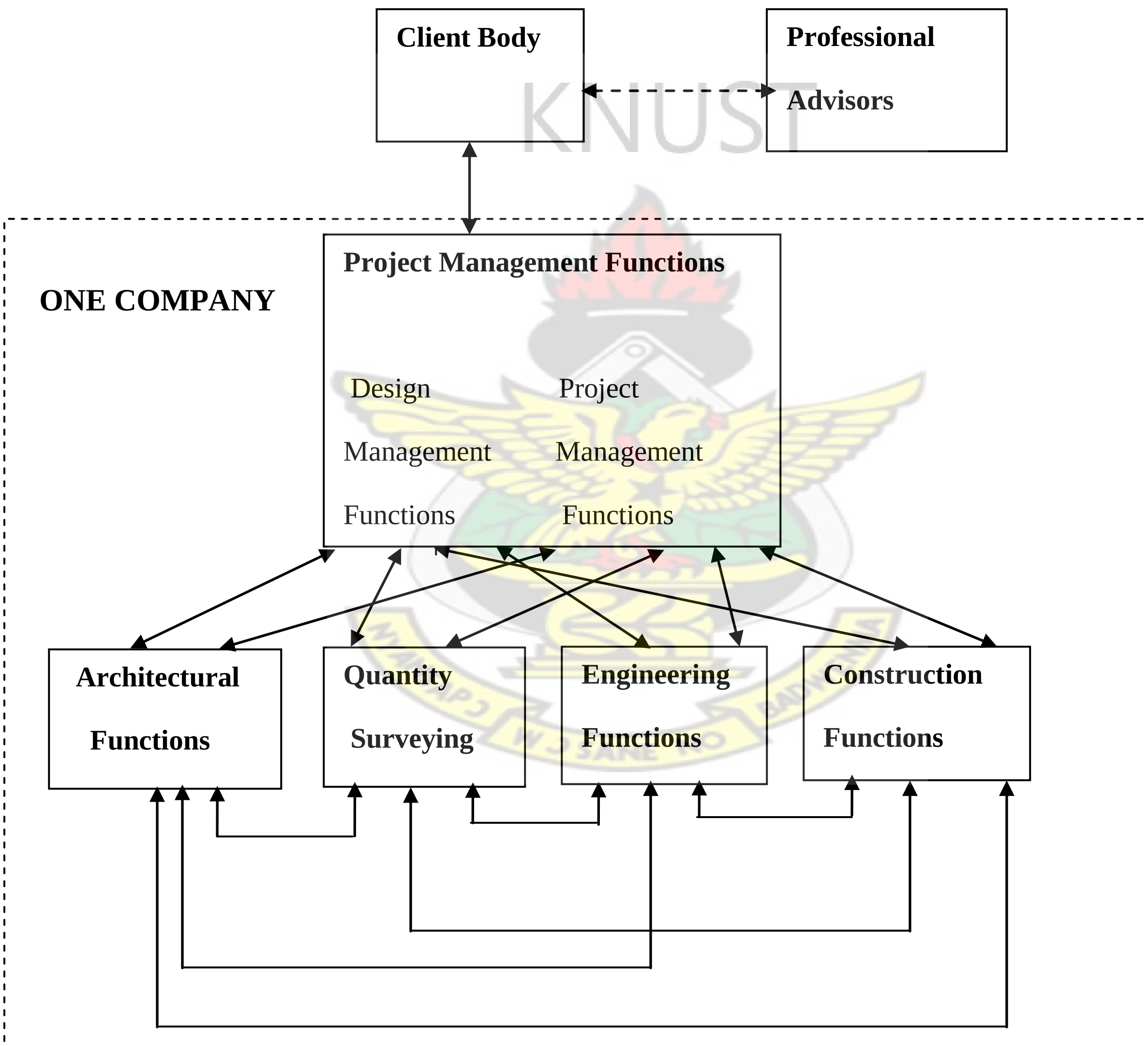


Figure 2.2: **Structure of design and build system** (Walker 1996)

A more integrated approach to design and construction is therefore appropriate under these circumstances of large size and complex projects. The integrated system is the generic term for many systems which seek to integrate design and construction processes. The system advocates that design; manufacture and assembly processes must not be separated but integrated to deliver quality, value for money, speed and high productivity to the client

c. Management - Oriented Procurement System:

Due to the uncertainties and failure associated with the traditional system, this is a management based integrated approach to procurement that has been adopted to address and respond effectively to the needs of the modern construction client (Walker, 2006).

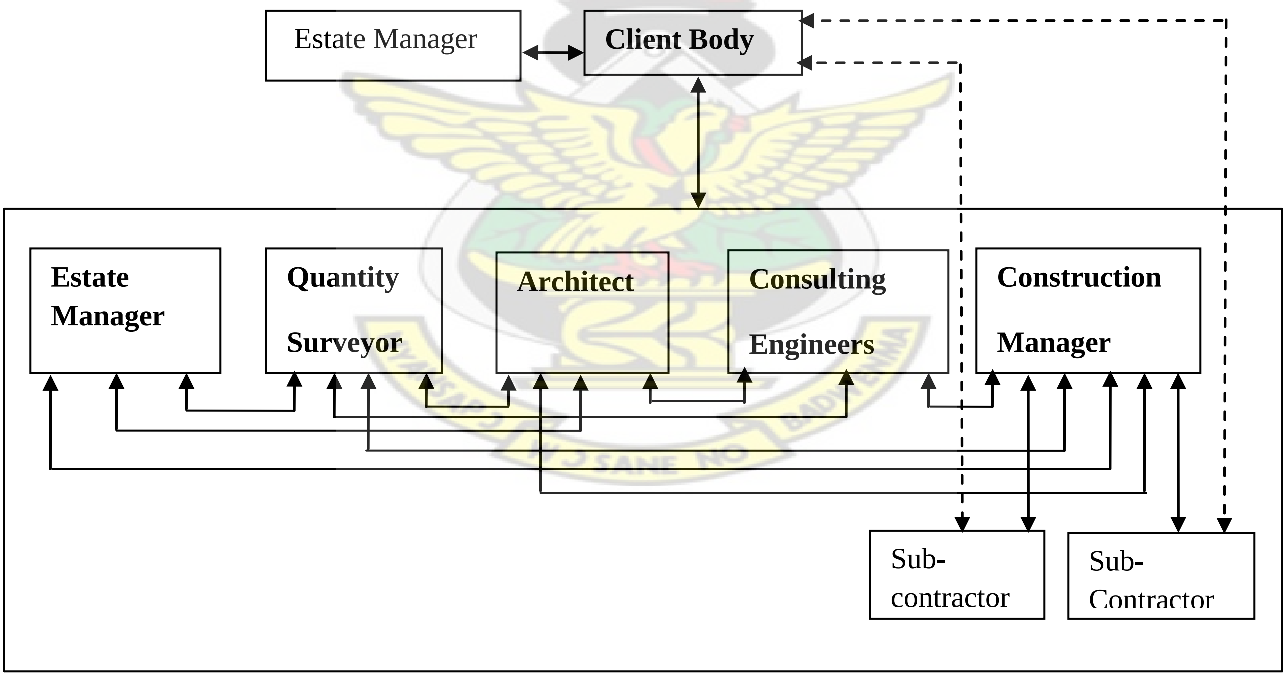


Figure 2.3: **Structure of the project management system** (Walker, 1996)

The system is implemented either as management contracting, project management or construction management (Fig. 2.3). The system aims to achieve better integration in the design and construction processes in order to reduce waste and deliver value to clients in a speedy fashion, thus bringing credence to the principles of buildability and off-site construction. Whereas buildability and off-site production focuses on both product and process design from the onset, the management oriented approaches place less emphasis on process design at the beginning of the project delivery process.

2.6 The Ghanaian Construction Industry

2.6.1 Overview of the Ghanaian Construction Industry

The construction industry in Ghana like in other countries has a significant proportion of its input from other industries. The performance of other industries is thus linked to those of the construction industry giving rise to the belief that government uses the construction industry to regulate the national economy. The Ghanaian construction industry's output has very high import content and since there are virtually no exports by the industry, it is often argued that construction activity has immense adverse effect on Ghana's balance of trade (Nicco-Annan, 2006). He defines the Ghanaian construction industry in its narrow sense (that is, to include the range of activities in which construction firms specialize, but to exclude the off-site manufacture and assembly of materials and components) occupies an important place in the national economy. Nicco-Annan observed that the construction industry represents 3% of Ghana's Gross Domestic Product and employs between 25,000-30,000 people. He further argues that even though these figures appear small, they ought to be considered in the context of the high degree of casualisation in the construction industry as well as a significant informal sector whose contribution is unaccounted for in certified statistics. The socio-political dimension of the implications of construction activities is reflected in the fact that the availability of good housing, roads, hospitals etc. depends on construction. Furthermore constructions as a process has considerable environmental impact in the form of flooding, noise, dust, and refuse among others. In Ghana the basis for judging the performance of the government of a political party depends on the number of rural electrification projects undertaken, health-posts commissioned, feeder roads constructed and rural water schemes realized (Nicco-Annan, 2006). Kwakye (2006) describes local construction as being composed of an assembly of materials or components in a fixed, confined or extended location. Construction activities in Ghana may either be of building utility or civil engineering utility. The government of Ghana is by far the main and biggest client in the construction industry, commissioning almost all infrastructural works, offices, hospitals and other non-housing work. Apart from government who fall under the category of public client, other types of clients in the Ghanaian construction industry include corporate clients such as Social Security and National Insurance Trust (SSNIT), and individual clients or sole proprietors usually in the construction of houses.

2.6.2 Ghanaian Construction Industry and Housing Delivery

The basic needs of man no matter where he finds himself are food, clothing and shelter but like many developing countries, the need that Ghana lacks most is shelter. The United Nations defines a house as a structurally separated and independent place of abode such that a person or a group of persons can isolate themselves from the hazards of climate such as storms and the sun (UN, 2003). According to Christina (1997) an ad-hoc group of experts on social programming of housing in urban areas defines housing as the area where the individual becomes capable of experiencing community and privacy, social well-being and shelter and protection against hostile physical forces and disturbances and also serves as the area, an abundant supply of social relationship and services are accessible, education, recreation, sports, social welfare and health protection services, shopping and transportation.

Like most governments, the Ghana government has an interest satisfying this need and therefore believe in the fact that implementation of housing as a human right must be strengthened and accelerated (Habitat, 2001). One of the major areas of concern in national development process is the problem of adequately providing for the housing needs of the mass of the people (Owusu and Boapeah, 2003). The population and housing census of 2000 puts the nation's population at 18.9 million and the total number of houses at almost 2.2 million dwelling units can be classified as houses, and the total dwelling units at almost 3.9 million, meaning that about 1.7 million of the dwelling units cannot be described as houses. This presupposes there is enormous demand for housing. Additionally, Cooperative Housing Foundation (CHF) Conference report in (2005) on the topic Promoting Economic Development and Stabilisation through Affordable Housing in Ghana at Accra revealed that Ghana had a housing deficit of one million units in 2005. This number is expected to double in the next decade if the status quo is maintained. From the above, Ghana must put up 2.5 million affordable houses by 2025 if we are to meet the housing needs in the country (HFC Bank, 2010). This means that there is the need to provide affordable, suitable and adequate housing units to meet the needs of the people. The important issue then is "How can we define housing affordability, especially in a country where 27% of the population lives in extreme poverty and 39% of the population lives below the poverty line" (Hokans, 2005). The concept of housing affordability varies from country to country. In the United States and Canada, a commonly accepted guideline for housing affordability is a housing cost that does not exceed 30% of a household's gross income. Housing costs considered in this guideline generally include taxes, insurance and utility cost (U.S Department of Housing and Urban Development, 2006).

Ghana, like many developing countries is caught in the throes of an inevitable housing problem emanating from rapid population growth (Ayeh - Solomon, 2003). Research shows that Ghana has a housing delivery system problem which needs to be looked at critically. The housing problem of Ghana is one that has a national need of about 400,000 housing units and an accumulated deficit of about 1,000,000 units needed to solve urban housing problems. An average annual delivery of 1,000,000 units will be needed to provide adequate housing within the next 20 years as compared with the average annual delivery of 400,000 units – a performance rate of 30 % (GREDA Today 2001). Housing delivery in Ghana since days of old has been a problem to subsequent governments. Only 8% of Ghanaians can afford to buy a property without mortgage but the sad issue is that less than 18% of Ghanaians have access the mortgages (Ghanaweb.com). According to a research by the Building and Road Research Institute (BRRI) –CSIR, out of the 40,000 housing units constructed nationwide, private individuals accounted for 38,200, District Assemblies – 470, Ministries, Departments and Agencies – 230, international NGO's 150, some housing corporations 140, GREDA – 750 and miscellaneous – 60 (Home Finance Company HFC, 2005). urbanisation has led to population increase in the urban areas and the high cost of acquiring decent accommodation in the cities has led to slums and ghettoes springing up in most of the cities especially in Accra and Kumasi. A typical example is Sodom and Gomorrah in Agboloshie in Accra. This is due mainly to the rural – urban migration and the inability of the migrants to rent proper accommodation. The Ghana government in a bid to solve the poor housing delivery system a few years back started the affordable housing scheme in most of the regional capitals in Ghana (Daily Graphic 2005). Efforts by individuals to provide their own housing needs have been on the ascendancy though that is also faced with its own problems of;

1. Lack of skilled professionals and even when available the refusal by home owners to engage their services due to the notion that it will increase the cost of construction. Thus individuals with virtually no construction knowledge supervise their own building projects resulting in sub standard construction.
2. Acquisition of land in the major cities like Accra and Kumasi, especially the former is now a frustrating business due to double sale of land by land owners leading to land litigations and destruction of houses by parties who claim to be the proper owners of lands.
3. Difficulty as far as the provision of services such as electricity and water among others is concerned.

2.6.3 Real Estate Development in Ghana

The magnanimity of the problem of housing delivery in Ghana cannot be over emphasized, and subsequent governments have tried their very best to help solve the housing menace. As far back as 1956, the State Housing Corporation (SHC) was established to build low to moderate price houses throughout Ghana for Ghanaians unable to buy houses from the private market. Due to internal problems and ineffective financing mechanism, the SHC was only able to produce 350 housing units per year, an infinitesimal portion of total house construction nationwide (Boadu, 1992). Tema Development Corporation was basically formed to carry out housing construction in Tema. Its record to date is somehow better than that of SHC. 14,500 housing units were constructed between 1959 and 1970. The three main institutions contracted to finance the housing schemes and projects were;

1. State Insurance Corporation

2. Bank for Housing and Construction and
3. The First Ghana Building Society.

Due to default of borrowers, mismanagement, political interference and lack of an effective housing policy backed by effective technical structures to ensure its implementation, the various housing schemes failed (Boadu, 1992). Later in 1972, a national low-cost (affordable) housing committee was formed by the government as part of the drive to provide housing for the masses. The committee was given money to construct housing units between one to four rooms with the necessary services. Out of the 1,974 units constructed under phase one of the project, only 21 cost more than $4,000. The units were planned to be located in the regional capitals. Apart from the implementation of the low cost (affordable) housing project, the committee was also to evolve an organisational structure to facilitate the planning and implementation of national housing programmes and policies, with emphasis on housing the low income Ghanaians and on the utilisation of local building materials wherever possible (Boadu, 1992). In the late 1980's the Social Security and National Insurance Trust (SSNIT) also ventured into the housing provision market constructing many high and low rise housing units in most of the regional capitals. Most of the houses were given out on hiring basis. Due to the inability of most people to honour their part of the bargain by paying the requisite rent, the houses were offered for sale so as of now most of the houses constructed if not all are no longer the property of SSNIT. At the moment, Real Estate Development in Ghana involve a group of private limited liability companies registered with Ghana Real Estate Development Agency - GREDA (1988) and Home Finance Company (HFC) as accredited developers with the sole aim of providing quality housing units at reasonable prices. GREDA was formed in

1988. It is a registered under the Act 179 of the Company Code of 1965 as a private companies limited by guarantee (Greda Today, 1999). Currently, it has a membership of about 540.

The main aims of GREDA are to:

1. Provide high quality housing units that are well serviced with good road network, electricity, pipe-borne water, telephone and good drainage system.
2. Employ professionals such as Architects, Quantity Surveyors, Planners, Engineers, etc. to come up with the appropriate technology to ensure good construction practices of achieving the best at the least cost.
3. Liaise with the service providers such as Electricity Company of Ghana, Ghana Water and Sewerage Company Limited and the Department of Urban Roads to provide the needed services in an efficient and economic manner.

Thus with the purchase of an estate house, from estate developers such as Regimanuel Gray Limited, Manet Estates, Trassaco, Parakou Estates, etc, one is provided with services such as electricity, water , telephone facilities, good road network and drainage systems, etc. Some of these estates also come with their own security, educational, recreational, and commercial facilities. By the end of 2004, Regimanuel Gray Limited, one of the leading Real Estate Developers in the country could boast of 1500 housing units and Manet Estates also added 500 units. Thus it can be said that among all the stakeholders in the construction industry, Real Estate developers have been contributing their quota to help solve the housing deficit in the nation.

2.6.4 Problems Facing the Ghanaian Construction Industry

Housing in most developing countries is one of the most complex and perennial problem that has engaged the attention of successive government. In Ghana, there has been considerable increase in the cost of buildings within the past decades and the possibility of an average Ghanaian to acquire a house before retiring from service is as slim as ever (Boadu, 1982). In Ghana, many factors are responsible for the state of affairs. They include;

a. Use of expensive building materials
b. Lack of adequate mechanisation in the housing construction industry
c. Lack of adequate qualified construction manpower and skilled artisans
d. Land tenure and cost
e. Shortage of housing finance
f. Low income of prospective buyers

Another pertinent problem is the lack of nationwide co-ordinated effort to evolve housing policy to guide both the public and private housing sector (Boadu, 1992). The development of a nation depends basically on the availability of requisite infrastructure which the construction industry can provide. The growth of other industrial sectors is stimulated by the construction industry which contributes greatly to the Gross Domestic Product (GDP) growth of the nation. The development of the construction industry in Ghana until quite recently was a slow and difficult one. The construction industry in Ghana is confronted by a lot of problems namely

a. Building Materials

The high cost of building materials in sub-Saharan countries is a crucial constraint to the housing sector. The high cost of building materials is undermining the efforts of Real Estate developers in their quest to provide affordable houses (United Nations report). Building materials constitute the single largest component in the construction sector. In Ghana, however, a large variety of items are imported into the country for use in the building materials industry. They include cement clinker, lime, galvanized iron and asbestos roofing sheets, sanitary wares and fittings, electrical fittings and fixtures, glass, steel reinforcing bars, paints and varnishes (Dogbey, 1992). The export of timber in the nation has led to the situation where the best type of timber is not available on the market. When available, due to scarcity, the cost is very high and cannot be bought by local building contractors. Imported clinker which constitutes about 82% of materials needed for the manufacture of cement is now very expensive. This has led to the situation where the price of cement has increased from 7.5 Ghana Cedis in the year 2006 to the current price of 18 Ghana Cedis. Until such a time when the local production of construction materials using appropriate technology is looked into, self sufficiency in the construction industry will be a mirage and there will hardly be any effective cost reduction. Simple and proven appropriate technologies can be implemented with minimal effort. This could be best achieved by committed government policy support, aimed at promoting increased use of local building materials. If such local building materials are used appropriately and substituted for conventional materials, there should be noticeable reductions in construction cost

b. Land

As far as housing delivery is concerned, land is the backbone on which everything rest. Current value of land in many areas of Ghana is very high. Where it is cheap, one has to wait for years until the slow nature of the industry's development catch up (Dogbey, 1992). He further stated that there are supply bottlenecks in the delivery of affordable land in appropriate locations and the state now lacks the human and logistic resources and funds to undertake further land acquisition to sustain the land-banking concept and pay compensation within the urban areas. High and rising prices of land increasingly make it less affordable to the moderate and low-income groups, who face the added problem of having no access to limited available credit facilities. There is also inadequate information about land due to the absence of land baking system and the poor institutional arrangement which exists for land management and administration constraints in the urban land market and make the delivery of shelter virtually impossible. Residential lands delivered in the private/traditional sector are usually without infrastructure and land litigations among chiefs and family groups are also a problem to the Ghanaian construction industry. Land litigation in Ghana, can be traced to the form of land ownership in Ghana. According to the 1992 constitution, there are four categories of land ownership in Ghana. These are;

a. Public/ vested lands: - state owned lands and lands vested in the president in trust for the people of Ghana.
b. Stool/vested lands: - lands vested in traditional leaders and or other community leaders on behalf of the community. Lands Commission must give approval to transactions in such lands to make its sale valid.
c. Private lands: - these are lands owned by individuals.
d. Family lands: - these are lands owned by families.

All these four categories have their own peculiar problems; Stool lands for example have the problem of a chief and his predecessor selling the same piece of land to different people. The same chief can also do the same. In recent times, sale of the same piece of land to two or more developers by family or clan members has resulted in time consuming and costly court cases.

Private land ownership has also led to the fragmentation of land. In this sense, if a Real Estate developer needs a large piece of land, he may have to negotiate with about three or more private owners. Land acquisition in Ghana is now a bureaucratic process, working on a lease could be long, expensive and frustrating (GREM Publication 2004). These problems work against the Construction Industry, and hinder the development of Real Estates. A greater percentage of land in Ghana falls under private lands. According to a Ministry of Works and Housing Global –Urban indicator database study in 1998, it came to light that an estimated 72.4 % of urban lands were privately owned and 19.2 % publicly owned. Due to the land administration system, Stools must consult heads of some families concerned before certain lands can be sold. The involvement of many persons in the administration of land has led to the scenario where the sale of land can lead to disputes between two or more stools, families or individuals concerning land ownership and in certain instances boundaries. The land use pattern in many parts of the country especially the major cities also give rise to concern as improper zoning of commercial, industrial, residential and other purposes coupled with the inadequate public awareness of the land use has given rise to adhoc sale of land some of which are not being used for its rightful zoning. Even when land is acquired without any problem, the cost of providing services in the case of Real Estate development before construction can proceed is also a problem. The cost of infrastructural services; electricity, water, telephone, drains, roads, etc can depending on the locality be very high. As far back as the year 2004, the Tema Development Council came up with a serviced scheme and the cost components (Table 1.3). It must however be emphasized that, in providing these services, the cost of all required equipments such as transformers, cables and poles was not included in the estimate. The huge monetary implications involved in the delivery of these utility services to a new site are seen as a major problem to the industry (GREM Publication, 2004).

Table 1. 3: **Services and their cost schemes for a whole estate.**

SERVICES	COST COMPONENT
Electricity	Gh. Cedis 360,000
Water	Gh. Cedis310,000
Underground drains and culverts	Gh. Cedis 994,000
Road network	Gh. Cedis 1,036,000

Source: (GREM Publication 2004).

c. Unaffordability of Houses

Real Estate Developers in the country are being blamed for their contribution to the housing menace as they pay more attention to the upper class to the detriment of low income earners who need low income houses. Due to this, the local market for Real Estate developers is not that big, hence developers deal most of the time with a clientele comprising foreigners, Ghanaians living abroad and high class residents who can purchase their buildings. Research has established that Ghanaians living abroad form 65% of Real Estate developers' clientele (Ghana News Agency, 2004). Due to the low income of many Ghanaians, though there is demand for houses, what is available is much more than what the average Ghanaian can afford. Thus defeating GREDA's aim of producing affordable houses for all class of people. (Atta-Poku, 2001).

d. Lack of Adequate Mechanisation in the Housing Construction Industry

Availability of construction equipment is an important factor that cannot be overlooked in construction if cost is to be reduced**.** Due to the fact that most of the equipment, machinery and other logistics are manufactured outside the country, getting some parts are difficult due to the money involved thus maintenance is difficult (Akkufo, 2004).

e. Construction Cost and Delay

Construction cost and delay is a major problem which has retarded the growth of the industry which has been fuelled by some factors. These factors include inaccuracy of material estimates, unpredictability of production output of the workforce, inclement weather, non-standardized input, price fluctuation, shortage of materials and equipment, shortage of skilled labour, restriction of project location and design alteration. These factors have a significant effect on project completion time and therefore lead to increase in cost of projects. Construction activities require huge capital as the cost of production is very high and usually beyond the reach of most developers(Dogbey, 1992). The existing housing finance institutions recoil from devising suitable loan portfolio for low-to-middle income groups because of the substantial risk. Incentives have not been created which allow for the mobilisation of savings from non-conventional sources that would give these people increased access to home ownership finance and also encourage them to use existing institutions to enhance their savings capacity (Dogbey, 1992). This problem can be solved by borrowed capital from financial institutions. Long term loans are discouraged by financial institutions as they view construction capital finance as high risk due to unfavourable economic indicator.

f. Government and Economic Influences

Budgetary allocations by the government to the housing sector greatly affect housing delivery. If sufficient, budgetary allocations will lead to the sector ministry implementing policies and schemes that improve the nation's housing delivery. Housing policies in the country are hardly implemented in full. In some cases, government shows partial commitments to projects resulting in abandoned or stalled projects (Akkufo, 2004).

g. Cost Data

A reliable cost data is based on the accuracy of material estimate, equipment and labour. The unreliability of any well defined data bank has made it difficult to come by an accurate cost data. Contractors therefore have to maintain or compile their own cost data regularly to act as a guide for future works but this hardly happens as most of them lack the personnel to do this. Thus, data is almost always unreliable (Boadu (1992).

h. Poor Contract Administration

The construction industry in Ghana is bedevilled with the problem of poor financial management and contract administration. Budgets are overrun thereby leading to the accruement of arrears to consultants and contractors (Boadu, 1992). Insufficient project preparation at the feasibility and design stages of procurement result in major changes in the scope of work during construction in some cases. In some other cases, project lengths were extended rather than they being treated as separate contracts as in current practice (Boadu, 1992 & Atta- Poku, 2001).

i. Inclement Weather

Whereas countries like Britain, America and Australia have four seasons, Ghana like any Sub-Saharan African country is located in the tropical zone with two seasons, namely the dry (hot) and wet (rainy) season. Like most countries the construction activities are therefore exposed to the vagaries of the weather, where temperature during the working day can range between 30-35 degrees Celsius. This does not favour construction work resulting in lower output. At certain stages of construction, during the rainy season, rain disrupts work schedules. (Boadu, 1992).

j. Design Changes

After the commencement of most construction projects, changes in volume, nature and order or work duration are experienced. The changes depend on thoroughness of the pre-site investigation (feasibility studies), working drawings prepared as of the time of estimate (actual designs) and unforeseen circumstances during construction (Atta- Poku, 2001).

k. Labour Productivity

Production or performance is a function of ability and motivation and the underlying concept of motivation is some driving force within individuals by which they attempt to achieve some goals in order to fulfil a need or expectation (Mullin, 2002). The unprofessional nature of the construction industry has led to the situation where most of the tradesmen are not well educated and not belonging to any recognizable body, thereby making it difficult to hold them accountable for their mistakes on site (Boadu, 1992). They are recruited by foremen and they are mostly unskilled labour. They earn low wages and thus are not well motivated leading to a low output.

l. Environmental

One major problem facing the nation is the problem of the activities that degrade the environment including illegal sand winning leading to unstable lands and ecological damages, water pollution, loss of forest, rapid urbanization leading to air pollution and pressure on existing infrastructure such as waste management systems. The Environmental Protection Agency (EPA), the body with the power to protect the Ghanaian environment lacks the human and financial resources to promulgate and enforce the protection of the environment.

m. Other Problems of the Industry

In conclusion, housing policies, if they exist at all are filled with ambiguity; because the mechanisms for implementing the policies, programmes, and projects have not been clearly defined. Consequently, almost all the past housing programmes and projects have had been abandoned before completion due to financial and/ or organizational bottle- necks (Boadu, 1992). Skilled personnel shortage due to inadequate educational and training programmes geared towards the construction industry is having a toll on the industry. The Universities and Polytechnics are not able to train enough technocrats and technicians to fill the available spaces.

One other major problem facing the construction industry worldwide is the problem of waste control and management on construction site.

2.7 Waste Control on Construction Site

2.7.1 Concept of Waste

According to Formoso *et al* (1999), Waste is defined as any losses produced by activities that generate direct or indirect costs but do not add any value to the product from the point of view of the client. Waste includes both the incidence of material losses and the execution of unnecessary work, which generates additional costs but do not add value to the product (Koskela, 1992). Earlier research by Skoyles (1976) stated that most of the problems concerning waste on building sites are related to flaws in the management system, and have very little to do with the lack of qualification of workers. Furthermore, waste is usually caused by a combination of events, and not due to an isolated factor. Formoso *et al* (1999) stated waste can be classified ino *unavoidable waste* (or natural waste), in which the investment necessary to its reduction is higher than the economy produced, and *avoidable waste*, when the cost of waste is significantly higher than the cost to prevent it. The percentage of unavoidable waste in each process depends on the company and on the particular site, since it is related to the level of technological development. The Ghanaian construction industry like that of most developing countries has its fair share of construction waste on site. But unlike the advanced countries there is little or no documentation on this topic therefore problems that could be avoided keep repeating it. Although waste is usually identified during the production stage, it can be originated by processes that precede production, such as materials manufacturing, training of human resources, design, materials supply, and planning. In their survey on methods of waste control in the building industry, Formoso *et al* (1999) further classifies waste under the following subtopics.

a. **Overproduction:** this includes the production of a quantity greater than required or earlier than necessary. This may cause waste of materials, man-hours or equipment usage. It usually produces inventories of unfinished products or even their total loss, in the case of materials that can deteriorate. An example of this kind of waste is the overproduction of mortar that cannot be used on time.

b. **Substitution:** is monetary waste caused by the substitution of a material by a more expensive one (with an unnecessary better performance); the execution of simple tasks by an over-qualified worker; or the use of highly sophisticated equipment where a much simpler one would be enough.

c. **Waiting time:** This is related to the idle time caused by lack of synchronization and levelling of material flows, and pace of work by different groups or equipments. One example is the idle time caused by the lack of material or by lack of workplace available for a gang.

d. **Transportation:** concerned with the internal movement of materials on site. Excessive handling, the use of inadequate equipment or bad conditions of pathways can cause this kind of waste. It is usually related to poor layout, and the lack of planning of material flows. Its main consequences are: waste of man hours, waste of energy, waste of space on site, and the possibility of material waste during transportation.

e. **Processing:** related to the nature of the processing (conversion) activity, which could only be avoided by changing the construction technology. For instance, a percentage of mortar is usually wasted when a ceiling is being plastered.

f. **Inventories:** related to excessive or unnecessary inventories which lead to material waste (by deterioration, losses due to inadequate stock conditions on site, robbery, vandalism), and monetary losses due to the capital that is tied up. It might be a result of lack of resource planning or uncertainty on the estimation of quantities.

g. **Movement:** concerned with unnecessary or inefficient movements made by workers during their job. This might be caused by inadequate equipment, ineffective work methods, or poor arrangement of the working place.

h. **Production of defective products:** it occurs when the final or intermediate product does not fit the quality specifications. This may lead to rework or to the incorporation of unnecessary materials to the building (indirect waste), such as the excessive thickness of plastering. It can be caused by a wide range of reasons: poor design and specification, lack of planning and control, poor qualification of the team work, lack of integration between design and production, etc.

i. **Others:** waste of any nature different from the previous ones, such as burglary, vandalism, inclement weather, accidents, etc. (Formoso *et al* 1999)

2.8 Findings of Literature Review

The outcomes of improving buildability through the adoption of off-site production are shown manifestly on the project cost. The early involvement of buildability with off-site production into the project design stage, could achieve 1% to 14% cost saving (Gray 1983). There is also achievement of effective saving of overall project cost (Pepper, 1994; Geile, 1996; Griffith and Sidwell, 1997), a more efficient human resource output, early completion of the project and also high project productivities (Griffith and Sidewell, 1997; Low and Abeyegoonasekera, 2001; Low, 2001). It cuts down on material waste (Koskela, 1992; Skoyles, 1976; Formoso *et al* 1999), and eliminates many traditional construction work task with serious risk factors (Simonsson and Rwamamara, 2007; Gibb, 2004). On the other hand, a major reason posted for the reluctance among clients and contractors to adopt off-site production is the percieved difficulty in ascertaining the benefits that such an approach would add to a project (Pasquire and Gibb, 2002).

A major problem that confronts buildability is the problem of construction failure such as: fundamental errors in concept, site selection and site development errors, programming deficiencies, design errors, construction errors, material deficiencies and operational errors. These are portrayed in extensive research by (Ortega, 2000; Feld and Carper, 1997; Gnaedinger, 1987; Orfano 2009; Petroski, 1994,). Such problems are faced by all construction industries worldwide of which Ghana is no exception.

In addition to this, the Ghanaian construction industry has specific problems which have led to the housing deficit being experienced. These include use of expensive building materials, lack of adequate mechanization in the housing construction industry, lack of adequate qualified construction manpower and skilled artisans, land tenure and cost, shortage of housing finance and low income of prospective buyers. (Boadu, 1992; Atta- Poku, 2001; Dogbey, 1992).

Research by Koskela (1992); Skoyles (1976) and Formoso *et al*, (1999) all point to the fact that material waste control is a major problem facing the construction industries of both developed and developing nations. This comes in the form of overproduction, substitution, waiting time, unnecessary movements of goods and workers and production of defective production.

RESEARCH METHODOLOGY

3.1 Research Methods

This chapter gives in depth details of the method and procedure of this study. A list of off-site factors as well as problems facing the Ghanaian construction industry and some factors of construction failure were collated qualitatively from literature review, internet search and preliminary survey and developed into a questionnaire for the main survey. A review of the literature also indicated the importance of off-site production in improving buildability. In order to establish the authenticity or otherwise of issues emanating from literature, the survey sought the perception of respondents on the effect off-site production will have on the Ghanaian construction industry especially in Real Estate development. The methodology included opinion survey which can be categorized as quantitative research. Quantitative approaches are more specific and result oriented and involves the collection of numerical data in a bid to explain, predict and control phenomenon of interest (Mojaheed, 2005).

To determine the state of off-site production in Ghanaian construction industry, the most significant among the data collection was a questionnaire survey because the views of the stakeholders can be best gathered through this process. Also, the pilot survey brought up the need to use well structured questions to test the consistency of the data collected. Data gathering was limited to Accra and Kumasi, where major construction activities are centred in Ghana, ensuring that a variety of perspectives were included in the study. Questionnaires were sent to 120 stakeholders in the Ghanaian construction industry such as construction professionals, real estate developers and suppliers and manufacturers of off-site produced building components as they are knowledgeable and qualified enough as respondents for the study and also because they are the target group whose activities will help in the acceptance of the concept of off-site production. 75 of the questionnaires were returned.

The research was also supplemented by a broad qualitative survey-based methodology. The study employed three particular approaches to determine the state of off-site production; these included a web-search, interview with stake holders (this was because of the need to explain the whole concept to some of the people interviewed which led to different areas not captured by the questionnaire being brought up) and visit to construction sites. The web-search provided the research with the types and variety of products being manufactured off-site the world over, as there is limited data on the use of off-site production in the Ghanaian construction industry. It provided a sense of the scope of off-site production. The analysis of the documents provided a number of benefits and hindrances that were based on those identified in the literature review. There were also interviews with some of the stake holders. Twenty-five people in the target group, ranging from clients, designers, constructors, manufacturers and suppliers and researchers were consulted. The open discussions centred on various off-site production systems, problems and solutions in the construction sector and answers that arose during the discussions and interviews were noted. The study also involved site visits by the researcher. Six site visits were undertaken to supplement the interview data. The notes and responses were collated into two documents corresponding to the two regions from which data was collected, namely; Accra and Kumasi. The documents were coded based on status of the interviewee. Each of these was reported, highlighting the benefits, hindrances and lessons learnt. The outcomes of the questionnaire survey were mapped against the findings of the site visits and interviews.

3.2 Procedure for Data Collection

The primary source of data for the research was in the form of structured questionnaires and interviews as well as observations from site visits designed to collect information from Real Estate Developers and top level building professionals (Architects, Quantity Surveyors, and Civil Engineers).

The questionnaires were distributed personally to respondents mainly in their offices. There was however instances where contacts were made on phone and questionnaires mailed to respondents. Some of the respondents, especially those who were totally unfamiliar with the concept of off-site production, were taken through the questionnaire before their responses were given. To eliminate bias and not skew their answers towards one particular direction, care was taken to be as neutral as possible, and answers were given to questions posed impartially. A personal observation of some activities of some of the stakeholders and site visits also provided an opportunity to obtain special information for the study.

3.2.1 Design of Questionnaire

The questionnaires were designed based on the findings of the literature review and the research objectives. The questionnaire dealt with general information on the respondents and their views on the advantages and hindrances to the adoption of off-site production in the Ghanaian construction industry. The first sets of questions were intended to seek information about the demography of the respondent (i.e., sex, age, educational level, position, years of experience and years of working with the firm). The second part of the questions in the questionnaire was related to the advantages of off-site production. The respondents were asked to rank the questionnaire using the scale of 1-5 in order of significance;

“LS” represented **Least Significant**, “FS” represented **Fairly Significant**, “S” represented **Significant**, VS represented **Very Significant**, and ES represented **Extremely Significant**

Ranking with limited number of values usually agree well enough for practical purposes

3.2.2 Sampling Technique

The random sampling technique (stratified) was used for the data collection. This was done by taking into consideration the respondents’ technical background and years of experience in the Ghanaian construction industry as well as the region one was based in, as this had an impact on the way questions were answered. The target population was Real Estate Developers and Construction Professionals such as Architects, Quantity Surveyors and Civil Engineers, Most in the Ashanti and Greater Accra region. Snow ball sampling was also utilized in the selection of the real estate developers.

3.2.2.1 Determination of Sample Size

Due to the difficulty of studying the whole population of over 400 registered Real Estate Developers, (70) active members, 380 Architects, 230 Quantity Surveyors, and 380 Civil Engineers, (www.Ghanaweb.com) a sample had to be chosen to represent each population. The sample size for the study was therefore obtained by using the following formula (Saunders, *et al.*, 1997).

n = n’ / 1+ {n’/N}

Where n is the minimum sample size;

n’ is $(s/v)^2$, with s referring to maximum standard deviation of the population

sample, calculated as s = p (1-p) ; P being the proportion belonging to the specified category (in this case p = 50% in applying the simple majority rule). Therefore s= 0.5 x (1 - 0.5) =0.25. v is standard error of sampling distributions (here, v=0.05 for a confidence level of 95%). This implies that $n' = (0.25/0.05)^2 = 25$

n = sample size

N = population size

3.2.2.2 Sample Size for active Real Estate Developers

$n = n'/(1+n'/N)$

N = 400

$n' = (0.25/0.05)^2 = 25$

n = 25 / (1+ (25/400)) = 23

3. 2.2.3 Sample Size for Other Construction Professionals

a. Architects

$n = n'/(1+n'/N)$

N = 380

$n' = (0.25/0.05)^2 = 25$

n = 25 / (1+ (25/380)) = 23

b. Quantity Surveyors

$n = n'/(1+n'/N)$

N = 230

$n' = (0.25/0.05)^2 = 25$

$n = 25 / (1+ (25/230)) = 22$

c. Civil Engineers

$n= n'/ (1+n'/N)$

$N = 380$

$n' = (0.25/0.05)^2 = 25$

$n = 25 / (1+ (25/380)) = 23$

The sample size of 91 was obtained. Assuming a non-response rate of 10%, the final sample of respondents to the questionnaire became 100 (i.e. 91+ 0.1x91). There was also the need to add a sample size for Manufacturers and Suppliers of Off-site produced components. Due to the fact that there is no way of knowing their number it was decided to add 20 more questionnaires for their use. The final sample size therefore became 120.

Table 3.1: **Questionnaire sample size for real estate developers and other construction industry professionals**

Respondents	Number of questionnaires distributed	Number of questionnaires received	Response rate (%)
Real Estate Developers	25	14	56
Architects	25	18	72
Quantity Surveyors	25	15	60
Civil Engineers	25	10	40
Manufacturers and Suppliers	20	18	90

3.2.3 Administration of Questionnaire

Most of the questionnaires were administered personally where advantage was taken to have a field survey to ascertain what was being done on the site of most of the Real Estate Developers. Other Construction Professionals (Architects, Quantity Surveyors and Civil Engineers) were also interviewed. In addition to the above mentioned groups, about 20 manufacturers and suppliers of prefabricated or off-site produced building components were also interviewed. All respondents were given the free will to answer the questions, as care was taken to ask simple, straight forward questions devoid of ambiguity, not much clarification was anticipated. A maximum of one week duration was agreed to respond to the questions in the questionnaire. In the event where the respondent's educational level was not adequate, assistance was given to answer questions. A total of 120 questionnaires were administered.

3.3 Analysis of Data

A qualitative and quantitative approach to data analysis was employed for the study. The data collected was edited, sorted, and coded. Microsoft Excel and Statistical Package for Social Scientists (SPSS Version) were then used to analyse the data. A correlation analysis of the factors was also established to determine which factors correlated with each other such that a change in one will affect the other. Frequency tables, percentages, bar charts and other descriptive were used to analyse the results. The results from these analyses provided the basis for finding out what patterns and common trends run through the responses with respect to the practice of off-site production by stakeholders of the Ghanaian construction industry especially those in Real Estate Development. The basis for deviations from the common trends running through the responses was also established from the analysis.

3.4 Ranking

3.4.1. Data Analysis Tools

Two different analytical tools were used in analyzing the responses from the survey. These are SPSS and Importance Index, Kappa statistic for multiple raters was also used to test the consistencies of answers provided by respondents.

The importance index was adopted from Lim and Alum (1995). A ranking of Importance indices were done to ascertain the most frequent factors. The use of the Importance index facilitates the identification of tactical approaches towards adopting off-site production. It gives an analytical explanation of the critical effect the various factors of the questionnaire on off-site production will have on improving buildability. It further gives the aggregate effect and significance to it. The nearer the value of importance index is closer to unity (1), the more significant the various factors have on adopting off-site production in the Ghanaian construction industry and hence attention needs to be directed towards the effects of such factors.

$$\text{Importance index (I.I)} = \frac{5n_1 + 4n_2 + 3n_3 + 2n_4 + n_5}{5(n_1 + n_2 + n_3 + n_4 + n_5)}$$

Where: n_1 = number of respondents answered “Extremely Significant”

n_2 = number of respondents answered “Very Significant”

n_3 = number of respondents answered “Significant”

n_4 = number of respondents answered “Fairly Significant”

n_5 = number of respondents answered “Least Significant”

3.4.2 Kappa Statistic for Multiple Raters

Kappa $\hat{k}$ statistics for multiple raters using categorical classifications was employed to test the level of agreement for respondents. This analytical tool is used to test the consistency of values and is employed when there are more than two raters and or subjects. The determination of $\hat{k}$ is demonstrated as follows.

$$m = \sum_{j=1}^{k} x_{ij} \qquad (1)$$

$$\bar{m} = \frac{\sum_{i=1}^{n} m_i}{n} \qquad (2)$$

$$\Rightarrow \sum_{i=1}^{n} m_i = n \times \bar{m}$$

$$\bar{P}_j = \frac{\sum_{i=1}^{n} x_i}{n \times \bar{m}} \qquad (3)$$

$$\hat{k}_j = 1 - \frac{\sum_{i=1}^{n} x_{ij}(m - x_{ij})}{nm(m-1)\,\bar{p}_j \bar{q}_j} \qquad (4)$$

Where $\bar{q}_j = 1 - \bar{p}_j$

Hence the overall kappa value for occurrence = $\hat{k} = \dfrac{\sum_{j=1}^{k} \bar{p}_j \bar{q}_j \hat{k}_j}{\sum_{j=1}^{k} \bar{p}_j \bar{q}_j}$ (5)

Where: m = number of different raters

x_{ij} = number of ratings on a subject

i = subject

n = number of subjects

j = category of rating

k = number of category

$\bar{m}$ = mean number of ratings per subject

$\bar{p}_j$ = $_{overall}$ proportion of ratings

$\bar{q}_j$ = overall proportion of non-ratings

$\hat{k}_j$ = kappa value per category

$\hat{k}$ = overall kappa value

Green (1996) explained that a perfect agreement will exist when $\hat{k}$=1.00. Also, a high degree of agreement beyond chance is said to occur when kappa value is $0.75 \leq \hat{k} \leq 1.00$. This means that there is no divergence in response from respondents. In addition when $0.40 \leq \hat{k} < 0.75$, a fair or good agreement is said to exist which gives the indication that there could be the possibility of divergence in opinions but not much. Finally, when $\hat{k} < 0.40$, there is said to be the existence of low agreement beyond chance.

3.4.3 Pearson's Product Moment Correlation Coefficient

The Pearson's correlation is used to find a correlation between at least two continuous variables. It is used when both variables are at least at interval level and data is parametric. The value for a Pearson's correlation can fall between 0.000 (no correlation) and 1.00 (perfect correlation). Other factors such as group size will determine if correlation is significant. Generally correlation above 0.80 is considered pretty high. Variables are arranged in a matrix such that where their row/column intersects there are numbers that tell about statistical interaction between the variable. Three pieces of information are provided in each cell - the Pearson correlation, the significance, and number of cases. When a variable interacts with itself, the correlation is obviously 1 and no significance is given in these cases. The Pearson's correlation coefficient "r" is a measure of the strength of the association between two variables.

It is obtained by dividing the covariance of the two variables by the product of their standard deviation. The value ranges from -1 (perfect decreasing negative linear relationship (anti correlation) to +1 (case of perfect positive increasing linear relationship (correlation). As it approaches zero, there is less of a relationship. The closer the value is to -1 and 1 the stronger the correlation between the two. Independent variables have a Pearson's correlation coefficient of 0. The t test (r) is used to establish if the correlation coefficient is significantly different from zero, and hence that there is evidence of an association between the two variables. Positive correlation indicates that both variables increase or decrease together, whereas negative correlation indicates that as one variable increases, so the other decreases and vice versa. It is interesting to note that with larger samples, a low strength of variation $r= 0.3$ can be highly statistically significant. That is ($p <0.01$). In conclusion, Table 3.2 indicates that the strength of association is high ($r= 0.968$) and the correlation coefficient is very highly significantly different from zero ($p< 0.002$).

Table 3.2: **Correlation table**

VARIABLES		Improve health and safety
Minimise on site operation (better supervision)	Pearson Correlation	.968
	Sig. (2-tailed)	.002
	N	72

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1 Introduction

The primary objective of the research was to establish how the use of off-site produced building components can improved buildability in the Ghanaian construction industry, especially in the development of Real Estate projects.. The various advantages and limitations to the practice of off-site production were established by the study. The resulting information was used to identify possible areas of improvement in the construction process that can be improved by adopting off-site production. Strategies for the smooth incorporation of off-site production principles in the Ghanaian construction industry, especially Real Estate Development was established to maximise productivity and minimise waste in the construction project delivery process to improve quality and increase efficiency. This Chapter focused on the presentation and analysis of the data obtained from the study. Study results were compared with data collected from secondary sources which allowed meaningful conclusions and appropriate recommendations to be made.

4.2 Results and Analysis

4.2.1 The Survey

The introduction of off-site produced building components (Prefabrication) into the construction activities in Ghana can effectively reduce waste generation and improve the overall environmental performance of construction sites. In a bid to come up with the advantages and hindrances of the development and application of off-site production (prefabrication) on construction site, a total of 120 questionnaires were sent out to 25 Real

Estate Developers, 25 Architects, 25 Quantity Surveyors, 25 Engineers and 20 Manufacturers and Suppliers. About 75 questionnaires were completed and returned with a response rate of 62.5%. All of the questionnaires were properly completed and were valid for the analysis.

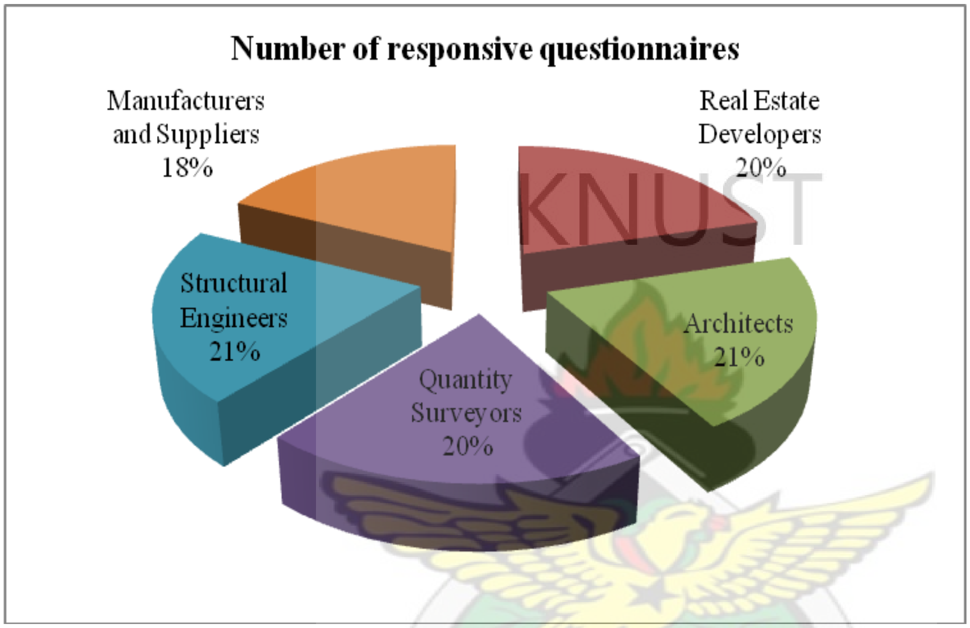


Figure 4.1.**Respondents**

4.2.2 Demographic Variables

The respondents of the survey represented construction professionals undertaking works in 2 geographical locations in Ghana, namely Accra and Kumasi. The years of experience of the various professionals ranged between 1-20 years and over. A total of 20 out of 75 professionals representing 26.7% have been in the Ghanaian construction industry for more than 20 years and about 30 representing 40 % have had 6 – 10 years of work experience, making them knowledgeable and qualified enough as respondents for the study (Table 4.1).

Table 4.1 **Demographics of the respondent**

AREA OF SPECIALIZATION OF RESPONDENT		
CATEGORIES	SAMPLE SIZE	PERCENTAGE BREAKE-UP
Quantity Surveying	15	20
Architecture	16	21
Estate Developers	15	20
Manufacturers and Suppliers	13	18
Civil Engineers	16	21
TOTAL	75	100
LEVEL OF EDUCATION		
CATEGORIES	SAMPLE SIZE	PERCENTAGE BREAKE-UP
Polytechnic	21	28
University	38	50.7
Postgraduate	16	21.3
Total	75	100
EXPERIENCE IN THE CONSTRUCTION INDUSTRY		
CATEDGORIES	SAMPLE SIZE	PERCENTAGE BREAKE-UP
0-5years	17	22.7
6-10years	30	40
11-15years	5	6.7
16-20years	3	4
More than 20years	20	26.7
Total	75	100
MEMBERSHIP OF PROJECT MANAGEMENT TEAM		
CATEDGORIES	SAMPLE SIZE	PERCENTAGE BREAKE-UP
Yes	68	90.7
No	7	9.3
Total	75	100

These experienced respondents have managerial responsibilities in their respective organizations, 7 of the 75 respondents stated they were not part of the project management team. Of the 17 who have between 0 -5 year of work experience 4 were National Service persons (Table 4.1). The research showed that years of experience and educational background of the respondents had nothing to do with their familiarity with the concept of off-site production. Only 44% rated their knowledge and use of prefabricated building components as average. The research established that even those with construction background in education and the technical know-how are not up to date with new technological advancements in the construction industry worldwide.

Most of the manufacturers and suppliers in themselves are into construction as most of the managers are involved in contract administration. The wide range of area of specification went just beyond Civil Engineering, Building Technology and Architecture. Surprisingly, the survey established that about 45% of the respondents who were Estate Developers did not read any construction related programme but had degrees in Pharmacy and Social Sciences among others. Others have done top up courses in Project Management and Contract Administration and had the capital to venture into estate development.

Table 4.2 **Respondents knowledge of off-site production**

KNOWLEDGE IN PREFABRICATED COMPONENTS		
CATEGORIES	SAMPLE SIZE	PERCENTAGE BREAK-UP
Very High	3	4
High	4	5.3
Average	33	44
Not used one before	1	1.3
Total	41	54.7
No response	34	45.3

Only 17% of respondents rated their knowledge in off-site production as being above average which brings to the fore the need to intensify the education of construction industry professionals on important technological advancement in construction such as off-site production of building components and their subsequent assembly on site in a bid to help tackle the issue of urban housing deficit. Of the 75 respondents, 34 (45.3%) shied away from answering the question of knowledge in the use of prefabrication (Table 4.2). This leads one to conclude that even the respondents who are stakeholders of the Ghanaian construction industry have limited knowledge about the use of prefabrication, this in one way or the other can contribute to the huge deficit in the housing delivery system nationwide. This supports the assertion by Boadu (1992) who observed overreliance on the traditional in-situ construction systems over the use of off-site produced building components in the construction industry in Ghana. This system is absolutely hostile to the tenets of off-site production as the concept of off-site production strives to achieve more integration between the design and construction phases of the project delivery process. Off-site production aims at minimising waste and maximising value to clients by ensuring a high concern for buildability and production economies, continuous feedback to design team, and the elimination of mistakes throughout the entire project delivery process.

4.3 Extent of the Practice of the Concept of Off-site Production by Stakeholders in the Ghanaian Construction Industry

Based on the survey results, it was established that a total of about 67% of respondents seldom recommend the use of off-site produced building components (Table 4.3). The 16 Estate developers and also manufacturers and suppliers also double up as building contractors. According to respondents, the use of prefabricated building components is not encouraged.

This has contributed to the notion that construction activities in Ghana are often delayed and the end product is costly and less affordable to the average Ghanaian.

Table 4.3 **Effect of reduction in construction cost on the recommendation of off-site production**

COST REDUCTION AND RECOMMENDATION OF PREFABRICATION							
Recommendation of Prefabricated		COST REDUCTION IN CONSTRUCTION				TEST	
		Fairly Significant	Significant	Very Significant	Extremely Significant	Chi-square	P-value
	Have not had the opportunity	2	0	0	0	34.833a	0.000
	Seldom	3	29	16	2		
	Sometimes based on the component	1	4	8	0		
	As often as possible	4	0	2	1		
Total		10	33	26	3		

Phi=0.912 Cramer's V =0.521

Inference of recommendation of prefabricated and cost reduction

The hypothesis is that the professional recommendation of the use of prefabricated material is independent on the cost of the material. The cross tabulation method is used to see if construction professionals' recommendation on the use of prefabricated material is likely to be influenced by the cost associated with its use at 4 degrees of freedom, the p-value is 0.00. Hence it proves a point that the construction professionals' recommendation of the prefabricated materials is dependent on the cost implication. From the cross tabulation the professional who rarely recommend the use of the prefabricated materials believes that reduction in cost is very significant in recommending the prefabricated materials. The Cramer's V statistics show the extent to which the cost reduction influences professional recommendation. It was found to have a strong association effect size of 0.521. Table 4.3 present the result of the cross tabulation.

Table 4.4 **Effect of respondents' years of experience on the recommendation of off-site production**

cross tabulation of experience on recommendation of prefabricated component****						TEST	
Experience in the construction industry		Recommendation of Prefabricated component				Chi-square	P-value
		Have not had the opportunity	Seldom	Sometimes based on the component	As often as possible	60.843	0.000
	0-5years	2	5	9	0		
	6-10years	0	22	4	2		
	11-15years	0	1	0	4		
	16-20years	0	3	0	0		
	More than 20years	0	19	0	1		
Total		2	50	13	7		

Phi=0.919 Cramer's V =0.531

The hypothesis here is that the professional recommendation of the use of prefabricated component is independent on the respondent experience in the construction industry. Cross tabulation method is used to see if construction professionals recommendation of off-site produced components use is likely to be influenced by respondent experience in the construction industry at 12 degrees of freedom, the p-value is 0.00. Hence it proves a point that the construction professional recommendation of prefabricated components depends on the respondents experience in the construction industry. From the cross tabulation the professionals who rarely recommend the use of the prefabricated components have worked for over six years in the firm. The Cramer's V statistics show the extent to which the experience influences professional recommendation. It was found to have a strong association effect size of 0.531.

Table 4.5 **Effect of respondents' years of experience on the knowledge in off-site production**

		Knowledge in off-site produced component				Chi-square	P - value
Experience in the construction industry		Very High	High	Average	Not used	12.282	0.056
	0 - 5years	2	0	4	1		
	6 - 10years	1	4	25	0		
	11 - 15years	0	0	4	0		
Total		3	4	33	1		

Phi=0.547, Cramer's V=0.387

The hypothesis here is that the respondents experience in the construction industry is independent of the knowledge in the prefabricated component. The author uses cross tabulation method to see if the respondent knowledge in the use of prefabricated component is influenced by respondent's experience in the construction industry at 6 degrees of freedom; the p-value is 0.00. Hence it proves a point that the knowledge in the prefabricated component is dependent on the respondents experience in the construction industry. From the cross tabulation the professionals who rarely recommend the use of the prefabricated component have worked for over six years in the firm. The Cramer's V statistics show the extent to which the experience influences professional recommendation. It was found to have a strong association effect size of 0.387.

Respondents were asked to state in their own views the type of building components that can be easily manufactured off-site. Some components that respondents associated with off-site production included floor slabs (20%), beams (8%), columns (14%), dry walls (7%), roofs and roof trusses (14%), doors, balustrades and windows (16%), septic tanks (7%) and (16%) for kerbs and pavement blocks (Figure 4.2).

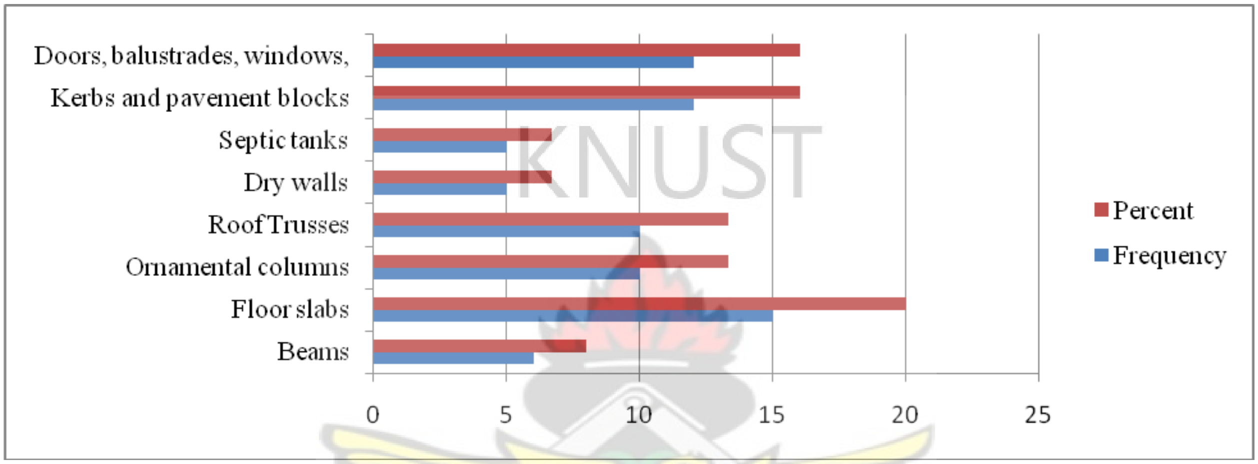


Figure 4.2 **Building components that easily lend themselves to off-site production**

Further study on the field showed their manufacture and subsequent usage in the Ghanaian construction industry is really gaining grounds. Maximum use of off-site produced building components will aid in the speed of building and thus completion time for projects as well as cutting down on the number of personnel on site and also aid in existing business continuity (Gibbs and Isack, 2003). Observations during the study indicated that, the problem of lack of finance to complete projects fully before occupancy has led to situations where the ground floor of a project can be occupied whilst the subsequent floors are under construction.

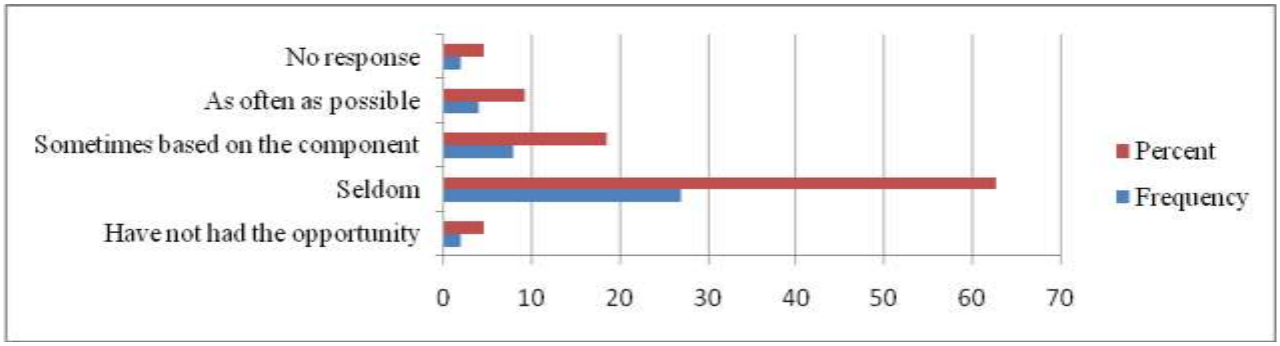


Figure 4.3 **Rate at which construction professionals recommend the use of off-site production**

A total of 66.7% of the respondents out of construction professionals seldom recommend the use of off-site produced building components. 18.6% stated they sometimes recommend off-site production based on the components, 4.7% have not had the opportunity to recommend it whilst only 9.3% admitted recommending off-site production as often as possible (Figure 4.3). This implies that even among construction professionals, the recommendation of the use of off-site production is not encouraging. This in one way or the other has contributed to the notion that construction activities in Ghana are often delayed and the end product costly, making it less affordable to an average Ghanaian.

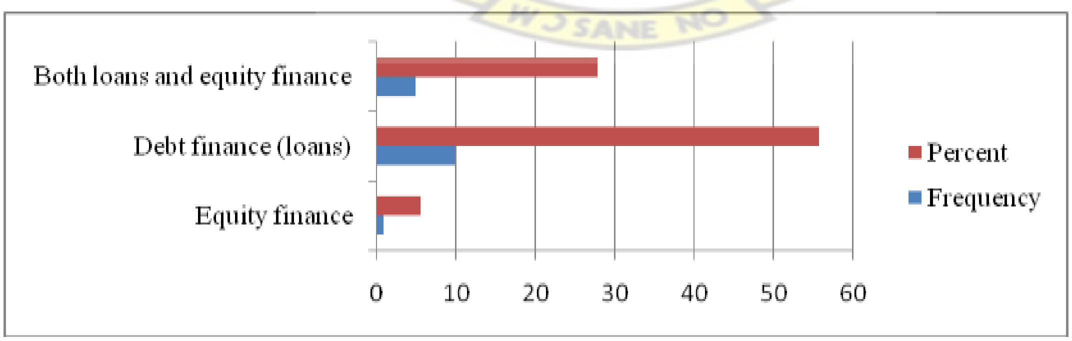


Figure 4.4 **Sources of capital mobilisation for manufacturers and suppliers**

Respondents (Manufacturers and suppliers) were asked to state the problems they encounter in the manufacture and supply of off-site produced building components. The findings are discussed further: Capital mobilisation for the manufacture and supply of prefabricated building component in the Ghanaian construction industry showed that of the 18 manufacturers and suppliers, only 5.6% of respondents stated the use of personal funds for manufacturing and supply of prefabricated building components. 27.8% stated the use of equity financing as well as loans and 55.6% stated debt financing or loans as their main source of capital (Figure 4.4). 94.4% of them went further to complain that this is a great problem to them as interest rates for such loans are very high. It is the demand for off-site produced building components that determine how soon manufactured components will be purchased. Therefore as manufacturers do not have control over when manufactured goods will be bought, they end up not making much profit as a bulk of their returns go into the servicing of loans especially from the local non banking firms where the interest rates are sometimes as high as 10% per month. This situation goes a long way to hinder the development and adoption of off-site production in the Ghanaian construction industry as the manufacturers and suppliers are facing a lot of financial challenges.

According to (Figure 4.5) 16.7% of manufacturers and suppliers mentioned Inclement weather as one challenge they are facing. 38.8% mentioned Capital injection, 16.7% stated Transportation of prefabricated components whilst 27.8% stated Supply of goods on credit as problems being encountered. These factors affect the manufacturers are not manufacturing under ideal factory conditions with the exception of those producing on a large scale. Thus the manufacturers are at the mercy of the weather as products have to cure under certain conditions which if not met will compromise the quality of the product.

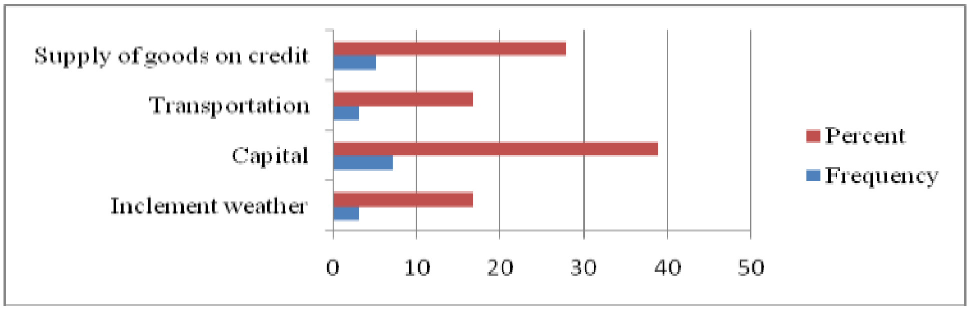


Figure 4.5 **Challenges of manufacturers and suppliers**

The supply of goods on credit after part payment is also seen as a major problem but manufacturers were forced to accept this condition as there is no ready market; as such compromises have to be made in order to get customers. 16.7% of manufacturers and suppliers stated transportation of prefabricated building components as a major problem (Figure 4.5) as they have to hire vehicles to transport goods to site. This goes a long way to cut down on their profit margin. The inability to provide transportation will lead to customers not patronizing some manufacturers and suppliers. Once again the problem of business financing is seen as one of the main problems as according to respondents, it takes sometimes up to about a month or two before manufactured components are bought. In addition, there is also the problem of production of components being mainly done through pre-financing (38%) and not based on order from clients (18%) according to Figure 4.6. This tends to affect the capital base of the manufacturers and thus minimise their profit margin. It is worth stating that these are some of the factors that work against the adoption of prefabricated building components in the Ghanaian construction industry. If the manufacturers have the right capital base to produce the components which will be bought at the right price within the shortest possible time then there will be availability of components and all the stakeholders will be ready to contribute their quota towards the adoption of prefabricated building components.

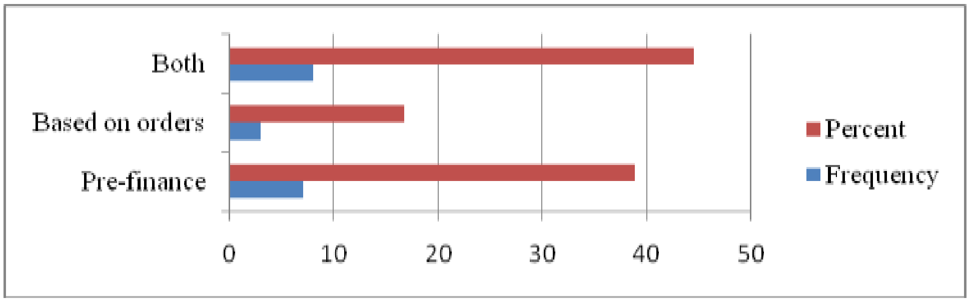


Figure 4.6 **Supply of off-site produced building components**

Respondents were asked to state their reasons for the perceived level of patronage of off-site production in the Ghanaian construction industry in terms of finances, mechanisation and labour. The findings are as presented:

Respondents according to Figure 4.7 believe that with the adoption of off-site production, there will be increase in profit at the end of construction as off-site produced components are comparatively cheaper. This notwithstanding, the survey showed that 18 respondents (Figure 4.7) believe that the adoption of off-site produced components will ensure value for money.

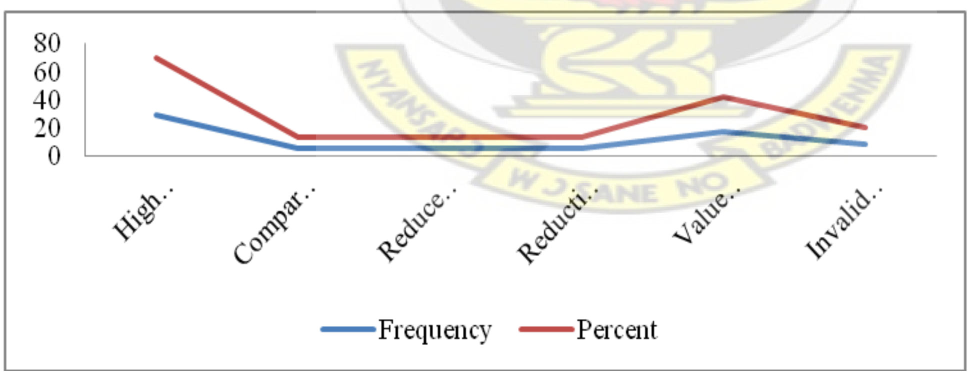


Figure 4.7 **Advantages of off-site production in relation to finance**

The main problem that respondents associated with financial constraints is the cost for purchasing or hiring of a plant (49.2%), the need for a special plant for each element (28%) and (14%) for running cost (Figure 4.8).

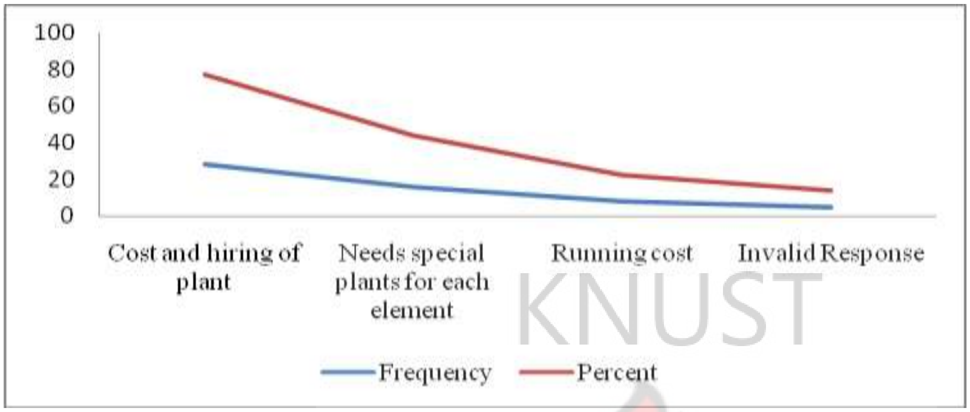


Figure 4.8 **Disadvantages of off-site production in relation to finance**

According to Figure 4.9 disadvantages that respondents associated with the use of a plant for off-site production is the constraint of high cost for purchasing a plant (66.7%), the requirement for special plant for each component (15.8%) and (12.2%) for transportation cost for manufactured components and limited space for storage

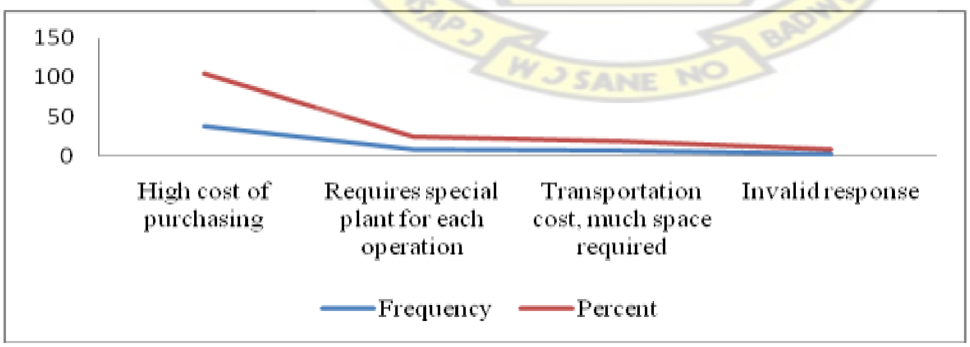


Figure 4.9 **Disadvantages of off-site production in relation to plant**

That notwithstanding, respondents stated mass production (38.7%) and precision of prefabricated components (14.7%) and (41.3%) for reduction in cost and speed of construction as some of the advantages that can be derived from the use of plant in the production of prefabricated components (Figure 4.10). This is translated into the finances as reduction in overall construction cost leading to a high margin of profit.

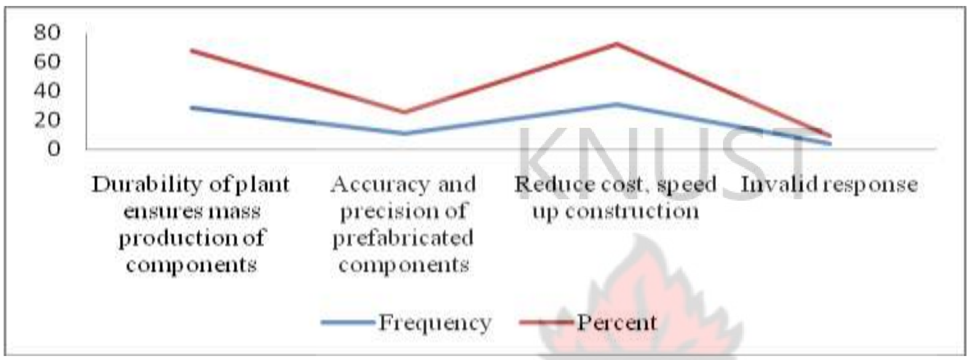


Figure 4.10 **Advantages of off-site production in relation to plant**

According to respondents, the advantages the use of off-site production will have on labour is a higher profit margin (40.3%), due to construction cost reduction (8.8%) which they perceived will be arrived at due to reduction in labour work (8.8%). In the end (8.8%) of respondents believe it will lead to value for money in the work executed (Figure 4.11).

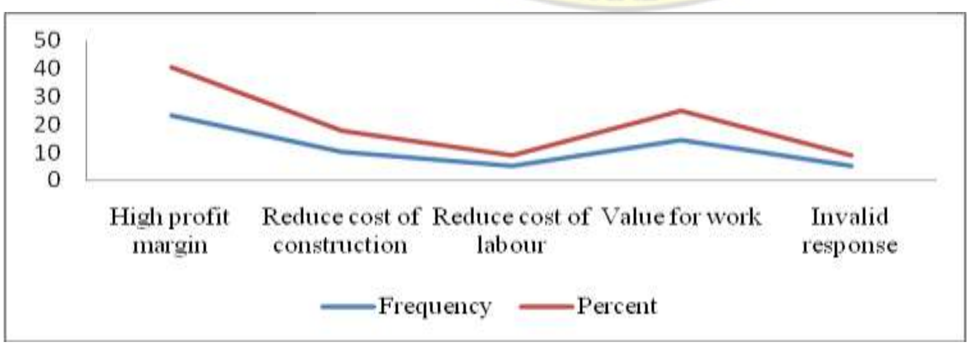


Figure 4.11 **Advantages of off-site production in relation to labour**

About 69.4 % of the respondents stated there is the need for specialised knowledge of artisans to aid in the adoption of off-site production assembly which the local labour lacks. As a result (17.5%) stated the manufacture of components is taken to domains outside the locality of the project and (8.8%) stated that because most of the components are manufactured under factory conditions, work on site is reduced thereby leading to the need for fewer worker on-site (Figure 4.12).

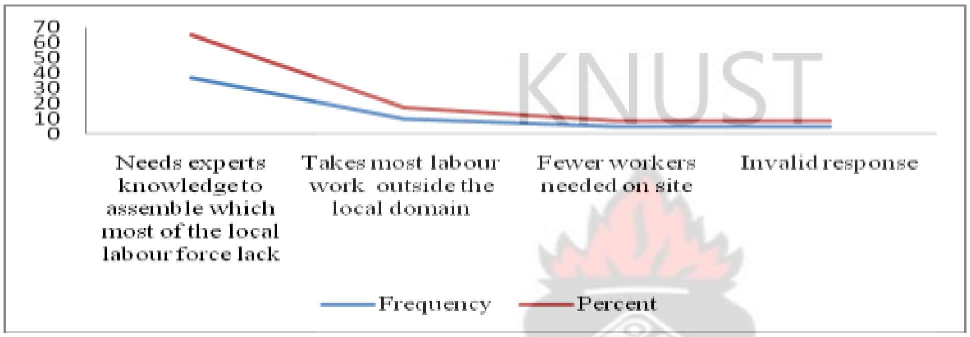


Figure 4.12 **Some disadvantages of off-site production in relation to labour**

The survey established that there is generally a low familiarity of the use of off-site produced building components among the respondents who are all stakeholders of the Ghanaian construction industry. Only a few of the stake holders contacted had been involved in the application of off-site production in their activities in order to minimise waste and increase productivity for clients. Stakeholders are still used to the traditional procurement system whereby design and construction activities are completely separated. This is still widely used for many construction projects. Suppliers and manufacturers of prefabricated building components are also not doing so well except in the use of prefabricated floor slabs, kerbs, pavement blocks and of late ornamental columns. Most Ghanaian contractors are a bit conservative and as such would like to stick to that which they believe they know best, that is, conventional / traditional construction method. Most Real Estate developers have not been using off-site production or know much about its principles. It is only at Parakou Estates and Trassaco - Villagio that the concept of prefabrication has really caught on but it is the latter that has been practicing it that much.

4.4 Advantages of Adopting Off-site Production

Many researchers had identified the advantages of applying off-site production in construction. Twelve advantages of applying off-site production were used for conducting the survey:

i) minimise on site operation (better supervision); ii) produce high quality/ integrity of the building; iii) reduce overall construction costs; iv) minimise number of site personnel; v) shorten construction time; vi) increase efficiency; vii) improve health and safety; viii) improve environmental performance; ix) aesthetic issues on the building; x) ease in placement; xi) enables existing business continuity xii) reduces congested work area and multi trade interfaces. Tam et al (unpublished) and Gibbs and Isack (2003). The advantages in applying off-site production are considered as having different levels of significance to the Ghanaian construction industry and the major focus of the survey was to identify the level of recognition of these beneficial aspects. The results derived were linked to the extent of the practice of off-site production in the country. For each beneficial factor, the respondents were requested to judge the significance level by selecting one of five grades, namely, least significant, fairly significant, significant, very significant and extremely significant. The survey results are summarized to examine the relative levels of the significance among these factors on the benefits in the adoption of prefabrication; an alternative approach is used to calculate the Importance Index. The calculation of the various factors under this section to determine the most important factor toward the adoption of prefabrication is given. A typical calculation for the level of significance for advantages of adopting of prefabrication is illustrated by **Reduction in construction time** which had the second highest importance index as shown in appendix 10.

Regression: Factors That Influences Prefabricated Component Usage And Rate of Recommendation

Regression analysis was conducted to examine the association between respondent's rate of recommendation and the factors that influence the respondent in using prefabricated component. The result of the correlation analysis between the response and the explanatory variable indicate that there is strong correlation($R = 0.983$). Hence recommendation rate of prefabricated component is used as dependent variable and factors that affect the use of prefabricated component are used as independent variables.

The result of the model was found to be significant as p-value is 0.0000. This indicates that there is a significant association between the dependent variable and the independent variables. Therefore the overall model explains professional recommendation of prefabricated components use. The majority of the explanatory variables are significantly associated with the professionals' recommendation of prefabricated component use except **'minimise number of site personnel'** (0.189) and **'reduced congested work area and multi trade interfaces'** (0.211). This indicates that these two factors are not considered by construction professionals when it comes to their recommendation of off-site produced building components. Hence the research has identified the other ten factors that are advantages towards the adoption of off-site production as significant factors that affect the construction professionals recommendation of off-site produced components use.

Table 4.6 **Factors that affect the recommendation of off-site production**

COEFFICIENTS					
	Unstandardized Coefficients	Std. Error	Standardized Coefficients Beta	t-Statistics	P-Value
(Constant)	-2.822	0.392		-7.196	0
Minimise on site operation	2.085	0.089	1.372	23.322	0.00
Produce high quality/integrity of the building	-0.401	0.049	-0.459	-8.167	0.00
Reduce construction cost	0.492	0.048	0.543	10.333	0.00
Minimise number of site personnel	**-0.07**	**0.053**	**-0.087**	**-1.333**	**0.189**
Minimise construction time	0.667	0.086	0.755	7.74	0.00
Increase efficiency	-0.673	0.072	-1.084	-9.377	0.00
Improve health and safety	0.513	0.088	0.788	5.821	0.00
Improve environmental performance	-1.432	0.087	-1.885	-16.528	0
Aesthetic issues	0.261	0.06	0.516	4.345	0
Ease of placement	0.237	0.056	0.318	4.263	0
Enables existing business continuity	-0.326	0.089	-0.443	-3.657	0.001
Reduces congested work area and multi trade interfaces	**0.104**	**0.082**	**0.16**	**1.268**	**0.211**
ANOVA TABLE					
	Sum of Squares	df	Mean Square	F	P-value
Regression	31.995	12	2.666	122.972	.000
Residual	1.084	50	0.022		
Total	33.079	62			
MODEL SUMMARY					
R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson	
.983	0.967	0.959	0.147	1.54	

Table 4.7 **Advantages in Adopting Prefabrication (Important Index)**

Variables	**I.I**
Minimise on site operation (better supervision)	0.65
Produce high quality/integrity of the building	0.76
Reduce construction cost	0.86
Minimise number of site personnel	0.66
Minimise construction time	0.77
Increase efficiency	0.76
Improve health and safety	0.56
Improve environmental performance	0.54
Aesthetic issues	0.55
Ease of placement	0.61
Enables existing business continuity	0.57
Reduces congested work area and multi trade interfaces	0.64
Total	7.93

Source: Survey

4.4.1 Minimising construction cost

Responses show that minimising construction cost is a significant factor as far as the adoption of off-site production in the Ghanaian construction industry is concerned. This is because if projects are to be considered as successful, Pitagorski (1998) writes it must satisfy the client and sponsors with an outcome that achieves project within time and cost constraints. According to Latham (1994) a successful project must have value for money and be timely delivered, According to the correlation analysis (Appendix 14) the research shows that reduction in construction cost does not necessarily mean an increase in the efficiency of the end product and the integrity of the building. Reduction in construction cost was ranked first with an importance index of 0.86 (Table 4.7). The respondents claimed adopting off-site production of building components can reduce construction cost effectively. Similar studies by

Gibbs and Isack, (2003) ranked "minimise on-site operation" as the first choice of respondents. This can be attributed to the fact that unlike Ghana, Britain has four seasons thereby limiting the actual time in a year that construction activities can be carried out effectively without so much of a problem with curing time for concrete works and construction time on site for other building trades among other things. The type of building construction in the two countries is totally different. Construction of sky scrapers with as many as fifty or more floors will require speed of work in erection whereas local constructions in Ghana are mostly below ten floors. That aside, finances is more a problem for the Ghanaian construction industry than the British thus respondents believe in cutting construction cost more than construction time. Nicco-Annan (2006) states; the construction of some buildings in Ghana reveals cost overruns of between 60%-180%, not taking inflation into account. According to Walker (1996), in Ghana, the separation of design and production function leads to design without concern for buildability or production economies, lack of feedback to the design team, and perpetuation of mistakes from project to project. The schedule of design and construction are separated because of the distinct responsibilities of design consultants and contractors respectively. Off-site production strives to achieve more integration between the design and construction phases of the project delivery process. It also aims at minimising waste and maximising value to clients by ensuring the elimination of mistakes throughout the entire project delivery process in a bid to cut down on construction cost. Respondents are more interested in reduction in construction cost which will eventually lead to maximisation of profit.

4.4.2 Minimising construction time

Due to the fact that most components will be manufacture under factory conditions, the construction time is minimised. The research shows that a reduction in construction time has an influence on improvement in the health and safety of workers in the quest to adopt prefabrication. Minimise construction time is ranked as second with an importance index of 0.77 (Figure 4.7). According to the correlation analysis (Appendix 14) the research established there is not much significant difference between reducing construction time and reduction in cost as far as the race to adopt prefabrication is concerned. But it is worth noting that, depending on the complexity of the building in question, off-site production may complete the project faster for the building to be used early, even though at a higher cost. This goes to support Gibb and Isack (2003), description of the benefits of off-site construction as being mainly time and quality based. But the use of off-site production will definitely lead to some amount of construction cost and time reduction no matter how small. Nicco-Annan (2006), reports that clients of the Ghanaian construction industry continue to complain about the industry's performance and its seeming inability to deliver projects on time, within budget and to expected quality standards. Delay in the completion of construction projects is also having an adverse effect on the credibility of stakeholders in Ghanaian construction industry to deliver optimum value for their customers' investment. Nicco-Annan (2006) observed time overruns of between 12-24 months from a survey conducted on the construction of some buildings in Ghana. Failure to complete projects at the right time is seen by most clients as a compromise on the value expected to be derived from the projects. Most clients are therefore left dissatisfied seeing their projects not being completed in time. According to Rosenfeld, (1994), as is common to off-site production, most of the work is carried out in the factory, leaving little to be done on-site. This increases the likelihood of more efficient, high quality and ultimately, faster construction being achieved as a result, the fewer the tasks that must be undertaken on-site, the shorter the overall duration and the more consistent the quality. A shorter construction time not only cuts down direct and overhead costs, but also allows the house to be occupied sooner. Munns and Bjeirmi (1996), notes that for a project to be successful, it must be completed on time. This can be achieved by setting a realistic goal which can be achieved by; planning with a commitment to complete the project; careful appointment of a skilled project manager; spending time to define the project adequately; correctly planning the activities in the project; ensuring correct and adequate information flow; changing activities to accommodate frequent changes; accommodating employee's personal goals with performance and rewards; and making a fresh start when mistakes in implementation have been identified (Munns and Bjeirmi, 1996). Unfortunately, the local procurement system which separates design from construction does not really help with the achievement of this goal. If off-site production of building components is encouraged then ultimately, construction time will minimise as the construction process will be getting nearer the manufacturing process.

4.4.3 Increase efficiency

Increase efficiency is an essential component of off-site production and it is therefore no wonder that respondents ranked it third with an importance index of 0.769 (Table 4.7). There was an indication from the survey that most of the respondents especially the construction professionals in carrying out their activities try in principle, to observe such tenets of buildability such as delivering what the client wants, avoiding defects and rework, driving out waste and so on. But because the use of off-site produced building components have not caught on well with the stakeholders not for mistrust in the system but for the simple fact that most of them lack the capital to venture into it, the local industry has been plagued with inefficiencies.. Most respondents share the view expressed by Toole and Gambatese (2006) that off-site production increases efficiency and reduce the hazard level by allowing the work location to be shifted to a lower hazard environment where risk associated with working at heights or in confined spaces are reduced. This allows for the use of safer, automated equipments and reduces waste to the barest minimum. This will increase the efficiency associated with the use of off-site produced components as compared to the traditional construction system.

4.4.4 Produce high quality/integrity of the building

The research sides with the assertion by Rosenfeld (1994) that, with prefabrication most of the work is carried out in the factory leaving little to be done on-site. Factory manufacture increases the likelihood of more efficient, high quality building components. With fewer tasks be undertaken on-site, the overall duration of construction projects are shortened and components are more consistent in quality. According to Gorgolewski (2003) building site exposed to adverse climatic conditions does not offer a good working condition for high quality workmanship and quality construction. Factory based activities allow better and safer working conditions and being protected from the climate, are more likely to lead to better quality. In a factory, it is easier to set up quality control procedures, with testing, prototyping and checking. This in the end ensures the best quality of products. It is a significant cost reduction and efficient benefit to the builder and leads to satisfied customers. Efficiency is also improved in the use of resources and reduced waste. This will lead to a successful project as espoused by Latham (1994) that, a successful project must have value for money, be pleasing to look at, be largely free from defects, timely delivered, fit for the intended purpose, guarantee reasonable running cost, durable and the end result must be customer delight. Nicco-Annan (2006), reports that in Ghana, clients of the local construction industry continue to complain about the industry's performance and its seeming inability to deliver projects on time, within budget and to expected quality standards. Another school of thought also believe that, the fact that there is a reduction in cost and site personnel as well as an increase in environmental performance does not necessarily lead to the production of high quality buildings. Respondents according to the survey view the introduction of off-site production as a means to the production of high quality buildings. It is ranked a joint third with "increased efficiency" with an average value of 0.76 (Table 4.7). The responses by the respondents indicate that the idea for applying manufacturing technologies to the Ghanaian construction industry will results in an increase in productivity, efficiency and quality of the product.

4.4.5 Minimise number of site personnel

Minimise number of site personnel is ranked fifth with an importance index of 0.66 (Figure 4.7). About 42 respondents cited that risk can be curtailed by reducing the amount of work done on the construction site and thus minimise site personnel mainly through increased use of some form of preassembly. The benefits of off-site production directly or indirectly lead to health and safety of the construction worker. Gorgolewski (2003) stated "on-site construction work can be a dangerous activity and can lead to a significant number of casualties and even fatalities". The research established that if site personnel are reduced, it will take a very significant increase in the training of the local workforce in new technologies in construction such as the ease of placing prefabricated components among others to significantly decrease construction time or cost irrespective of the adoption of prefabrication. But that notwithstanding, the adoption of prefabrication is a far better option than the traditional construction system. According to Fergusson (1989) many builders are pushing to consider different ways of building, mainly, off-site manufacturing techniques. Respondents believe due to the production of most components under factory condition, onsite work will reduce thereby prompting a reduction in site personnel which is a significant point towards the adoption of off-site production. Proponents of off-site production argue that it will shift the work to other countries or environments where labour will be cheap and where only well trained personnel can work. One thing the research established is the fact that quality is not found in the number but in the expertise of the workers. Thus, there is the need to organise training programmes for the local construction workforce to bring them abreast with new technological advancement in the construction industry worldwide.

4.4.6 Minimise On-site operation

According to Gorgolewski (2003) with the key feature of off-site production being that most of the work is removed from site to a controlled factory condition, there is a reduction in the time spent on site as on-site operation is minimised. Experience has shown that most off-site manufactured building components can be assembled and be ready for use in about half the time needed by traditional buildings of the same type (Fergusson, 1989). This means that the locality around the site is disrupted for a shorter period of time. This finding by the survey leaves one to wonder if the very people who are stakeholders in the Ghanaian construction industry really understand the concept. It is therefore not surprising that many big construction projects start in Ghana and project time is far exceeded due to the local procurement system. This is because the construction industry is more into the use of the traditional construction system. It is a fact worth stating that the adoption and proper use of the concept of off-site production will speed up the construction process immensely as on-site operations will be reduced to the barest minimum. Respondent of the survey believe that on a scale of 1-12 of the importance of off-site production on buildability in the Ghanaian construction, minimise on-site operation is ranked sixth with an importance index of 0.65 (Figure 4.7). The research indicated that, when on-site operation is highly significantly minimised and the use of off-site produced building components are highly maximised, it will have a very significant positive effect on the overall on-site operation. In the literature review of the research, evidence is presented demonstrating that current evaluation methods for comparing traditional and off-site produced building solutions do not adequately account for all the main factors that affect cost. Gorgolewski (2003) stated that building site exposed to adverse climatic conditions does not offer a good working condition for high quality workmanship and quality construction. Factory based activities allow better and safer working conditions and being protected from the climate. Manufacture in a factory provides much better working conditions than a building site. Fergusson (1989) stated that good buildability is a main determinant if the constructions of buildings are to be efficient and economical. This depends on the assembling of materials, components and sub-assemblies at the assembly point into the building to optimise efficiency. Logical, accurate and speedy assembly does not only depend on organisational competence but also on the ease of assembly and the competence of the site personnel to achieve a successful project.

4.2.7. Reduces Congested Work Areas

Congestion on construction site is one problem that faces the local construction industry due to the use of more than necessary workmen, improper storage facilities and also mainly due to poor waste management on site. Off-site production helps reduce congestion on site by allowing most of the work to be shifted from the construction site to a factory (Toole and Gambatese, 2006). The use of off-site production eliminates or reduces many traditional construction work task with serious risk factors (Simonsson and Rwamamara, 2007). The research however portrayed there need to be a significant increase in the adoption off-site produced components which will impact directly in the minimisation of on-site operation to impact directly on congested work area from both workmen and their on-site trade (Appendix 14). This will impact directly by reducing construction time and cost due to a significant increase in efficiency, leading to a significant improvement in health and safety of workers.. According to (Ferguson, 1989 & Griffith and Sidewell, 1995), good buildability is a main determinant if the constructions of buildings are to be efficient and economical. It depends on the assembling of materials, components and sub-assemblies at the assembly point into the building to optimise efficiency. Logical, accurate and speedy assembly does not only depend on organisational competence but also on the ease of assembly and the competence of the site personnel to achieve a successful project.

4.4.8 Ease of placement

One problem the research established to be facing the nation's construction industry is the quality of qualified construction workforce who have the knowledge base in off-site production techniques. Researchers like Ferguson (1989), Griffith and Sidewell (1995), Glavinich (1995), and Gary and Hughes (2001) all attest to the fact that, designing for buildable projects should take account of the efficient use of available resources which includes labour force on site. This is because after the off-site production process is carried out in a factory (where conditions are more controlled and comfortable, and where safety requirements can be easily met and monitored, and healthy and comfortable working conditions can be maintained more easily), there will be the need to position or assemble these components on site. (Fergusson, 1989).

4.2.9. Enables Existing Business Continuity

As per the research, respondents are of the view that one problem with the local construction industry is the problem of continuous work on already inhabited buildings still under construction. This according to respondents can be taken care of better and faster if most of the wet works can be turned into off-site produced components. This goes to buttress Gorgolewski (2003) statement that "experience has shown that most off-site produced buildings can be assembled and be ready for use in about half the time needed for traditional buildings of the same type". This means that the locality around the site is disrupted for a shorter period of time, reducing noise pollution emission and local traffic disruption in the case of built-up areas. Financially, a shorter the construction period means quicker returns on investment to the client and reduced overheads. This factor was ranked ninth (9^{th}) by respondents with an importance index of 0.57 (Table 4.7).

4.4.10 Improved health and safety

The health and safety practices of the local construction industry according to the survey are not the best. Sites visited during the survey left much to be desired as far as safety of workers is concerned. This is mainly due to the fact that only a few of the practitioners of the industry really have safety equipments and safety officers. Where safety equipments are provided construction workers on site choose not to put them on. The respondents agree with the assertion of Gibbs (2004) that permanent works designers could reduce the risk by reducing the amount of work done on the construction site, mainly through increased use of some form of preassembly. Construction production process is usually carried out at the final project delivery site. According to Koskela (1992), this leads to such problems as little protection against elements or intrusion thus rendering operations prone to interruptions. He further explains that in site production the working environment, unlike that within factories, is continuously evolving, making layout planning laborious and visual controls difficult to implement. Respondents rated it a surprising tenth with an importance index of 0.56 (Table 4.7). The question that arises from this survey is how construction stakeholders assess the health and safety of the workforce if it is not deemed to be so important. The benefits of off-site production will directly or indirectly lead to health and safety of the construction worker and should be considered at the design and construction stage.

4.4.11 Aesthetics issues

The age old idea that use of prefabricated building components lead to the problem of monotony in design and lack of interesting facades in buildings came up significantly in the survey. Some of the respondents when pressed on this view expressed the concern that it is a bit difficult to change prefabricated components if the need arises. There was the issue of some shapes being difficult to work with, which impacts negatively on the aesthetic appeal of the finished product. Respondents of the survey do not view this as a major hindrance affecting the introduction of off-site production and thus rated it a distant (11^{th}) on a scale of 1 – 12 (Table 4.7). But one thing that featured significantly in the research is that most construction professionals believe cast in-situ construction and the use of off-site produced components can both be aesthetically pleasing. But for the respondents, this is not an important factor as 48% did not view it as a significant factor. According to the research, the main factor that respondents believe impacts directly on this will be the ease of placement of prefabricated building components.

4.4.12 Improvement of environmental performance

Surprisingly, most respondents do not believe that improved environmental performance is of utmost importance as far as the adoption of prefabrication in the Ghanaian construction industry is concerned. Thus it was rated (12th) with an importance indice of 0.54 (Table 4.7). This may be due to the reason that unlike temperate zones, buildings in Ghana don’t go into details as far as installing certain building components, especially insulation materials and air barriers. These are of utmost importance to buildings in other zones but are of little importance locally to the performance of a building in use. Secondly, since it is a new concept that is now being introduced fully in the Ghanaian construction industry, most respondents are not fully aware that Factory manufacture allows operatives to be better trained and supervised in these tasks and allows regular checking and testing for performance. Since manufacturers will be producing such components en-mass for different sites, there is the potential for manufacturers to take more time with the selection of environmentally friendly materials and establish local supply chains in the area of the factory. The research shows there is the need for a highly significant improvement of all the other factors before they can impact positively on this factor.

4.5 Hindrances in Adopting Off-site production

In addition to the advantages in adopting prefabrication, the disadvantages on the applications of prefabrication were also being investigated. Nine hindrances on applying prefabrication are being adopted for the survey i) inflexible for changes of design; ii) higher initial construction cost; iii) time consuming in the initial design development; iv) limited site space for placing prefabricated building components; v) lack of experiences on the contractors; vi) monotone in aesthetics issues vii) leakage problems at joints of prefabricated components; viii) inadequate background research information; ix) lack of demand for offsite produced (prefabricated) components - (Tam *et al*, unpublished). Similar to the analysis on the advantages of prefabrication, five significant levels will be responded from least significant to extremely significant. SPSS is used to collate the data from respondents. To examine the relative levels of the significance among the factors that hinders the adoption of prefabrication, an alternative approach is used to calculate the Importance Index based on the SPSS data. A typical calculation for the level of significance for hindrances towards the adoption of prefabrication is illustrated by '***Higher Initial Construction Cost'*** which had the highest importance index (Appendix 11).

A regression analysis is used to examine the association between respondent's rate of recommendation and the factors that influence the respondent in using prefabricated component. The result of the correlation analysis between the response and the explanatory variable indicate that there is strong correlation(R = 0.672). Hence recommendation rate of prefabricated component is used as dependent variable and factors that affect the use of prefabricated component are used as independent variables. The result of the model was found to be significant as p-value is 0.0000.

This indicates that there is a significant association between the dependent variable and the independent variables. Therefore the overall model explains professional recommendation of prefabricated components use. Eventhough the overall model showed that the factors under consideration as hindrances towards the adoption of off-site production are significant, meaning majority of the explanatory variables were significantly associated with the professionals' recommendation of prefabricated component use. The model identified **Monotony in aesthetics** as the only factor that is not a serious hindrance considered by construction professionals in their recommendation of off-site produced building components.

Table 4.8 **Hindrances to the adoption of off-site production**

MODEL COEFFICIENTS					
	Unstandardized Coefficients	Std. Error	Standardized Coefficients Beta	t-Statistics	P-Value
Inflexibility for changes in design	-0.006	0.119	-0.008	-0.051	0.959
Higher initial construction cost	0.224	0.181	0.385	1.239	0.22
Time consuming in initial design development	0.352	0.228	0.451	1.544	0.128
Limited space for placing components	-0.011	0.1	-0.017	-0.114	0.91
Lack of experience on the part of contractors	0.058	0.131	0.098	0.442	0.66
Monotony in aesthetics	**0.343**	**0.12**	**0.567**	**2.861**	**0.006**
Leakage problem at joints of components	-0.17	0.113	-0.286	-1.507	0.137
Inadequate background research information	-0.25	0.151	-0.603	-1.659	0.102
Lack of demand for off-site production	-0.189	0.136	-0.368	-1.388	0.17
ANOVA TABLE					
	Sum of Squares	df	Mean Square	F	P-Value
Regression	15.518	9	1.724	5.686	.000a
Residual	18.801	62	0.303		
Total	34.319	71			
MODEL SUMMARY					
R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics	
				R Square Change	F Change
.672a	0.452	0.373	0.551	0.452	5.686

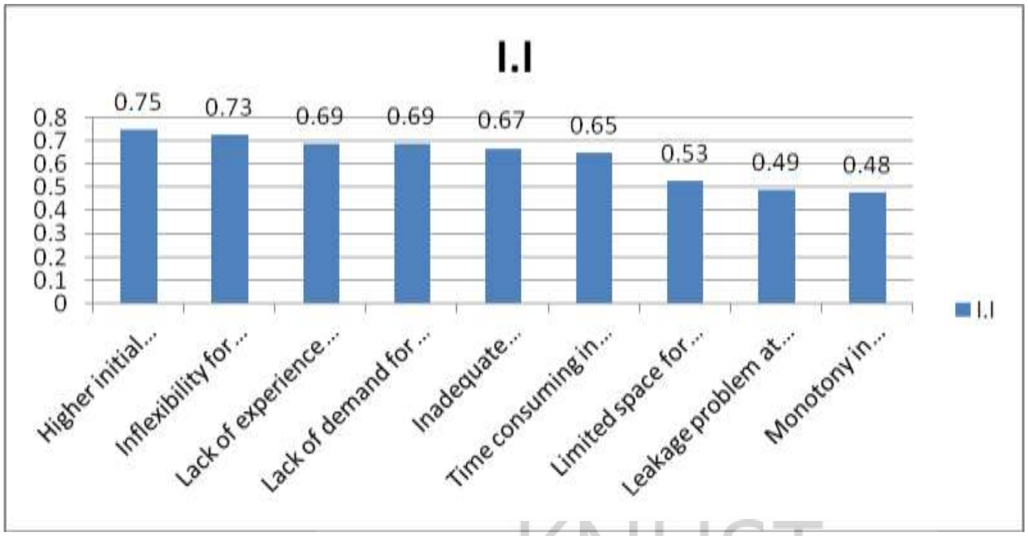


Figure 4.13 **Hindrances in adopting off-site production (importance index)**

Source: Survey

4.5.1 Higher Initial Construction Cost

Higher initial cost was viewed by respondents as the most important factor that is hindering the adoption of off-site production by the local construction industry. Thus it was rated first with an importance index of 0.75 (Figure 4.13). This agrees with the views expressed by Gibbs (2001) that many view the approach as too expensive to justify its use. Though most respondents ranked it as the highest deterrent, the survey result showed that respondents still sided with Latham (1994) that, a successful project must have value for money, guarantee reasonable running cost, durable and the end result must be customer delight. Strong cost, value and productivity constraints outweigh any related advantages. Off-site production is seen as more expensive. the challenges include i. High initial capital outlay, ii. Higher design iii. Cranage and iv. Transport costs.

While cost seems greater with off-site production there appears to be a lack of awareness of the possible cost savings over the whole-life of off-site produced products. Production efficiencies, given sufficient volumes, together with reduced onsite operations can decrease overall cost. Whole-life cost needs to be emphasised with an understanding of value rather than purely direct material/labour cost (Cole, 2003). The research showed that conditions to be met to make off-site production attractive and acceptable include i. Adequate research information and interest in the use of off-site produced components ii. Adequate training of the local construction workforce in the changing face of the construction industry worldwide iii. Mass production of off-site components.

These will lead to a decrease in the cost of components which will raise the affordability of the houses constructed using off-site produced building components. This will lead to a decrease in the housing deficit, and the perceived problem of low income of prospective buyers will be somehow solved, and in so doing whip up people's interest in the use of prefabricated building components.

4.5.2 Inflexible For Changes of Design

Inflexibility for changes of design is ranked second by respondents on hindrances of adopting prefabrication with an importance index of 0.73 (Figure 4.13). The research indicated that stakeholders of the Ghanaian construction industry are reluctant to adopt off-site production for construction projects because of the fear that existing site conditions may call for a lot of changes in the design details on site. To help address this problem, the designer must spend time to solve all the design problems at the design conception stage; this will ensure flexibility of the design thereby raising the buildability status of the building. There is also the need to educate the local construction professional workforce in new technological advancements in the construction field. It will make it easier to easily adopt new changes on site even with the use of prefabricated building. This will make the changes on site if need be, work better. This support the assertion by Holroyd (2003) that the goal of buildability is to achieve optimum integration of construction knowledge in the building process. Howell (1999) explains this point further that off-site production is largely dependent on project –specific conditions, and the combination of building methods used on a project. He explains the peculiarity of the construction industry from the manufacturing sector. He stated manufacturers make parts that go into projects but the design and construction of unique and complex projects in highly uncertain environments under great time and schedule pressure is different from making tin cans. Thus in construction, designs must be flexible, but care must be taken to ensure what is design specific and what is for everyday construction use.

4.5.3 Lack of Experience on the Part of construction professionals

Respondents ranked this hindrance as the third most important hindrance affecting the local construction industry in its adoption of the use of off-site produced building components with an importance index of 0.69 (Figure 4.13). This is not surprising as the level of the use of prefabricated components in the local industry is one way or the other really related to these two factors. The research showed that due to the fact that most of the local construction workforces are not very well educated and their knowledge of off-site production is low, there is a low level of the use of prefabrication. The lack of experience on the part of the local artisans can lead to construction failure on site. According to Feld and Carper (1997) construction failures result from a combination of condition, mistakes, oversight, misunderstanding, ignorance, incompetence and dishonest performance. According to Boadu (1992), the unprofessional nature of the construction industry has led to the situation where most of the tradesmen do not belong to any recognizable body, thereby making it difficult to hold them accountable for their mistakes on site. If this is so then it can be inferred that lack of use will certainly trigger the effect of lack of demand for prefabricated building components. This notwithstanding, stakeholders believe there is still the need to train the local artisans on its application as that is the way forward for any construction industry that aspires to meet the housing challenge of its populace. The research indicates that there must be ongoing research on the concept of off-site production in order to help solve all the misunderstanding of the concept to make stakeholders accept it.

4.5.4 Lack of Demand for Prefabricated Components

Lack of demand for prefabricated components many respondents believe is one of the major problems hindering the adoption of off-site production, thus it is ranked a joint third with an importance index of 0.69 (Figure 4.13). The research indicated that lack of demand for prefabricated components is brought about by the perceived problems of higher initial construction cost with the use of prefabricated components as well as the inexperience on the part of the local artisans. This coupled with the lack of adequate information on the use of prefabricated building components on the part of both professional and other stakeholders of the Ghanaian construction industry has led to disinterest in the adoption of off-site production as against the traditional in-situ construction. But all these notwithstanding, the current trend of globalisation offers a lot of opportunities for the Ghanaian construction industry as far as systems and techniques that support a smooth implementation of this concept is concerned. The use of standard building components as well as prefabricated systems according to Harris and McCaffer (2001) is becoming common in the construction industry because of the transfer of technology from the industrialised world. The current presence of construction and consultancy firms from various parts of the world in Ghana will also make it possible for Ghanaians to learn from them new construction management practices. According to Koskela

(1992) standardising components as well as utilising modularised and prefabricated building systems is one of the remarkable ways of bringing construction closer to manufacturing industry. The current technological and industrial base in Ghana is however not adequate to support the use of industrialized building systems involving standardised and prefabricated components. The lack of experience on the part of the local contractors in the comprehensive use of off-site production has been attributed to lack of demand for off-site production as well as the educational background of artisans. The adoption of off-site production components must be seen as the way forward, other than the traditional building system which according to Walker (1996), separates design and production function, leading to design without concern for buildability or production economies, lack of feedback to the design team, and perpetuation of mistakes from project to project. The unprofessional nature of the construction industry has led to the situation where most of the tradesmen do not belong to any recognizable body, thereby making it difficult to hold them accountable for their mistakes on site (Boadu, 1992). If this is so then it can be inferred that lack of use will certainly trigger the effect of lack of demand for prefabricated building components. This notwithstanding, stakeholders believe there is still the need to train the local artisans on its application as that is the way forward for any construction industry that aspires to meet the housing challenge of its populace.

4.5.5 Inadequate Background Research Information

A major constraint in the industry is a lack of adequate knowledge on off-site production. There is limited expertise among designers and contractors of off-site production and its processes. Approaches to design are still largely based on traditional methods that are unsuited to off-site production. More integrated design skills and understanding are required to ensure system interfaces are managed and designed for production, erection and performance.

Education and training is still focused on current practice with specific off-site production skills particularly limited. A lack of general guidance and information on off-site production in the market-place further exacerbates this hindrance. A pilot study by Pasquire and Gibbs (2002) demonstrated that the decisions to use off-site production are still largely based on anecdotal evidence rather than rigorous data, as no documented measurement procedures are available. It became evident from the survey that there is a fair level of familiarity with the concept of off-site production within the Ghanaian construction industry. But unfortunately, its practice is generally absent in the project delivery processes. There is failure to consciously put in place systems to ensure the practice of off-site production and respondents believe this stems from the problem of lack of adequate information on this concept. According to the research findings, it is the exposure that stakeholders have on the concept that will inform their interest in its use. Therefore there should be ongoing studies and sensitization of the concept among the academia and stakeholders of the construction industry. The survey revealed that stakeholder are of the belief that, the current trend of globalization will enhance technological and information transfer to Ghana in order to support the production and use of industrialized and standardized building systems to speed up construction processes. With the required background information, designers will be able to get enough data on material types and sizes among others to help them speed up the design process and come up with designs that address the issue of material wastage on site. This factor is ranked fifth by the respondents with an importance index of 0.65 (Figure 4.13).

4.5.6 Time Consuming in Initial Design Development

The buildability of a housing design according to the survey must be thought of as early as the design stage, In order for the concept of off-site production to be widely approved and implemented on site to the benefit of the client as well as the design team, care must be taken by the design team to consider the technique at an early stage of design (CIRIA, 2003). Designers must understand prefabrication involves geometric rules, that the design of a house needed numerical rules and analysis, calculations, statistics and measurements and they must be viewed with extraordinary detail (Hersey and Freedman, 1992). It is necessary for designers to consider the buildability of their design during the design process, since there is the need to achieve a harmonic fit of geometric orders in plan as well as in section, while at the same time resolving the problem of structural co-ordination among the various parts of a building without losing sight of its aesthetic appeal, thus allaying the fear of most clients that the end product will be a dull, boring building without identity or flexibility (Hersey and Freedman, 1992). With this in mind, there is the need to review the process whereby materials are converted into components, components into subassemblies and subassemblies into the completed building, and the preparation stages during which the materials, components and sub-assemblies will actually be converted, either off-site or on-site. The designer should envisage how the conversion can take place and if it can be done with minimum preparation using the most widely used and best understood materials, components and sub-assemblies (Ferguson, 1989). A pilot study by Pasquire and Gibbs (2002) demonstrated that the decisions to use off-site production are still largely based on anecdotal evidence rather than rigorous data, as no documented measurement procedures are available. This point to the fact that there is the need to collate information on the concept, before designers will have enough references and be well informed to shorten the initial design development stage. The research indicated that design problems should be solved at the conception stage for the sub assemblies to be worked out. Responses from some respondent are that though this process is considered as being cumbersome it is very necessary if the issue of off-site production is to gain roots in the local construction industry. Respondents surprisingly do not see this as a very important factor that is hindering the adoption of prefabrication, thus it is rated sixth among the factors (Figure 4.8).

4.5.7 Limited Space for Placing Prefabricated Building Components

It is worth noting that storage facilities on most construction sites in Ghana leave much to be desired. Some construction sites especially in the central business districts nationwide have a problem with limited space for storing bulk construction components. When available, it may come at a high cost. Thus with the introduction of bulky prefabricated components that may even need a crane to lift into place, there is the fear of there being limited space for placing prefabricated building components. This issue can be addressed by bringing in the components to site only when it ready to be installed. This factor is ranked seventh by respondents.

4.5.8 Leakage Problems

Although there is the fear that leakage problems will occur at the joints of prefabricated components from the survey, it is not found to be a major hindrance in adopting prefabrication as it is ranked eighth with an importance index of 0.49 (Table 4.8). The level of significance is also very low. 26% and 19% of respondents viewed it as being least significant and fairly significant respectively.

4.5.9 Monotony in Aesthetics

The main goal of prefabrication is to achieve a harmonic fit of geometric orders in plan as well as in section, while at the same time resolving the problem of structural co-ordination among the various parts of a building without losing sight of its aesthetic appeal. The use of standardization or building rationalization depends on geometry and requires in- depth explorations on the part of the Designer or Architect to allay the fear of most clients that the end product will be a dull, boring building without identity or flexibility (Hersey and Freedman, 1992). Surprisingly, most of the responses do not show that monotony in aesthetics is a major problem hindering the adoption of prefabrication in the local construction industry as it was ranked last (ninth).

An interesting pattern that was established in the cause of the study revealed that some of the problems being experienced in the Ghanaian construction industry impact directly on the factors that hinder the adoption of off-site production in the country. Researchers like Ferguson (1989), Griffith and Sidewell (1995), Glavinich (1995), and Gary and Hughes (2001) all attest to the fact that, designing for buildable projects should take account of the efficient use of available resources which includes labour force on site, general attendance provision from main contractor, specific machinery plants and equipment. External factors should be considered upon the change of geographic site conditions, local political situations and global economic climate (Pong 2009). Besides, as stated by Adams (1989); designers are required to assess the craftsmanship level and the competence of specialist to perform their buildable designs. Some of the problems are discussed further.

4.5.10 Problems Of The Ghanaian Construction Industry That Impact On The Factors That Hinder The Adoption Of Off-Site Production

4.5.10.1 Shortage In Housing Finance

The research showed that with the right injection of finances into the construction industry to help stakeholders, the issue of applying manufacturing technologies to the construction industry by full mechanisation of the construction process in Ghana using heavy plants and turning construction into an assembling industry rather than following the traditional construction method can be achieved. Shortage in housing finance was ranked first by respondents with an importance index of 0.84 (Figure 4.9). Most of the responses pointed to the fact that most financial institutions consider the construction industry especially the Real Estate industry as a high risk sector making it difficult to acquire loans. Even where available, high interest rates deter most construction professionals from going in for local loans. This according to Owusu and Edusei (1991) is more serious in the rural areas because eventhough finance is a universal constriant to the development of quality houses, it is even more not readily available to developers in rural areas and low income neighbourhoods than to those even in the urban areas. This is because the financial institutions have little incentive to invest in housing because of low returns.Owusu and Edusei (1995) stated that in spite of the network of banking and other financial institutions in the country, there is very little mobilisation of savings which can be channelled into the housing delivery sector. Due to limited funds for long term lending, the housing finance institutions of the country have catered mainly for the needs of a restricted population, mostly the middle and upper income groups. Respondents shared the view that, most individuals and households finance their house building activities through personal informal savings and loans from friends and families. The resultant effect is prolonged construction period. It is estimated that most houses take between 5 to 10 years to complete as a result of the limited funds. Further field study revealed the fact that most of the well established Estate Developers and well established Construction firms in Ghana even prefer sourcing for funding for their construction work from foreign banks either in Europe or America where interest rate is sometimes as low as 1% per anum as against an average interest rate of about 23% charged by local financial institutions. But unfortunately, not many of them have assess to such credit facilities.

Table 4.9 **Ranking of problems facing the Ghanaian construction industry**

Factors	**Important Indices Ranking**
Shortage of housing finance	0.84
Lack of adequate mechanisation in the housing construction industry.	0.81
Low income of prospective buyers	0.77
Land tenure and cost	0.81
Lack of adequate qualified construction manpower and skilled artisans.	0.77
Use of expensive building materials	0.63

Source: Survey

4.5.10.2. Lack Of Adequate Mechanisation In The Housing Construction Industry

The research showed that lack of adequate mechanisation in the housing construction industry which is a major problem of the Ghanaian construction industry is also a major factor that is also hindering the adoption of off-site production in Ghana. For mechanisation of the construction industry and the use of new building technologies such as off-site production to be encouraged, there will be the need to drastically improve the knowledge base of the local artisans to bring them to the required standard. It has a good impact as for now stake holders in the Ghanaian construction industry are not able to move from over dependence on labour to the use of machines which will speed up construction. Lack of ready finance, high cost of purchase and running cost are also some reasons why people do not want to enter into the use of machines in the Ghanaian construction industry. It is ranked second with an importance indice of 0.81 (Table 4.9). Most construction equipment and machinery that will turn the Ghanaian construction industry into a manufacturing process are not readily available. Capital for procuring such machines is virtually non existent unlike most advanced countries where there are loan facilities specially spread over a long period at a very low interest rate for construction companies to purchase machines. There is also the problem of hiring machines and local contractors prefer manual labour as they believe the running cost of machines are very expensive. Thus the absence of machines and equipment has the problem of delaying the construction process which according to Boadu (1982) leads to cost overrun.

4.5.10.3 Land Tenure And Cost

Most respondents interviewed shared the views of Boapeah, (2003) that, the market for land in Ghana is highly unorganised. Information about who owns what piece of land is not readily available and the legal and administrative systems for transferring titles are very cumbersome. These features have serious repercussions on housing supply. Currently, property transactions are slow and costly, and financial institutions are unwilling to extend credit to property holders without clear land title due to the involvement of many people in land administration, the sale of land may instigate disputes. A typical example is multiple delivery of the same piece of land to different developers. Processing of land grants up to lease validation stage is also long, frustrating and very expensive. Respondents interviewed believe the situation can be rectified by reducing the time it takes for documents to be processed at the lands commission and the simplification of land acquisition process nationwide. It is therefore not suprising that respondents ranked this factor as joint second most important problem facing the Ghanaian construction industry with an importance index of 0.81 (Table 4.9).

4.5.10.4 Low Income of the Prospective Buyers

The research portrayed that, the low income of the prospective buyers is hindering most Ghanaians from owning a house. It shows that there need to be a significant increase in the income of the average Ghanaian prospective house buyer before banks will deem them credit worthy enough to grant them the required loans which will give them the requisite money to purchase land and employ the qualified workforce to execute their construction works for them to get value for money. It was ranked fourth with importance index of 0.77 (Table 4.9). According to Edusei, J (2003), the average worker spends about 10 years to put up a house with loans from friends, siblings, the workplace and banks. Most times, the right construction professionals are not employed due to their percieved high charges. In the end what most people spend all their live savings on, is substandard construction, thus they don’t get value for their money. Respondents share the views expressed by Edusei, J (2003) that eventhough the demand for housing is more than the supply, lack of mortgage coupled with low income of prospective buyers has led to the situation of low purchasing power, the resultant effect is that, only the few well to do in society own houses (Boadu, 1992).

4.5.10.5 Lack Of Adequate Qualified Construction Manpower And Skilled Artisans

The low productivity of the local construction industry can be atributed to the low quality of available artisans that result in substandard works (Boadu, 1992). Due to this problem, new technological advancement in the construction field are difficult to adopt as the better qualified manpower cannot be employed by the people who need them most. The local construction workforce is not very well educated and this coupled with the unprofessional nature of the construction industry has led to the situation where most of the tradesmen are not abreast with new technologies. This is because due to the over reliance on the traditional construction system, there is not much training in new technological advancement in construction such as use of prefabricated building components among others. Most of the artisans do not belong to any recognizable body, thereby making it difficult to hold them accountable for their mistakes on site. They are recruited by foremen and they are mostly unskilled labour. “Lack of adequate qualified construction manpower and skilled artisans” was ranked a joint fourth with an importance index of 0.77 (Table 4.9).

4.5.10.6 Use Of Expensive Building Material

The research shows that, due to the problem of shortage of housing finance, the use of expensive materials will impact directly on the final cost of the end product which will lead to the era where even completed buildings cannot be purchased due to the low income of prospective buyers. It is no wonder that many people have blamed the Real Estate developers for the housing problem in the country as they believe the developers pay more attention to providing for the upper class at the expense of low cost housing for the average income earner (Boadu, 1992). This is the least ranked stated problem with an importance index of 0.63. according to the survey. The fact that most building components are not manufactured in the sub region and the unstable nature of the local currency has led to the imported materials coming in at a high cost (Atta- Poku, 2001). When available, the cost is very high and cannot be bought by local building contractors. Until such a time when the local production of construction materials using appropriate technology is looked into, self sufficiency in the construction industry will be a mirage and there will hardly be any effective cost reduction (Atta-Poku, 2001).

4.6 Effect of Construction Failure on buildability

The issue of construction failure is a worldwide problem. But in Ghana, if the definition of failure first advanced by Leonard (1982) and adopted by The American Society of Civil Engineers which states that, *"failure is an unacceptable difference between expected and observed performance"* is to be used then it will mean that more than half of the buildings constructed in Ghana can be described as construction failure. Roddis, (1993) however consider failure as occurring in a component when that component can no longer be relied upon to fulfill its principal functions. Limited deflection in a floor which causes a certain amount of cracking/ distortion in partitions could reasonably be considered as defect but not a failure, whereas excessive deflection resulting in serious damage to partitions, ceilings and floor finishes could be classified as a failure. Hall (1984) ascribes faulty design, faulty execution of work and use of faulty materials as major causes of structural failures. Oyewande (1992), states that in a country like Nigeria, design faults account for (50%) of construction failure whilst fault in construction and product failure accounts for (40%) and (10%) respectively. According to Akinpelu (2002), structural failures are due to environmental changes, natural and manmade hazards; and improper design presentation and interpretation. Frederick and James (1989) believe that the overturning of structures due to heavy wind loads, sliding of structures due to high wind, roof uplift or sliding and building sway due to lateral loads are major types of failures in buildings.

Similar as the analysis of the others, five significant levels will be responded from least significant to extremely significant. Seven causes of construction failure identified by earlier researches were considered. These are; i) Fundamental error in concept; ii) Site selection and site development errors; iii) Programming deficiencies iv) Design errors; v) Construction errors; vi) Material deficiencies; vii) Operational errors. - Feld and Carper (1997).

To examine the relative levels of the significance among these factors on construction failure, an alternative approach is used to calculate the Importance Index based on the table generated by the SPSS. A typical calculation for the level of significance for construction failure in the Ghanaian construction industry is illustrated by **Site selection and site development errors** which had the lowest importance index. (See Appendix 12).The correlation analysis in appendix 16 is used to derive the *p* value of the various variables.

4.6.1 Fundamental Error in Concept

The research indicated this factor accounts for a lot of constructional failures not only due to the fact that the local workforce may not be abreast with the technology behind some of these constructions, but also that the main problem is more of an economic and political dimension. Thus the research established the fact that as far as most respondents of the Ghanaian construction industry are concerned, Feld and Carper (1997) assertion that fundamental errors in basic concept occur when there is an original attempt to build something beyond available technology on a scale of which may be unique and outside the envelope of past experience, is true but not wholly responsible for the fundamental errors in the Ghanaian construction industry. 14.2% who ranked it as the fourth most important factor affecting construction failure in the country with an importance index of 0.667 (Table 4.10) rather routed for his assertion that some of these failure types in Ghana go beyond just the economic to political as projects started by one government are discontinued when a different government takes over. Project in this category may be abandoned and will be considered failure by most observers. According to Akkufo (2004), housing policies in the country are hardly implemented in full. In some cases, government shows partial commitments to projects resulting in abandoned or stalled projects. According to appendix 16, the issue of construction errors due to the inexperience of the local workforce also contributes a lot to this. Akkufo (2004) writes the unprofessional nature of the construction industry has led to the situation where most of the tradesmen are not well educated. Most of the local workforces are not abreast with technological advancements in construction due to their low level of education. The correlation shows that construction error, operational error and material deficiencies have a significant difference with fundamental error in concept buttressing the point raised by Feld and Carper (1997) that some people believe that materials do not fail but it is human being, this being some of the main reasons why many buildings are failing on site.

Table 4.10 **Ranking of factors that affect construction failure**

Factors	**Important Indices Ranking**
Construction errors	0.78
Design errors	0.73
Operational errors	0.67
Fundamental errors in concept.	0.667
Material deficiencies	0.65
Programming deficiencies	0.63
Site selection and site development errors	0.62

Source: Survey

The research shows the adoption of the concept of off-site produced or prefabricated components can lead to the era where knowledge in construction which is not available locally can be produced and fabricated elsewhere and assembled locally. In so doing, whatever project is of a technology far beyond what can be possible in a locality, can be brought to fruition.

4.6.2 Site Selection and Site Development Error

Many construction failure in terms of buildings in Kumasi and Accra collapsing can be attributed not only to construction error but also site selection and site development for a building project, the respondents do not see this as being of much importance to the types of construction failures experienced by the local construction industry. Respondents rated site selection and site development error last (seventh) with an importance index of 0.62 (Table 4.10). This is a bit alarming as development on old rubbish dumps and water logged sites is now very rampant in Ghana. The correlation analysis in appendix 16 showed a correlation between site selection and site development error and the other factors. These include error in design, deficiency in the materials used for construction, fundamental error in concept and programming deficiency. The right construction practices for such site developments are not followed as they are deemed very expensive. Reports from committees tasked to sit on the reasons for the collapse of some buildings cited among other factors the type of construction and the nature of the site chosen not being the best due to the bearing capacity of the soil. To address this problem, building designs must be site specific and thus there is the need to conduct site analysis such as soil tests to determine the bearing capacity of the soil in order to come up with building structure designs that will best suit the site and the design of the structures of the building. For lightly loaded building constructions, settlement considerations may be the dominant factor in a successful design (Greenfield and Shen, 1992) as cited in (Feld and Carper, 1997). To check the nature of the soil from having adverse effect on the building structure, the components can be manufactured off-site and assembled on-site to make sure certain quality standards are met and maintained.

4.6.3 Programming Deficiencies

Programming deficiencies in the Ghanaian construction industry is a significant aspect of construction failure in the local construction industry though respondents ranked it a distant sixth with an importance indice of 0.63 (Table 4.10). Most construction activities locally start without a clear programme of works to define the critical path that the construction process should follow in order to complete the construction project within the shortest practical period as possible. Goodden (1996) stated, to help solve this problem, several review meetings should be held starting from the design phase until the actual construction phase. This is one of the major factors that has led to many construction projects not being completed on time or not completed at all. With construction being a risky job, improper construction sequencing which is absolutely critical for some construction types such as post-tensioned pre-stressed concrete if not properly followed can have catastrophic results (Holroyd, 2003). The adoption of off-site production will aid buildability which is concerned with activities on site and, specifically, with sequences of operations and building methods.

4.6.4 Design Errors

Feld and Carper (1997) stated that most failure cases can be attributed to design errors. These include : error in design concept; calculation errors; failure to consider a load or a combination of loads; deficient connection details; detailing problems, including selection of incompatible materials or assemblies that are not constructible; failure to consider maintenance requirements or durability; inadequate or inconsistent specifications for materials or expected quality of work; and Unclear communication of design intent. The research shows it is such factors as these that have led people to shy away from the adoption of off-site produced building components. Respondents of the survey ranked design error a high second with an importance index of 0.73 (Table 4.10) . Design errors pertain because of the wide gap between design and construction in the local construction industry. Rice (1994) stated designers must never forget that we do not build our designs ourselves but if an error does occur it must be evident from the very beginning that we will be there to take our share of the responsibility. It is worth noting that if the design team is kept in touch of the work of the construction team then common design errors can be corrected during the construction phase. This supports the assertion by Orfano (2009) that designs developed by an architect or an engineer may be aesthetically good, but it could be functionally ineffective. Therefore, the builder and the architect should work jointly to ensure that the design is perfect and will not cause structural failures.

Walker (1996) argues that unless this is adhered to, it will lead to design without concern for buildability or production economies, lack of feedback to the design team, and perpetuation of mistakes from project to project. Thus design errors can go a long way to work against the principles of buildability if not checked. The correlation analysis in appendix 16 indicates that design error has a highly significant difference with material deficiencies. This brings up the question as to whether it is the materials that fail or the people who specify their usage as well as the workmen on site who due to their limited knowledge cannot even see design flaws in specifications. This raises the concern of the need to integrate design and construction as espoused by Walker (1996). With one of the main principles behind off-site production being that work is moved to factory sites, such problems with design errors can be easily identified and corrected at the factory level before assembly on site.

4.6.5 Construction Error

According to Koskela (1992), construction production process is usually carried out at the final project delivery site. This leads to such problems as little protection against elements or intrusion thus rendering operations prone to interruptions and errors. Besides the spatial flow of work stations (teams) has to be coordinated (in contrast to a factory, where only material flow through work stations is planned). Koskela further explains that in on-site production the working environment, unlike that within factories, is continuously evolving and is prone to standards not being followed thereby leading to construction errors. Respondents ranked “construction error” as the most significant cause of construction failure with an importance index of 0.73 (Table 4.10). The research established there is no significant difference between construction error and the problem of design errors (Appendix 16). This is not surprising as separation of design and production function which is prevalent in the Ghanaian construction industry usually has its own problems. The traditional procurement system is failing to achieve more integration between the design and construction phases of the project delivery process (Walker, 1996). This can be addressed by adopting off-site production which seeks to improve quality, increase efficiency and improve the quality of placement and as much as possible eliminate mistakes throughout the entire project delivery process. The sad aspect is that, the local construction industry is filled with people who have the money but not the expertise and are still not ready to hire the right professionals to execute their construction projects. Architects who design buildings are not made to supervise construction because they are tagged as expensive. Structural details for storey buildings are changed on site by foremen who sometimes know virtually nothing about building load distribution. Construction details are thrown to the wind and finished products at times are totally different from what the designer sought to achieve. With the introduction of the massive use of prefabricated building components manufactured under factory conditions, most of the construction errors on site will be a thing of the past as precision and accuracy is one of the hall marks of off-site production.

4.6.6 Material Deficiencies

Deficiency in materials is mostly a manufacturing problem. This supports Feld and Carper (1997) that manufacturing or fabrication defects may exist in the most reliable structural materials. Respondents ranked it sixth with an importance index of 0.63 (Table 4.10). Another factor is also the improper handling and storage of materials on site which can lead to some material losing some important properties which at the end will impact negatively on the end product. Ortega (2000) also stated, the use of unconventional materials without a thorough understanding of their behaviour in the intended environment should not be attempted. To help check this problem, off-site production in a factory will ensure all the building materials being used are up to the standard required to achieve maximum strength.

4.6.7 Operational Errors

Operational errors occur after occupancy. This according to respondents is manifested in negligent overloading of building structures that affect its structural stability. The research established a very significant correlation with construction error, and material deficiencies appendix 16. The Ghanaian problem of inadequate maintenance culture was also brought to the fore by most respondents as according to the research, buildings are left dilapidated even though people may be occupying them. This issue of low maintenance culture according to respondents cut through ownership of buildings as the same situation persist from private houses through to government bungalows. Another operational error espoused by respondents is alteration made to buildings that affect its structural stability. According to research results, refurbishment and renovation of buildings are most often than not carried out by people who don't have the technical expertise thus shoddy work is executed and in no time changes in the building structure affects load distribution which leads to the structural failure of such buildings. Respondents rated Operational errors as the third most important factor that affects construction failure with an importance index of 0.67 (Table 4.10).

4.7 Material Waste Control in the Ghanaian Construction Industry. - A Financial Analysis in Adopting Off-site production

4.7.1 Wastage Levels between Traditional Construction and Off-site Produced building components

Waste can be classified into unavoidable waste, in which the investment necessary to its reduction is higher than the economy produced, and avoidable waste, when the cost of waste is significantly higher than the cost to prevent it. The percentage of unavoidable waste is related to the level of technological development. Although wastage levels may vary from different types or natures of project, the wastage levels are believed affected by the adoption of either Conventional (in-situ) or Prefabrication construction methods. Skoyles and Skoyles (1987) stated that the natural level of material wastage depends on the cost effectiveness of the approaches used to control it. Therefore, the cost of reducing wastage is directly related to the values of material saved; Higher cost effectiveness can only be achieved at the initial project development stage, and lower cost effectiveness happens at the later stages. Thus, the optimum level of material saved should be identified before projects start, to maximise saving from material wastage. Between traditional construction methods and off-site production, it can be said that the latter can help minimise construction waste effectively; the magnitude of waste reduction depends on the level of prefabrication. Prefabrication technique can be applied for all construction projects; In order to explore wastage levels between traditional construction and off-site production (Prefabrication), the respondents were interviewed on their experiences with the two. In the survey, traditional construction methods are mainly adopted by most stake holders in the Ghanaian construction industry especially Real Estate developers. Although wastage levels may vary from different types or natures of project, the wastage levels are believed to be affected by the adoption of traditional construction methods and off-site production. A field survey was conducted to measure the wastage level for the different construction methods. The average wastage levels (in per cent) for various construction trades, namely, concreting, reinforcement, block laying, plastering, screeding and tiling, are measured for two groups of projects adopting conventional in-situ trades and prefabrication. The main problem encountered is that since most construction in Ghana commence without a waste management plan, most of the respondents could not give answers that could pass as well documented information according to the initial pilot survey. Most of the information gathered was not from the structured questionnaire but from discussions with the respondents. Another problem was also that most of the respondents are more familiar with the conventional construction and as such cannot compare it well with off-site production which they have not been using or which they seldom use. In computing the findings on the average wastage levels for the major construction activities carried out on site either by the use of conventional construction or off-site production (Table 4.11) the formula for the percentage of waste reduction was adopted from Tam *et al* (unpublished) who conducted a similar study on the adoption of prefabrication in Hong Kong. It is noted that the most effective waste reduction trade is plastering, which can have 100% of wastage reduction after adopting prefabrication.

This is because plastering can be avoided since the concrete surface of the precast items is smooth enough for receiving subsequent finishes. Parakou Estates is one such place where at the moment steps are being put in place to adopt the practice of this concept. The average wastage level of the traditional construction method is much higher than that of prefabrication in the trades of concreting, reinforcement, plastering and tiling.

Table 4.11 **Percentage wastage of materials for various trades in conventional construction**

Trade	**Material**	**Percentage Wastage (%)**
Concrete	Concrete	3 - 5
Reinforcement	Steel Bars	1 - 9
Plastering	Plastering	5 -15
Screeding	Screeding	5 -15
Formwork	Timber Boards	12 -15
Masonry	Blocks/ Bricks	3 -10
Tiling	Tiles	6 -12

Source: Survey

Table 4.12 **Wastage between conventional (cast in-situ) and off-site production (prefabrication)**

Trade	**Average wastage level (%) – Traditional construction (A)**	**Average wastage level (%) – Off-site production (B)**	**Percentage of Waste reduction [C=(A-B)/ A]**
Concrete	5	2	60%
Reinforcement	8	2	75%
Plastering	10	0	100%
Screeding	10	3	70%
Formwork	12	2	83.3%
Masonry	8	0	100%
Tiling	10	2	80%

Source: Survey

The adoption of off-site production can reduce waste generation in reinforcement, concreting, and tiling (Table 4.12). The results of the interviews and observations show that the wastage levels will vary with different trades when off-site produced building components are adopted; therefore, the adoption of off-site produced building components can help reduce the wastage levels effectively.

Though some level of consciousness regarding waste associated with construction project delivery process existed, most of the construction activities in Ghana at both the design and documentation stages are bedevilled with waste. Such sources of waste areas are demonstrated in waiting, errors and inventories. These sources of waste act seriously against the speedy delivery of value to clients. The main problem is that, most construction in Ghana commence without a waste management plan. Thus it is high time stakeholders in the construction industry are sensitized on this. The average wastage level of the Conventional construction method is much higher than that of Prefabrication in the trades of concreting, reinforcement, plastering and tiling. Results show that the wastage levels vary with different trades. Off-site produced building components when adopted in the Ghanaian construction industry will curtail the unnecessary cutting and waste associated with Conventional construction.

4.7.2 Cost Implications between the Use of Traditional Construction Method and Off-site Production With Respect To Material Waste Control in the Ghanaian Construction Industry

After analysing the wastage reduction in adopting prefabrication, seven materials were considered for analysis. These include concrete, reinforcement, plastering, screeding, formwork, masonry and tiling. The wastage level on most construction sites as per the survey is about 15%. As analysed the wastage reduction after adopting prefabrication will be significant (Table 4.12). The unfortunate thing is that after discussions with the respondents, it was realised that most of them did not really have any clear cut answers or were not ready to give the right information on the cost analysis from previous works as they see issues regarding money as confidential information.

The results under this heading were derived from an interviews with the respondents and observations on site. It became clear from the interview and observation that wastage can be reduced drastically after adopting off-site production as according to Table 4.12 it is clear there will be significant levels of waste reduction for the seven major types of materials. Based on the analysis as presented in Table 4.13 and Table 4.14, it is quite evident that the reduction in material wastage alone based on the seven building trades under discussion can reduce the cost of the building by as much as $ 3430.

Table 4.13 **Cost analysis for the use of conventional construction**

TRADE	ASSUMED COST ($)	PERCENTAGE OF WASTE	COST OF WASTE ($)	FINAL COST ($)
Concrete	20,000	5	1,000	21,000
Reinforcement	5,000	8	400	5,400
Plastering	6,000	10	600	6,600
Screeding	5,000	10	500	5,500
Formwork	3,000	12	360	3,360
Masonry	8,000	8	640	8,640
Tiling	8,000	10	800	8,800
TOTAL	55,000		4,300	59,300

This is because per the analysis of waste reduction, it was realised that if one want to get value for money, then in order to achieve cost effective construction at the cost of $ 55,000 one has to spend $ 59,300 using the conventional construction method. The cost of waste alone will be $ 4,300 whereas $55,870 will be spent when off-site produced building components are used with the cost of waste being $ 870.

Table 4.14 **Cost analysis for prefabricated building components construction**

TRADE	ASSUMED COST ($)	% WASTE	COST OF WASTE ($)	FINAL COST ($)
Concrete	20,000	2	400	20,400
Reinforcement	5,000	2	100	5,100
Plastering	6,000	0	0	6,000
Screeding	5,000	3	150	5,150
Formwork	3,000	2	60	3,060
Masonry	8,000	0	0	8,000
Tiling	8,000	2	160	8,160
TOTAL	55,000		870	55,870

However, prefabrication will only be successful when stakeholders of the Ghanaian construction industry have enough knowledge on cost savings.

Respondents suggested that cost was a key factor in this era of a world-wide credit crunch. Off-site production will only bring about much cost saving when the following issues are addressed:

i) Full mechanisation of the construction process in Ghana using heavy plants; and

ii) Turning construction into an assembling industry rather than following the traditional construction method.

4.8 Possibilities for the Practice of Off-site Production in the Ghanaian Construction Industry

4.8.1 Suitable Construction Method for Various Building Trades

The idea for applying manufacturing technologies to the construction industry had applied for many years and many Designers had explored the use of off-site building components as a solution for solving the housing deficit problem. The adoption of off-site production had been introduced in construction to use mass production techniques which results in an increase in productivity, efficiency and quality of the product (Tam *et al*, unpublished). The survey was constructed based on major building elements against the construction process one will choose, be it conventional or off-site production. Six building elements including substructure, structural frame, external works, internal works, building services and others (Tam *et al*, unpublished) were chosen and respondents were tasked to their choice construction method, be it conventional or off-site production, in relation to types of projects. It is worth noting that most respondents interviewed did state that their choice is based on the fact that such a technology is not far advanced in Ghana thus their choice of conventional construction method for certain building works is based on the existing technological knowhow and level of usage.

Based on the raw data that was computed from the questionnaire survey as presented in Table 4.15, an SPSS Cross tabulation was derived between the choice of construction method chosen and the need to reduce construction cost which was established as the most important significant factor that will affect the advantages for the adoption of off-site produced building components as presented in Table 4.7. (This could have been done for all the significant factors that impact on the advantages of adopting off-site production to see how they impact on the choice of construction method). This was to determine if the choice of either conventional construction of off-site production is based on the cost implications or on a different factor.

Based on that a contingency table was derived using Chi-square test of independence to analyse the impact of construction cost reduction on the preference for construction method of all the building elements.

Table: 4.15 **Choice of construction method for building elements based on current knowledge and use of off-site produced building components**

Description	Conventional (IN-SITU)	Off-site production (Fabrication)	No response	Total
Foundation(Substructure)	75	0	0	75
Basement(Substructure)	75	0	0	75
Column (Structural frame)	52	23	0	75
Beam (Structural frame)	51	24	0	75
Bearing wall (Structural frame)	51	23	1	75
Slab (structural frame)	8	67	0	75
Stairs (Structural frame)	52	23	0	75
External wall (External works)	52	23	0	75
Roof (External works)	26	49	0	75
Partition wall (Internal works)	30	45	0	75
Tilling (Internal works)	65	10	0	75
Ductwork (Building services)	42	33	0	75
Frames(Others)	75	0	0	75
Doors (others)	2	73	0	75
Windows (others)	1	74	0	75
Kerbs (others)	3	72	0	75
Septic tanks (others)	46	29	0	75
Furniture (others)	1	74	0	75

Source: Survey

The hypothesis here is that the choice of construction method is independent of the cost implication at 5 degrees of freedom. The results of the test prove significant with p-value < 0.000. This indicates that the construction method chosen for a particular building element is dependent on the cost implication of the constructional method, being traditional construction or off-site production. The results of the test prove not significant with p-value < 0.05. This indicates that the construction method chosen for a particular building element is not dependent on the cost implication of the constructional method. Be it traditional construction or off-site production but rather on a different factor other than cost.

4.8.1.1 Substructure

Foundation

According to Chudley (1987), the function of any foundation is to transmit to the subsoil the load of the structure. The plan size of a foundation is a constant feature derived from:

$$\frac{\text{Load}}{\text{Bearing capacity of subsoil}}$$

be it conventional construction or use of off-site production. Conventional construction method was 100% recommended for foundation construction in substructure (Figure 4.15). This is understandable as foundations are non-standard design and are subject to changes due to underground conditions which are difficult to predict beforehand. Fergusson (1989) asserts that, if the subsoil is uncomplicated and of good bearing quality, the option of foundation type will be left to the designer. The decision as to which type of construction method to choose will depend partly upon the complex nature of the plan form, partly on the subsoil condition in relation to loading and stability.

Basement

A basement is a storey with a floor which at some point is more than 1.2m below the highest level of ground adjacent to the outside walls (Chudley, 1987). The structural wall of a basement below ground level, constructed either through conventional method or the use of off-site production are in fact retaining walls which have to offer resistance to the soil and ground water pressure as well as assisting to transmit the superstructure loads to the foundations. Just as in the case of foundations, the unpredictable nature of the ground from one building site to another within the same plot can make the use of prefabricated component an unlikely choice. All respondents in respect of this chose conventional construction as their method of construction (Table 4.15).

4.8.1.2 Superstructure

Five sub-elements in structural frame are classified: column, beam, bearing wall, stair and slab.

Columns

The main function of a column is to take the load on a building and transmit it to the foundation for even distribution (Chudley, 1987). The use of precast concrete columns is a bit complex and care must be taken that load distribution is well taken care of. The complexity of all this informed respondents in their choice as 69.3% of them chose conventional cast in situ concrete columns whilst 30.7% chose precast columns (Table 4.16).

Table 4.16 **Effect of cost reduction on construction method (column)**

Column					
		Conventional	Off-Site production	Chi-square	P-value
Reduce construction cost	Fairly Significant	10	0	38.189	0.000
	Significant	32	1		
	Very Significant	9	19		
	Extremely Significant	1	3		
Total		52	23		

About 85% of the 30.7% who chose precast columns further stated their choice though taking cost into consideration were also based on the use of ornamental columns to beautify exterior views, and for enhancing the performance in terms of productivity and waste reduction; however it would depend on the nature of projects.

Further analysis on the construction cost reduction and the preference for construction method was conducted using chi-square test of independence. The results of the test prove significant with p-value < 0.000 which indicate that the construction method chosen for column as a superstructure is dependent on the cost implication of the constructional method, being conventional or off-site production. The analysis further indicated that majority of the construction professional who are of the view that construction cost reduction is significant in adopting prefabricated material would rather go in for conventional construction method rather than prefabricated. The result of the test can be found in Table 4.16

Beams

The choice of construction type for beams according to the research depends on the building type in question as to whether it is a new build or a building under renovation but it is worth noting that most of the respondents agreed that the use of precast concrete beams will speed the construction time and in some cases ensure continuity of business during renovations as the long period for curing is done away with. 68% or the respondents chose conventional method to be the best choice for beam construction according to Table 4.15.

Table 4.17 **Effect of cost reduction on the choice of construction method (Beams)**

Beam					
Reduce construction cost		Conventional	Off-Site production	Chi-square	P-value
	Fairly Significant	6	4	29.832	0.000
	Significant	33	0		
	Very Significant	11	17		
	Extremely Significant	1	3		
Total		51	24		

Chi-square test of independence was used for the analysis of the impact of construction cost reduction on the preference for construction method of beams. The results of the test prove significant with p-value < 0.000. This indicates that the construction method chosen for beams is dependent on the cost implication of the constructional method, being traditional construction or off-site production. The analysis also indicated that majority of the construction professional who are of the view that construction cost reduction is significant in adopting prefabricated material would rather go in for conventional construction method rather than prefabricated. The test results can be found in Table 4.17.

Stairs

The design consideration for a precast stair is the same as those for in situ stairs of comparable span, width and loading conditions (Chudley, 1987). 52 out of the 75 respondents (Table 4.15) vouched for the use of traditional construction as against prefabricated stairs as it is seen as being costly and complicated to work with. The inexperience of the local workforce in the use of prefabricated components makes its use unattractive. Based on field surveys, it was realized that prefabricated metal spiral stairs is the type that is commonly used. But even that has its limitations as the local metal workers are not able to make it aesthetically pleasing thereby limiting the type of clientele.

Table 4.18 **Effect of cost reduction on the choice of construction method (stairs)**

Stairs					
		Conventional	Off-Site production	Chi-square	P-value
Reduce construction cost	Fairly Significant	5	5	7.176a	0.067
	Significant	28	5		
	Very Significant	17	11		
	Extremely Significant	2	2		
Total		52	23		

Further analysis on the construction cost reduction and the preference for construction method was conducted using chi-square test of independence. The results of the test prove insignificant with p-value < 0.067. It indicates that the construction method chosen for stairs is not dependent of the cost implication of the constructional method. In other words other factors rather than cost are the determinant factors as far as the construction method of stairs are concerned. The analysis further indicated that majority of the construction professional who are of the view that construction cost reduction is significant in adopting prefabricated material would rather go in for conventional construction method rather than prefabricated. The result of the test can be found in Table 4.18

Slabs

67 out of 75 respondents (Table 4.15) opted for off-site produced ones as it is really catching on well with the Ghanaian construction industry.

The chi-square test of independence was further used for the analysis of the impact of construction cost reduction on the preference for construction method of slabs. The results of the test prove significant with p-value < 0.000. There is the indication that the construction method chosen for slab which is off-site production is dependent on the cost implication of the constructional method. Thus responses from stakeholders of the Ghanaian construction industry indicate that their choice of off-site production is based on the fact that it will lead to cost savings.

Table 4.19 **Effect of cost reduction on the choice of construction method (slabs)**

Slabs					
Reduce construction cost		Conventional	Off-Site production	Chi-square	P-value
	Fairly Significant	4	6	19.829	0.000
	Significant	0	33		
	Very Significant	2	26		
	Extremely Significant	2	2		
Total		8	67		

The analysis further indicated that majority of the construction professional who are of the view that construction cost reduction is significant in adopting prefabricated material would rather go in for prefabricated rather than traditional construction method. The result of the test can be found in Table 4.19

External walls and roofs

The majority of the respondents (68%) chose conventional construction for bearing wall. For the elements of external works, conventional method is also highly recommended by the respondents, for external wall (69.3%), but for roofs (65.3%) of the respondents opted for prefabricated roof trusses. The research showed that adopting comprehensive prefabrication can achieve waste minimisation especially for the roof members in terms of prefabricated metal trusses. Prefabrication external walls can be applied if there is the use of metal frame structures as is being looked into by Parakou Estate and Trassaco – Villagio. Though 65 out of 75 respondents (Table 4.15) opted for conventional method for laying of tiles, this the researcher believe is based on the knowledge base of most respondents that with designers using modular coordination to determine the type and size of tiles which will be the final floor finish at the design conception stage, it will help in that, cutting of tiles will be reduced to its barest minimum thereby cutting down on the overall waste and leading to a maximization of profit. Chi-square test of independence was used for the analysis of the impact of construction cost reduction on the preference for construction method. The results of the test prove significant with p-value < 0.013 for the construction method chosen for external walls which is traditional construction. It indicates that the choice is dependent on the lower cost implication of the constructional method. The test results can be found in Table 4.20

Table 4.20 **Effect of cost reduction on the choice of construction method (external walls)**

External walls					
Reduce construction cost		Conventional	Off-Site production	Chi-square	P-value
	Fairly Significant	6	4	10.730a	0.013
	Significant	29	4		
	Very Significant	14	14		
	Extremely Significant	3	1		
Total		52	23		

A similar analysis for the choice of construction method for roof (trusses) indicated the results of the test prove insignificant with p-value < 0.613 for the construction method chosen for roof which is off-site production. It indicates that the construction method chosen for roofs is independent of its cost implication. Meaning other factors rather than cost are the determinant factors for the choice of construction method of roofs. Some of these factors may include structural stability of the roof member and safety of end users.

Table 4.21 **Effect of cost reduction on the choice of construction method (roof system)**

Roof system					
Reduce construction cost		Conventional	Off-Site production	Chi-square	P-value
	Fairly Significant	5	5	1.809	0.613
	Significant	10	23		
	Very Significant	9	19		
	Extremely Significant	2	2		
Total		26	49		

Others

For internal works such as partition walls, most of the research showed that choice of construction type will be determined by the use of the space. 60% of respondents opted for prefabrication as against conventional construction. In terms of Building Services, 44% of the respondents chose prefabrication for the ductwork. For the others, out of the 75 respondents, they were rated as frames (100%), doors (97.3%), windows (98.7), kerbs (96%), and furniture (98.7%) respondents all in favour of prefabricated components. 61.3% of respondents opted for conventional construction for septic tanks according to Table 4.15.

Table 4.22 **Effect of cost reduction on the choice of construction method (partition wall)**

Partition wall (Internal works)					
Reduce construction cost		Conventional	Off-Site production	Chi-square	P-value
	Fairly Significant	5	5	12.545	0.006
	Significant	19	14		
	Very Significant	4	24		
	Extremely Significant	2	2		
Total		30	45		

An analysis of construction cost reduction and the preference for construction method for partition walls was conducted using chi-square test of independence. The results of the test prove significant with p-value < 0.006 for the construction method chosen for partition walls which is off-site production. The results indicate that the construction method chosen for partition wall is dependent on the cost implication of the constructional method. The result of the test can be found in Table 4.22

Chi-square test of independence was used for the analysis of the impact of construction cost reduction on the preference for construction method of tiling. The results of the test prove insignificant with p-value < 0.843 for the construction method chosen for tiling which is traditional construction. This means that other factors rather than cost reduction is the basis for that choice, as the construction method chosen for tiling is independent on the cost implication of the constructional method. The result of the test can be found in Table 4.23

Table 4.23 **Effect of cost reduction on the choice of construction method (tiling)**

Tiling					
		Conventional	Off-Site production	Chi-square	P-value
Reduce construction cost	Fairly Significant	9	1	.828a	0.843
	Significant	28	5		
	Very Significant	25	3		
	Extremely Significant	3	1		
Total		65	10		

Table 4.24 **Effect of cost reduction on the choice of construction method (ductworks)**

Ductworks (Building Services)					
		Conventional	Off-Site production	Chi-square	P-value
Reduce construction cost	Fairly Significant	6	4	21.737a	0.000
	Significant	9	24		
	Very Significant	24	4		
	Extremely Significant	3	1		
Total		42	33		

Chi-square test of independence was used for the analysis of the impact of construction cost reduction on the preference for construction method. The results of the test prove significant with p-value < 0.000 for the construction method which is traditional construction. The results indicate that the construction method chosen for ductwork is dependent on the cost implication of the constructional method. Table 4.24shows the results of the test.

An analysis of construction cost reduction and the preference for construction method was conducted using chi-square test of independence. The results of the test prove significant with p-value < 0.0366 for the construction method chosen for doors which is off-site production.

Test results indicate that the construction method chosen for doors is dependent on the cost implication of the constructional method. The result of the test can be found in table 4. 25.

Table 4.25 **Effect of cost reduction on the choice of construction method (doors)**

Doors (Others)					
Reduce construction cost		Conventional	Off-Site production	Chi-square	P-value
	Fairly Significant	1	9	3.174	0.0366
	Significant	0	33		
	Very Significant	1	27		
	Extremely Significant	0	4		
Total		2	73		

An analysis of reduction in construction cost and the preference for construction method was conducted using chi-square test of independence. The results of the test prove insignificant with p-value < 0.086 for the construction method chosen for windows which is off-site production is not dependent on cost. The result of the test can be found in Table 4.26

Table 4.26 **Effect of cost reduction on the choice of construction method (windows)**

Windows (Others)					
Reduce construction cost		Conventional	Off-Site production	Chi-square	P-value
	Fairly Significant	1	9	6.588	0.086
	Significant	0	33		
	Very Significant	0	28		
	Extremely Significant	0	4		
Total		1	74		

Chi-square test of independence was used for the analysis of the impact of construction cost reduction on the preference for construction method of kerbs. The results of the test prove significant with p-value < 0.003 for the construction method chosen namely, off-site production. The result indicates the construction method chosen for kerbs is dependent on its cost implication. The result of the test can be found in Table 4.27.

Table 4.27 **Effect of cost reduction on the choice of construction method (kerbs)**

Kerbs (Others)					
Reduce construction cost		Conventional	Off-Site production	Chi-square	P-value
	Fairly Significant	2	8	13.802	0.003
	Significant	0	33		
	Very Significant	0	28		
	Extremely Significant	1	3		
Total		3	72		

Table 4.28 **Effect of cost reduction on the choice of construction method (septic tank)**

Septic tanks (Others)					
Reduce construction cost		Conventional	Off-Site production	Chi-square	P-value
	Fairly Significant	6	4	16.434	0.001
	Significant	14	19		
	Very Significant	25	3		
	Extremely Significant	1	3		
Total		46	29		

An analysis of construction cost reduction and the preference for construction method was conducted using chi-square test of independence. The results of the test prove significant with p-value < 0.001 for the construction method chosen for septic tank, which is traditional construction. Test results indicate that the construction method chosen for septic tanks is dependent on the cost implication of the constructional method. The result of the test can be found in Table 4.28

An analysis of reduction in construction cost and the preference for construction method was conducted using chi-square test of independence. The results of the test prove insignificant with p-value < 0.086 for the construction method chosen for furniture which is off-site production. The result shows that cost was not a factor that is considered by respondents when they state their choice is off-site production for furniture. The result of the test can be found in Table 4.29.

Table 4.29 **Effect of cost reduction on the choice of construction method (furniture)**

Tiling					
		Conventional	Off-Site production	Chi-square	P-value
Reduce construction cost	Fairly Significant	1	9	6.588a	0.086
	Significant	0	33		
	Very Significant	0	28		
	Extremely Significant	0	4		
Total		1	74		

Although traditional construction system was chosen for 61% of the construction elements including substructure, structural frame, external works, and internal works and building services, prefabrication should also be encouraged in the construction. The current use of prefabrication is still not strongly encouraged by the Ghanaian construction industry from the structured survey; it became evident that the responses given were based on current level of acceptability and knowledge of off-site produced building components as clearly stated by about 45% of the respondents. There is a tendency for adopting prefabrication in the near future as all stake holders believe it will cut down on waste generation and speed up construction work. Warszawski (1999) states that off-site production will lead to standardisation and repetition, and if adopted at the design stage, will encourage mass production to meet client's requirements. This will really go a long way to help the local construction industry especially in the Real Estate Industry where the use of prototype designs can encourage its use. Based on the discussions with some of the respondents, three major elements can fulfill the basic pre-requisite requirements of the effective prefabrication model in the presents practices of the construction activities: i) Steel structural frame; including steel trusses that is now widely accepted ; ii) Prefabricated external cladding and partition walls; iii) Prefabricated concrete slab and beams, ornamental columns and pavement blocks; due to the fact that most of the prefabrication products are load bearing, the development of lightweight prefabrication should be introduced to reduce the cost of materials and transportation which are major tasks in construction.

4.8.2 Possibilities for the Adoption of Off-site production

Notwithstanding the challenges that exist against the implementation of off-site production in Ghana, some opportunities also exist. The appreciation by stakeholders of the Ghanaian construction industry, as established from the survey, of the need to minimise waste and obtain value for clients in the project delivery process is a positive step towards introducing systems in the application of off-site production in Ghana. The need to conform to certain design standards as required by some statutory regulations can contribute immensely towards ensuring quality of products and services delivered to customers thus enhancing value in construction delivery. Current trends of globalisation are also likely to enhance the transfer of technology to Ghana to support attempts at adopting standardized and prefabricated building components and the use of modular construction systems. The study also revealed that most of the respondents having understood the concept of off-site production as the maximisation of value in construction delivery and minimisation of waste were able to recognize to a large extent, the possible limitations that may act against a successful implementation of off-site production in Ghana. The stake holders in the construction industry are therefore in a good position to identify and address these limitations if they have to adopt the practice of off-site in their operations.

The big question as to whether the Ghanaian construction industry is ready for the use of prefabricated building components is one that cannot be answered easily. According to the survey, it became evident that though the respondents (Construction professionals) contacted have the basic knowledge as to what off-site production is, they are yet to venture into its use. According to the respondents who are manufacturers and suppliers of off-site produced building components, it needs a lot of capital injection into their businesses. Thus for now, according to the respondents, most of them will prefer the use of traditional construction to off-site production in most of the trades in the construction process (Tables 4.15).

This notwithstanding, 75% of the respondents believe with the right education and injection of capital, based on expectation and optimisation, they will be better off going in for off-site produced building components (Figure 4.14). This is because it will aid in the speed of construction and reduce construction cost thereby increasing efficiency among other things. Most of the respondents are not really into the use of comprehensive prefabrication but in terms of finances they all agree that though the initial start up cost is very high, off-site production will be cheaper for the overall construction of buildings if the right steps are taken, especially in the field of Real Estate development due to the repetition of the same plans.

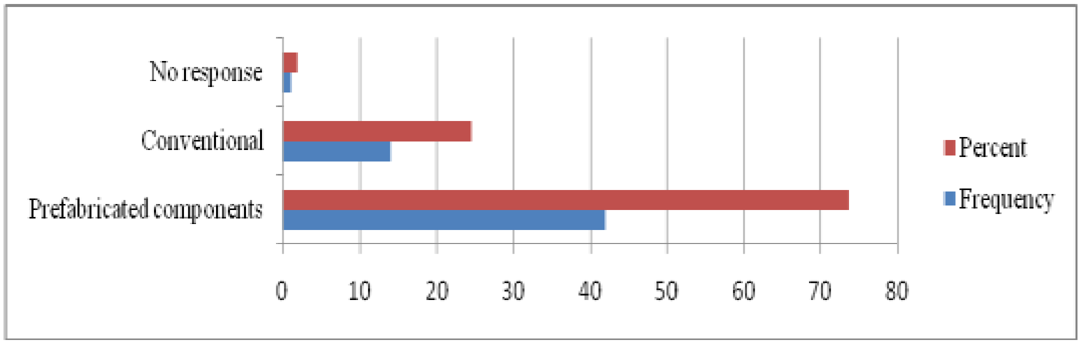


Figure 4.14 **Choice of respondents between off-site production and conventional construction based on expectation and optimisation**

. Of the few who have been using it especially at Trassaco- Villagio, they stated that as far as they are concerned, extensive use of off-site production can reduce the total cost by as much as between 5% - 15% depending on the type of construction.

The idea for applying manufacturing technologies to the construction industry had applied for many years. Designers had explored the use of industrialized building techniques which results in an increased productivity, efficiency and quality of the product (Tam *et al*). The concept can be propagated based on major building elements against the construction process one will choose, be it traditional or off-site production. Although the adoption of off-site production is still not strongly practiced by the Ghanaian construction industry, there is a tendency for adopting prefabrication for general construction projects, especially in the Real Estate industry where the use of prototype designs can encourage its use.

Based on the survey, the major elements can fulfill the basic pre-requisite requirements of the adoption and future use of prefabrication in the construction practices of the Ghanaian construction industry are: i) steel structural frame (13.3%) and roof trusses (16%), ii) prefabricated external cladding (13.3%) and dry wall(10.7%); this is really being explored by

Parakou Estates and Trassaco – Villagio and iii) prefabricated concrete slab and beams (17.3), columns (16%) and pavement blocks and kerbs (13.3%) which are now being used widely.

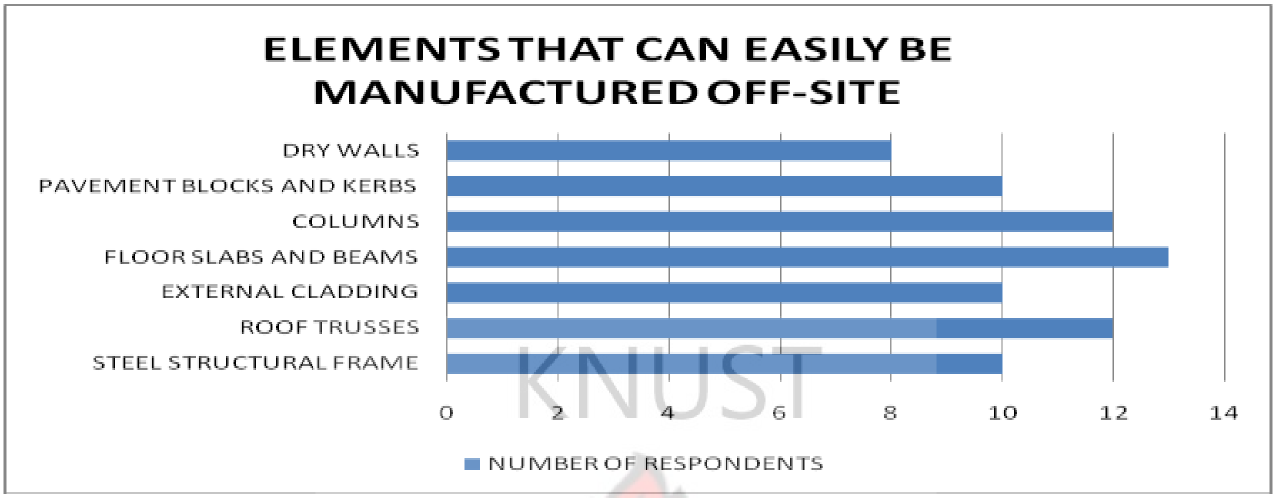


Figure 4.15 **Choices of respondents on elements that can easily fulfil the prerequisite for off-site production**

Since most of the prefabrication products are load bearing, the development of lightweight prefabrication should be introduced to reduce the cost of materials. But it must be emphasized that for a very effective prefabrication model to be established, the local construction industry must embrace the concept of off-site production so that further studies can be establish into even the type of prefabrication to go in for. That is, either semi prefabrication, comprehensive prefabrication or volumetric prefabrication. In all cases, there is the need to develop standard procedures for planning and managing the design and construction of unique facilities. Furthermore, the problems associated with construction failure in the Ghanaian construction industry can be mitigated with the adoption of off-site produced building components. Factors such as material deficiencies and construction errors can be addressed as manufacturing of components under factory conditions will check deficiencies in materials and the precision and accuracy of the components will lower the errors that arise from traditional construction due to poor workmanship. The problem of Ghanaian construction industry such as inclement weather can be addressed as minimum work will be site based due to the assembly of prefabricated components. Also the lack of adequate mechanisation of the construction industry will be addressed as the sole aim of prefabrication is to turn the construction industry into a mechanised production system. According to Rosenfeld, (1994), with prefabrication, most of the work is carried out in the factory, leaving little to be done on-site. This increases the likelihood of more efficient, high quality and ultimately, faster construction being achieved as a result, fewer tasks on-site means fewer workmen on site with shorter overall duration and a more consistent quality. A shorter production time not only cuts down direct and overhead costs, but also allows the house to be occupied sooner.

CHAPTER FIVE

RESEARCH CONCLUSION AND RECOMMENDATIONS

While it is generally perceived that off-site production can lead to faster construction, it is also criticized as causing migration of job opportunities to countries with cheaper labour costs. But an abundance of hindrances associated with traditional in-situ construction and installation would be mitigated by an extensive adoption of prefabrication, which would assist in the enhancement of the operational efficiency and productivity of our construction industry (Yeung *et al,* unpublished). Off-site production is considered the way forward in the housing delivery system worldwide within the construction industry though there may still be some problems associated with its application. The adoption of off-site production in the Ghanaian construction industry should be built up by enhancing awareness through education and training focused by the stakeholders and educational institutions. The good news is that the survey results indicate that stakeholders believe that the future of the local construction industry is tied to the adoption and applications of off-site production (prefabrication) especially in the field of Real Estate development where the use of repetitive design is prevalent. This study focused on how best the use of off-site production will impact on buildability in the Ghanaian construction industry to improve productivity in the construction industry especially in the Real Estate sector. This chapter highlights on summary of findings and conclusion of the study. The chapter further gives recommendation on how buildability in the Ghanaian construction industry can be improved with the use of off-site production.

To help address this, the following research objectives were used as guiding principles.

1. To establish the extent of the practise of the concept of off-site production by stakeholders of the Ghanaian construction industry especially those in Real Estate Development

2. To look into the advantages of the adoption of off-site production in the Ghanaian construction industry

3. A look at the limitations to the practise of off-site production in Ghana

4. To look at effect of construction failure on buildability in the Ghanaian construction industry

5. Examine the cost implications between the use of traditional construction method and off-site production with respect to material waste control in the Ghanaian construction industry.
6. The likely possibilities; if any, for the practise of off-site production in the Ghanaian construction industry especially in the field of Real Estate development.

To meet the objective of the study, the following research questions were set:

1. To what extent is the concept of off-site production being practiced by stakeholders of the Ghanaian construction industry
2. What are the likely advantages to the practice of off-site production in Ghana
3. What are the likely limitations to the practice of off-site production in Ghana
4. What are the effect of construction failure on buildability in the Ghanaian construction industry

5. What are the cost implications in the use of traditional method of construction and off-

site production with respect to material waste control

6. What likely possibilities are there for the practice of off-site production in the Ghanaian construction industry especially in the field of Real Estate construction

A questionnaire survey was used because the views of the stakeholders can be best gathered through this process. Data gathering was limited to Accra and Kumasi, where major construction activities are centred in Ghana. Questionnaires were sent to 120 stakeholders in the Ghanaian construction industry such as construction professionals, real estate developers and suppliers and manufacturers of off-site produced building components because their activities will help in the acceptance of the concept of off-site production. 75 of the questionnaires were returned.

The research was also supplemented by a broad qualitative survey-based methodology. The study employed three particular approaches to determine the state of off-site production. These included web-search to provide the research with a quick indication of the types and variety of products being manufactured off-site the world over, as there is very little data on the use of off-site production in the Ghanaian construction industry. There were interviews with some of the stake holders that centred on various off-site production systems, problems and solutions. Site visits were also undertaken to supplement the interview data. The outcomes of the questionnaire survey were mapped against the findings of the site visits and interviews.

5.1 Summary of Findings

Kappa statistics for multiple raters using categorical classifications was employed to test the level of agreement among respondents. Based on the calculation (Appendix 18), the kappa values for:

Advantages in the adoption of prefabrication was **0.787**

Hindrances towards the adoption on prefabrication was given as **0.782**

Problems facing the Ghanaian construction industry **0.772**

Construction failure was **0.775**

It was observed that a fair to good agreement beyond chance existed between responses given by respondents on all the content of the questionnaire. This gave the indication that stakeholders of the Ghanaian construction industry believe that there is a bright future for the industry if stakeholders accept the practice of off-site production, especially in the field of Real Estate development. The summary of findings is discussed below.

i. Extent of the practise of the concept of off-site production by stakeholders of the Ghanaian construction industry especially those in Real Estate Development:

The survey established that there is generally a low familiarity of the concept of off-site production among stake holders of the Ghanaian construction industry, especially Real Estate developers though there is the awareness of the need to improve quality and increase efficiency and productivity in the project delivery process. Only a few of the stake holders contacted had been involved in the application of off-site production. Construction professional seldom recommend its use. Most Ghanaian contractors are a bit conservative and as such would like to stick to the traditional construction method for now. Suppliers and manufacturers of prefabricated building components are also not doing so well except in the use of prefabricated composite floor slabs, kerbs, pavement slabs and of late ornamental columns.

ii. Advantages in adopting the practise of off-site production in Ghana

According to the survey, for buildability to be carried to its utmost best, there is the need to incorporate the principles of off-site production as this helps achieve construction in a shorter time at a lower cost as most of the construction components are manufactured under factory conditions and only assembled on site. The resultant early completions, user satisfaction, ease of maintenance and replacement all points to the fact that off-site production has a great potential. It can therefore be stated that though not widely used in the Ghanaian construction industry, most stakeholders believe that in the near future, off-site production will be the way forward for the industry especially where Real Estate development is concerned due to the repetitive nature of building construction in this field. This is because it will help in cost reduction and early completion as well as achieving value for money to clients.

In a similar study into the benefits of Prefabrication Techniques to the Construction Industry and its influence on buildability, the Construction Industry Review Committee commissioned by the Hong Kong SAR Government (CIRC, 2001) recommended that off-site production will contribute to improved buildability and associated efficiency gains in terms of time, cost, quality, safety and environmental targets. The study established all these factors are not country specific but that all construction industries worldwide need to strive toward trying to reap the benefits of improved buildability by adopting off-site production. According to the research, if all these are met then the chart developed by Sanvido *et al* (1992) for a successful project will be achieved and all three parties involved, that is the owner, the design team and the contraction team will all be satisfied in the end (Table 1.1).

iii.Limitations to the practise of off-site production in Ghana

Some peculiar problems exist in the Ghanaian construction industry against the application of the tenets of off-site production. One of these peculiar limitations is the generally low familiarity of stakeholders of the Ghanaian construction industry with the concept of off-site production, especially in the Real Estate development sector. Secondly, the low level of construction technology in Ghana does not support the use of industrialized and prefabricated building systems to speed up project delivery (Walker, 1996). This often leads to the undermining of integration of design and construction activities. Some limitations associated with the practise of off-site production in the Ghanaian construction industry stems from some perceived peculiar characteristics of the industry compared to the manufacturing industry. Some stakeholders believe that standardising building components is one strategy for a successful implementation of off-site production in construction.

iv. The effect of Construction Failure on buildability

Buildability is the ability to construct a building efficiently, economically and to agreed quality levels from its constituent materials, components and subassemblies. (Ferguson, 1989). It is when these are not achieved that the issue of construction failure comes in as failure is an unacceptable difference between expected and observed performance. In Ghana, the research observed that the problem goes beyond just the economic to political as according to Akkufo (2004), housing policies in the country are hardly implemented in full. In some cases, government shows partial commitments to projects resulting in abandoned or stalled projects. He also stated the unprofessional nature of the construction industry has led to the situation where most of the tradesmen are not in tune with technological advancements in new construction trends. The result of the survey showed design errors and construction errors pertain because of the wide gap between design and construction in the local construction industry (Walker, 1996). Most construction activities start without a clear programme of works to define the critical path that the construction process should follow in order to complete the construction project within the practical shortest period as possible. Many construction projects are therefore not completed on time or not completed at all. The Ghanaian problem of inadequate maintenance culture was also brought to the fore through observations on building sites visited. Low maintenance culture cut through ownership of buildings from private houses through to government bungalows. Alteration made to buildings (refurbishment and renovation) are most often than not carried out by people who have no technical expertise and in no time changes in the building structure affects load distribution which leads to the structural failure of such buildings.

v. Material waste control in the Ghanaian construction industry. - A Financial Analysis in Adopting off-site production

Though some level of consciousness regarding waste associated with construction project delivery process existed, most of the construction activities in Ghana at both the design and documentation stages are bedevilled with waste. The main problem is that, most construction works commence without a waste management plan. The average wastage level of the traditional construction method was found to be much higher than that of off-site production in the trades of concreting, reinforcement, plastering and tiling. Analysis was done for the wastage reduction in seven trades including; concrete, reinforcement, plastering, screeding, formwork, masonry and tiling. The analysis as presented in Table 4.13 and Table 4.14 shows evidence that the reduction in material wastage alone based on the seven building trades discussed can reduce the cost of the building considerably. Off-site production will only bring about cost saving when there is full mechanisation of the construction process in Ghana by turning construction into an assembling industry rather than following the conventional construction method.

vi. Possibilities for the practice of off-site production

The question as to whether the Ghanaian construction industry is ready for the adoption of off-site produced building components currently is one that cannot be answered easily. There are some problems facing the Ghanaian construction industry like low levels of industrialisation and non-standardisation of building systems. But with the world now becoming a global village, stakeholders believe current globalisation trends will enhance technological transfer to the Ghanaian construction industry to support the production and use of industrialised and standardised building systems to speed up the construction processes in line with the principles of off-site production. This will in the long run ensure that designs meet a certain level of quality standard to ensure the comfort, convenience and safety of clients. Successful implementation of off-site production in construction will soften the differentiating characteristics of construction by making construction more like manufacturing; by standardising building components, utilising modularisation and prefabrication as well as using enduring or multidisciplinary teams. Where it is difficult to standardise components, it is proposed that there is the need to develop standard procedures for planning and managing the design and construction of unique facilities. This notwithstanding, between off-site production and conventional traditional construction based on expectation and optimization 75% of the respondents stated they will be better off adopting off-site produced building components (Figure 4.14). This is because it will aid in the speed of construction and reduce construction cost thereby increasing efficiency among other things. Most of the respondents are not really into the use of comprehensive prefabrication but in terms of finances they all agree that though the initial start up cost is very high, off-site production will be cheaper for the overall construction of buildings if the right steps are taken, especially in the field of Real Estate development due to the repetition of the same design. Of the few who have been using it especially at Trassaco- Villagio, they stated that as far as they are concerned, extensive use of prefabrication can reduce the total cost by as much as between 5% - 15% depending on the type of construction. Based on the survey (Figure 4.15), the major elements that can fulfill the basic pre-requisite requirements of the adoption and future use of off-site production in the construction practices of the Ghanaian construction industry are: i) Steel structural frame and roof trusses, ii) Prefabricated external cladding and dry wall; this is really being explored by Parakou Estates and Trassaco – Villagio and iii) Prefabricated concrete slab beams and columns and pavement blocks and kerbs which are now being used widely Since most of the products are load bearing, the development of lightweight prefabrication should be introduced to reduce the cost of materials.

The research showed that conditions to be met to make off-site production attractive and acceptable include:

1. Adequate research information and interest in the use of off-site produced components

2. Adequate training of the local construction workforce in the changing face of the construction industry worldwide

3. Mass production of off-site components.

In conclusion, it can be said that the research questions were very well addressed throughout the research and the objectives were met.

5.2 Conclusions

The following conclusions can be drawn from the study regarding how buildability in the Ghanaian construction industry can be enhanced with the adoption of the practice of off-site production, especially in the Real Estate Development sector:

- Though some level of awareness exists among stakeholders on the need to improve quality and increase efficiency and productivity in the project delivery process, there is a low level of familiarity with the concept of off-site production within the Ghanaian construction industry. Mass off-site production and modular construction is generally absent.
- There are some problems facing the Ghanaian construction industry like low levels of industrialisation and standardisation of building systems. But with the world now becoming a global village, current globalisation trends will enhance technological transfer to the Ghanaian construction industry in order to support the production and use of industrialised and standardised building systems to speed up construction processes in line with the principles of off-site production. This will in the long run ensure that designs meet a certain level of quality standard to ensure the comfort, convenience and safety of clients.
- The research reinforced findings by earlier researchers such as Egan (1998), Griffith and Sidwell (1995) and Low and Abeyegoonasekera (2001) that off-site production must be thought through at the early design stage by designers to solve all design and construction problems if that will be the construction method to be used. Thus

designers must take care of construction difficulties and not expect it to be the contractor's responsibilities. Under traditional procurement method, there is a late involvement of the contractor in the contract and thus they are unable to realise more buildable designs at the early stage.

- Although the use of off-site production is still not strongly practiced by the Ghanaian construction industry, there is a very high possibility for its adoption for general construction projects in the very near future, especially in the Real Estate Industry where the use of prototype designs can encourage its use. The choice of respondents between off-site production and conventional traditional construction based on expectation and optimization is 75% for off-site production (Table 4.14).

5.3 Recommendations

Although many previous studies have addressed some aspects of the study, some investigated the problem of waste in the local construction industry; others addressed the problem of buildability. However, this study introduced a more comprehensive view by combining all these factors which impact on the study. Based on the findings of this study and a review of previous research, the following recommendations are suggested for future projects in the Ghanaian construction industry to enhance the application of off-site production to improve buildability in the Ghanaian construction industry especially in Real Estate development in order to ensure minimisation of waste and increased productivity, quality and efficiency.

General recommendation

Offsite production will only bring about cost saving, efficiency and productivity improvement when the following issues are addressed:

- Some simulators are needed in adopting off-site production (prefabrication). These include full mechanisation of the construction process using heavy plants under factory conditions to produce prefabricated components. This will help in the introduction of more productive construction methods with the sole aim of effectively reducing construction cost. For the tenets of off-site production to catch on well with the local construction industry, a feasibility study in examining the prefabrication of building components and the idea for applying manufacturing technologies to the construction industry must be applied. Designers must explore the use of industrialised building techniques and methods as a solution for solving problems of the Ghanaian construction industry. Industrialisation in building construction and adoption of prefabrication can be introduced in construction. This will result in using mass production techniques under factory conditions leading to an increase in productivity, efficiency and quality of the product.
- During the project delivery process, stakeholders must make improving quality and increasing efficiency as well as value maximisation and waste minimisation the focal point of their activities. Off-site production principles should be observed during the construction process. There must be a conscious effort by stakeholders in the construction industry to reduce waste plan in all construction projects to the barest minimum. To encourage the use of off-site produced components, a rational design and construction approach is necessary as a tool for cost and time saving and reducing waste during the design, manufacture and assembly of building components.
- There must be ongoing research towards establishing strategies to bring construction closer to manufacturing by turning construction into an assembling industry through

prefabrication rather than following the conventional construction method in order to facilitate improving quality and increasing efficiency as well as waste minimisation and reduction in the Ghanaian construction industry.

Specific recommendations

- Due to the important role pre-fabricated building systems can play in the Ghanaian construction industry, an enabling environment must be created to make it possible for the manufacture and installation of these systems in Ghana. Transfer of technology, involving the use of industrialised buildings between the advanced nations and the local industry must be encouraged. This can also be achieved by collaboration between stakeholders of the Ghanaian construction industry and that of other industrialised nations such as the USA, UK and Australia. Government incentives to encourage the manufacture, import and use of prefabricated building components can also help in the mass production of components. Mass off-site production will lead to a decrease in the cost of components which will in the long run bring cost reduction benefits which will lead to adoption of the use of off-site produced building components.
- To improve buildability through the use of off-site production, considering construction methods at the early design stage is very important. Prefabrication can be applied for the future projects; however, the levels in adopting prefabricated building components should be dependent on the natures of the projects. Prefabrication together with the use of standardisation and modularisation must be made essential components in the principle of the design and construction industry nationwide.
- During the survey, it was established that most of the construction professionals did not rank their knowledge in and recommendation of off-site production to be very high

(Table 4.2 and Figure 4.3). Construction related Professional bodies such as the Ghana Institute of Architects (GIA), the Ghana Real Estate Developers Association (GREDA), the Ghana Institution of Surveyors (GhIS) and the Ghana Institution of Engineers (GhIE) must expose their members to the concept of off-site production and other new technological advancements in the construction field through professional training programmes. There is also the need for the teaching of the concept of off-site production to be introduced or strengthened in the academic and professional training of students pursuing construction related disciplines like Architecture, Building Technology and Civil Engineering among others as this will enhance the familiarity of these trainees with the concept so that when they get out of school, they can easily champion its usage and put it into practice.

Recommendation for future research

It is recommended that now that the awareness is being created among stakeholders of the need to use more off-site produced building components, future research on this topic should continue with the research into how best to propose effective prefabrication models for the construction sector especially, in the development of Real Estate projects to define the choice of prefabricated building components for different building trades from substructure to superstructure level. More importantly, the type of off-site production, be it semi prefabrication, volumetric prefabrication, or modular construction should also be addressed. The results on the answers on the type of prefabrication can then be used to derive a prefabrication model for the Ghanaian construction industry especially in the field of Real Estate development where the use of repetitive designs can improve drastically the move towards the adoption of prefabrication.

In conclusion, this study is a valuable academic finding, which provides the concepts of improved buildability through the use of off-site production to construction industry practitioners and other stakeholders of the Ghanaian construction industry to help reduce the housing deficit plaguing the housing sector. The research shows there is high hope for the adoption of off-site production of building components in the Ghanaian construction industry in the very near future.

GLOSSARY OF ABBREVIATIONS

The Construction Industry Institute (CII)

The Construction Industry Institute Australia (CII Australia)

The Construction Industry Review Committee (CIRC)

The Construction Industry Research and Information Association (CIRIA)

Construction Management Committee (CMC)

Off-site Production (OSP)

REFERENCES

- Arditi, D., Elhassan, A. and Toklu, Y.C. (2002) *'Constructability analysis in the design firm,'* Journal of Construction Engineering and Management, 128(2),117-126
- Adams, S. (1989) *Practical Buildability,* Butterworth, London
- Akinpelu, J.A. (2002) *"The Need for Code of Conduct, Building Regulations and By-Laws for the Building Industry in Nigeria,"* The Professional Builder, Nigeria Institute of Building, Pp11-14.
- Akkufo, S (2004) *Accelerated Development of Affordable Housing in Ghana*, Ghana Real Estate Magazine
- Atta- Poku, C (2001) *Project Report, Factors Affecting the Demand For Real Estate Development in Ghana*
- Ayininuola, G.M and Olalusi, O.O. (2004) *"Assessment of Building Failure in Nigeria: Lagos and Ibadan Case Study",* UNESCO African Journal of Science and Technology (AJST), Science and Engineering Series, Vol 5, No. 1, pp. 73-78
- Barker, K. (2004) *Review of Housing Supply – Final Report*, ODPM, London, HM Treasury
- Bell, G.R., Liepins, A.A. (1997). "*More Misapplications of the Finite Element Method,"* Rens, K. (ed.) Forensic Engineering: Proceedings of the First Congress. Minneapolis, ASCE, pp. 258-267.
- Blismas, N.G. (2007) *Off-site Manufacture in Australia: Current State and Future Directions*, Cooperative Research Centre for Construction Innovation for Icon.net Pty Ltd., Brisbane.

- Blismas, N.G., Pasquire, C.L., Gibb, A.G.F., Aldridge, G.B. (2003) *IMMPREST – Interactive Method for Measuring Pre-assembly and Standardisation Benefit in Construction*, (CD format), Loughborough University Enterprises Limited, Loughborough University, Loughborough.

- Boapeah, S.N (2003) *Planning for Affordable Housing in Ghana: A Framework for Analysis and Policy*, Bi Annual Journal of Building and Road Research Institute (CSIR). Ghana Vol. 8, June – December 2003.

- Bottom, D., Gann, D., Groak, S., Meikle, J. (1994) *Innovation in Japanese Prefabricated House-Building Industries*, Construction Industry Research and Information Association, London.

- Buildoffsite (2006) *Cameo Case Studies*, Discovering offsite, available at: www.buildoffsite.org (accessed 9th June 2010)

- Carper, K. (1987) *"Structural Failures during Construction,"* Journal of Performance of Constructed Facilities, Vol. 1, pp. 132-144.

- CIRIA, compiled by, Gibb, A.G.F., Groak, S., Neale, R.H., Sparksman, W.G. (1999) "*Adding Value to Construction Projects through Standardisation and Pre-assembly in Construction*," Report R176, Construction Industry Research and Information Association, London

- CIRIA, and principal author, Gibb, A.G.F. (2000) *Client's Guide and Toolkit for Optimising Standardisation and Pre-assembly in Construction*, Report CP/75, Construction Industry Research and Information Association, London

- Chen, S.E., and McGeorge, W.D. (1994) *"A systems approach to managing buildability."* Australian Institute of Building Papers, 5, 75-86
- Chen, S.E. and McGeorge, D. and Varnam, B.I. (1991) *Report to the government architect, New South Wales, buildability stage 1*, University of Newcastle, United Kingdom
- Chiang, Y.H. and Anson, M. (2004) In: Raftery, J. (ed.) (2004) *The construction sector in Asian economies. London*: New York: Spon Press.
- Chudley, R. (1997) *Construction Technology, 4*, Longman, England.
- Cole, T.R.H. (2003) *Final Report of the Royal Commission into the Building and Construction Industry, v6 Reform – Occupational Health and Safety*, Commonwealth of Australia, Canberra.
- Construction Industry Institute (1996) *Construction manual*, CII, Austin, Adelide
- Construction Industry Institute (1993) *Constructability Implementation Task Force*
- Construction Industry Institute (1986) *Constructability: a primer*, University of Texas, Austin Construction Industries Research and Information Association (2008) UK Construction 2010 – future trends and issues online, http://www.ciria.org/downloads/archive/ uk%20construction%202010.pdf (Nov 2008)
- Construction Industry Review Committee (2001) *Construct for excellence: Report of the Construction Industry Review Committee.* Hong Kong: CIRC
- Construction Industry Research and Information Association (1983*) Buildability: an assessment*, CIRIA, London
- Construction Management Committee of the American Society of Civil Engineering construction division (1991) 'Constructability and constructability programme: white paper', *Journal of Construction Engineering and Management*, 117(1), 67-89

- Daily Graphic "*House Beyond the Reach of Ghanaians"* - March 30, 2005. Graphic Communication Group

- Edusei, J (2003) "*Mass Housing Development by public estate developers – the experiences of state housing company limited,"* Bi Annual Journal of Building and Road Research Institute (CSIR). Ghana Vol. 8, June – December 2003, Pp17-26.

- Egan, J. (1998) *Rethink construction: the report of the Construction Task Force to Deputy Prime Minister, John Presott, on the scope for improving the quality and efficiency of UK construction,* Dept. of Environment, Transport and the Regions, London

- Feld, J. and Carper, K.L. (1997) *Construction Failure*, John Wiley & Sons, Inc

- Ferguson, I. (1989) *Buildability in practice*, Mitchell, London

- Fergusson, I. (2003) *"Buildability - Successful Construction from Conception to Completion".* Thomas Telford.

- Formoso, C.T, Isatto E.L. and Hirota E.H (1999) *"Methods of Waste Control in the Building Industry."* 26-28 July 1999, University Of California, Berkeley, CA, USA. 326-330 pp.

- Fredericks, M and Ambrose, J, (1989) *"Building Engineering Systems Design",* Van Nostrand Reinhold, New York vol. 2.

- Geile, R.J. (1996) *"Constructability, the stretch vision.''* Transactions of American Association of Cost Engineers International, VE& C 6.1- VE& C 6.5

- Gibb, A.G. (1999) *Off-site Fabrication – Pre-assembly, Prefabrication and Modularisation*, Whittles Publishing Services, Caithness, pp.262.

- Gibb, A.G.F (2000), *Standardization and Pre-assembly-clients guide and toolkit*, www.eci-online .org (accessed 5th July 2009).

- Gibb, A.G.F. (2001) *'Standardization, and pre-assembly – distinguishing myth from reality using case study research'*. Construction Management and Economics, 19(3), 307-315.

- Gibb, A.G.F & Isack, K (2003) Re-engineering through pre assembly*: client expectation and drivers.* Building research and information.31 (2) 146-160

- Gibson, G.E., McGinnis, C.I. and Flanigan, W.S. (1996) *'Constructability in public sector'*. Journal of Construction Engineering and Management', 122(3), 274-280

- Glavinich, T.E. (1995) *'Improving constructability during design phase'.* Journal of Architectural Engineering, 1(2), 73-76

- Gnaedinger, J.P. (1987). *"Case Histories - Learning from our Mistakes,"* Journal of Performance of Constructed Facilities, Vol. 1, pp. 35-47.

- Goodden, R.L. (1996). *Preventing and Handling Product Liability*. Marcel Dekker Inc., New York.

- Goodier, C.I., Gibb, A.G.F. (2004a) *Barriers and Opportunities for Off-Site Production*, DTI, October.

- Goodier, C.I., Gibb, A.G.F. (2004b) *The Value of the UK Market for Offsite*, DTI/Buildoffsite.

- Gray, C. and Hughes, W. (2001) *Building design management*, Butter-worth-Heinemann, England.

- GREDA Publication (2001) "GREDA Today", www.ghanaweb.com, (accessed 12th March 2008).

- GREDA Publication "*Brief Profile of Ghana"* (1999) www.ghanaweb.com, (accessed 12th March 2008).

- GREM Publication, Ghana Real Estate Magazine 2004 Vol. 1 No. 2.

- Griffith, A. and Sidwell, A.C. (1997) *'Development of constructability concepts, principles and practices',* Engineering, Construction and Architectural Management, 4(4), 295-310.

- Griffith, A. and Sidwell, A.C. (1995) *Construction in building and engineering projects*, Macmillan press, England.

- Griffith, A (1984) *Buildability-the effect of design and management on construction (a case study),* Heriot-Watt University, Dept. of Building, Edinburgh.

- Groak, S. (1992) *The Idea of Building*, E. & F.N. Spon Routledge, London.

- Habitat:(1989) UN Centre For Human Settlement: *An Unorganized Global Issue* (1989), www. UNhabitat.org.

- Hall, G.T. (1984) *"Revision notes on building maintenance and adaptation".* Butterworth and Co. England.

- Hampson, K., Brandon, P. (2004), *Construction 2020: A vision for Australia's Property and Construction Industry,* Cooperative Research Centre for Construction Innovation for Icon.Net Pty Ltd., Brisbane.

- Harvey, R.C. &Ashworth A. (1997) "*The Construction Industry of Great Britain".* MPG Books Ltd, Second Edition.

- Hersey, G. & Freedman R. (1992). "*Possible Palladian Villas". MIIT* Press. 1992

- Higgin and Jessop (1963) *Communications in the Building Industry,* Tavistock Institute and Routledge & Kegan Paul, London.

- Holroyd, T.M (2003), *Buildability- Successful construction from conception to completion*, Thomas Telford

- Howell, G. (1999). "*Managing Construction: The Lean Perspective".* The Lean Construction Chronicle, spring 1999, Lean Construction Institute, Ketchum, pp.1-3. http://www.leanconstruction.org/pdf/1999Chronicle.pdf

- Katminesky, D. (1991) *Design and Construction Failure – Lessons from Forensic Investigations*, McGraw – Hill, New York

- Koskela, L. (1992*) "Application Of The New Production Philosophy Of Construction*" CIFE, Technical report No. 72, Stanford USA.

- Kerridge, A.E. (1993) "Plan for constructability," Hydrocarbon processing, Jan, 135-145

- Kwakye, A. (2006) "*Maintenance of Construction Products".* The Quantity Surveyor, issue 1, 2006, pp2.

- Lam, P.T.I. (2002) *"Buildability assessment: the Singapore approach,"* Journal of Building and Construction Management, 7(1), 2-27.

- Latham, M. (1994) "*Constructing the Team",* Department of the Environment, HMSO, London.

- Levy, M. and Salvadori, M (1992) *Why Buildings Fall Down*, Norton, New York.

- Leonards, G. (1982) *"Investigation of Failures."* J. Geo-tech. Eng Div. Am. Soc. Civ. Eng. Pp 115-246.
- Lin, T.Y. and Stotesbury, S.D. (1988) *Structural Concepts and Systems for Architects and Engineers*. Van Nostrand Reinhold Company, New York.
- Lim, E.C and Alum, J (1995) *Construction Productivity :Issues Encounted By Contractor In Singapore,* International Journal Of Project Managers, Vol. 22 No. 1 , Pp51-58.
- Low, S.P. (2001) "*Quantifying the relationships between buildability, structural quality and productivity in construction*." Structural Survey, 19(2), 106-112.
- Low, S.P. and Abeyegoonasekera, B. (2001) *'Integrating buildability in ISO 9000 quality management systems: case study of a condominium project'*. Building and Environment, 17(1), 45-47
- Masterman, J.W.E. (2002) *Introduction to building procurement systems*, Spon Press, London
- McGeorge, D, Chen, S.E. and Ostwald, M.J. (1992) *The development of a conceptual model of buildability which identifies user satisfaction as a major objective*, CIB Conference, Rotterdam
- Mitchell, C.T (1996), "*New Thinking in Design",* John Wiley & Sons, Inc
- Mojaheed, S. (2005). "*A Project Improvement System for Effective Management of Construction "* PHD Dissertation, (unpublished)
- Munns, A.K. and Bjeirmi, B.F. (1996)." *The Role of Project Management in Achieving Project Success",* International Journal of Project Management 14, Pp 81- 87

- Neale, R.H., Price, A.D.F., Sher, W.D. (1993) *Prefabricated Modules in Construction: A Study of Current Practice in the United Kingdom*, Chartered Institute of Building, Ascot.

- Nicco-Annan, J. (2006) "*Partnering in Construction".* The Quantity Surveyor, issue 1 2006 Pp. 14-19.

- Nima, M.A., Abdul-Kadir, M.R., Jaafar, M.S. (1999) 'Evaluation of the engineer's personnel's role in enhancing the project constructability'. *Facilities*, 17(11), 423-430

- Orfano, F. (2009) *Construction Failures*, www.fed.up.pt/disciplinas - (assessed 20th April 2011).

- Ortega, I. (2000) *"systematic prevention of failures,"* Quality Management and Technology Report No. 9.

- Owusu, E.S and Boapeah S.N (1991) *"Housing Policy in Ghana: Experiences and Interventions for Public/Private Sector Support Systems."* BI Annual Journal of Building and Road Research Institute (CSIR). Ghana Vol. 8, June – December 2003, Pp9 – 16.

- Owusu, E.S and Edusei J. (1991) *"Financing of Rural and Low – Income Urban Housing Development in Ghana"*. Discussion paper.

- Owusu, E.S and Edusei J. (1995) *"Housing Finance programmes: the experience of Ghana".* Housing finance working paper No. 1.

- Oyewande, B. (1992) *"A Research for Quality in the Construction Industry".* Builder's magazine, June / July. Ed. Nigeria.

- Pasquire, C.L. and Gibb, A.G.F. (2002) *Considerations for assessing the benefits of standardisation and pre-assembly in construction.* Journal of Financial Management of Property and Construction, **7**(3), pp 151-161 December 2002.
- Pasquire, C.L., Gibb, A.G.F. and Blismas N.G. (2004) Off-site production: evaluating the drivers and constraints. *Proceedings of the 12th Annual conference on Lean Construction*. Copenhagen, Denmark, 3-5 August, 2004.
- Pepper, H.C. (1994) '*The benefits of constructability reviews during the design of environmental capital projects'*. Cost Engineering, Feb, 36(2), 19-21.
- Petroski, H. (1994) *Design Paradigms: Case Histories of Error and Judgment in Engineering*. Cambridge University Press, Cambridge.
- Petroski, H. (1993) *"Failure as a Source of Engineering Judgment: Case of John Roebling,"* Journal of Performance of Constructed Facilities, Vol. 7, pp. 46-58.
- Petroski, H. (1992). *To Engineer is Human: The Role of Failure in Successful Design*. Vintage Books, New York.
- Pitagorski, G (1998), "*The Project Manager / Functional Manager Partnership",* Project Management Journal, December 29, pp 7 – 16.
- Pong W.C. (2009) *An Investigation of the Development of Buildability Improvement Mechanism in Building Design –Unpublished MSc. Dissertation*
- Rice, P. (1994). *An Engineer Imagines*. Artemis London Limited, London.
- Roddis, W. M. K. (1993), "*Structural Failure and Engineering Ethics*", American Society of Civil Engineering (Structural Division) 119, Vol. 5, pp. 1539 – 1555.

- Sanvido V, Gobler F, Parfitt K, Guivenis M and Coyle M (1992), *Critical success factors for construction projects*, ASCE Journal of Construction Engineering and Management March, 118(1), 94-111.

- Saunders M. *et al*, (1997) "*Research Methods for Business Students"* Great Britain, Pearson professional ltd. Pp 412-413.

- Schneider, J. (1997). *Introduction to Safety and Reliability of Structures*. International Association for Bridge and Structural Engineering, Zurich, Switzerland.
- Simonsson, P. and Rwamamara, R. (2007), *Consequences of industrialized construction methods on the working environment*. Discussion paper.

- Skoyles, E.R. (1976) *"Material Wastage, a Misuse of Resources."* Building Research and practice, July / August 232 -243 pp.

- Skoyles, E.R and Skoyles, J.R (1987) *"Waste prevention on site"* London: Mitchell

- Solomon-Ayeh, B (2003) "*The effect of population growth on housing in Kumasi"* Bi Annual Journal of Building and Road Research Institute January – December 2003, Pp1-8.

- South Asia Building (1993) *Interviews: are we ready for buildability*? SAB

- Strauss, A.L., Corbin, J. (1990), *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*, Sage, Thousand Oaks, CA.

- Tam, W. Y.V, Tam C. M., Zeng S. X., and Ng W. C. Y. *"Towards Adoption of Prefabrication in Construction"* Unpublished – www.98.griffith.edu.au.

- Toole, T.M. and Gambatese, J. (2006) *The future of designing for construction safety* – www.design for construction safety .org.

- Turner DF (1995) *Design and build contract practice*, Pearson education Ltd, England.

- Voordit, T.J.M. and Wegen, H.B.R. (2005) *Architect in use: an introduction to the programming, design and evaluation of buildings*, Architectural Press, Burlington

- Walker, A. (1996) "*Project Management in Construction,"* Blackwell Science, Oxford 198-227pp.

- Warszawski, A. (1990) *"Industrialization and Robotics in Building: A Managerial Approach".* Harper & Row, New York. pp466

- Warszawski, A. (1999) *"Industrialization and Automated building systems"* London and New York E & FN Spon

- Wong F.W.H., Lam P.T.I. and Chan E.H.W. (2005) 'Optimising procurement approaches to address 'constructability' problems', In: *QUT Research Week Internal Symposium*, Brisbane, Australia

- Yeung, NSY, Chan A P C, Chan D W M "*Application of Prefabrication in Construction – A New Research Agenda for Reform by CII – HK*" Paper submitted to the "Conference on Precast Concrete Building Systems".

- Yu, W.D. and Skibniewski, M.J. (1999) 'Quantitative constructability analysis with a neturo-fuzzy knowledge-base multi-criterion decision support system'. *Automation in Construction*, 8(5), 553-565.

- Zallen, R.M. (1990). *"Proposal for Structural Design Peer Review."* Journal of Performance of Constructed Facilities, Vol. 4, pp. 208-212.

APPENDIX 5A

QUESTIONNAIRE

This questionnaire forms part of an MPhil research being undertaken by Mr. Oti Amankwah at the Department of Building Technology, Kwame Nkrumah University of Science and Technology. This research seeks to investigate how Buildability can be improved by adopting Off-Site Production (Prefabrication) and the effect it will have on the Ghanaian Construction Industry, especially in the field of Real Estate Development.

Objective of the study

*To establish the extent of the practise of the concept of off-site production by stakeholders of the Ghanaian construction industry especially those in Real Estate development

*To look into the effect of off-site production on buildability

*Limitations to the practise of off-site production in Ghana

* What are the effect of construction failure on buildability in the Ghanaian construction industry

*A look at material waste control in the Ghanaian construction industry and explore a financial analysis between Traditional construction method and off-site production (prefabrication).

*Possibilities for the practise of off-site production in the Ghanaian construction industry especially in the field of Real Estate Development.

Instruction to respondents

The questionnaire has been divided into six parts; part one gathers the background information about the respondent. Parts two to six deals with questions on buildability, Off-site Production, Ghanaian Construction Industry, and construction methods. Please rank them by ticking in the appropriate column.

Thank you sincerely for your valuable contribution to the research project.

Oti Amankwah

MPhil. Building Technology

Department of Building Technology

College of Architecture and Planning

Kwame Nkrumah University of Science and Technology

APPENDIX 5B

PART ONE – GENERAL INFORMATION

RESPONDENT AND COMPANY BACKGROUND

Name of respondent ………………………………………………….

Name of company ………………………………………………….

Address ………………………………………………….

Job title ………………………………………………….

Please tick one of the boxes and fill in the blank if you select others.

1. What is your highest level of education?
   a. Junior Secondary [ ]
   b. Senior Secondary [ ]
   c. Polytechnic [ ]
   d. University [ ]
   e. Post graduate [ ]

   Area of specialization, please specify

………………………………………………………………

2. What is your experience in the construction industry
   a. 0 – 5 years [ ]
   b. 6 – 10 years [ ]
   c. 11 – 15 years [ ]
   d. 16 – 20 years [ ]
   e. More than 20 years [ ]
3. Are you a member of the Project Management team in your Organization

   a. Yes [ ] no [ ]

APPENDIX 5 C

PART ONE CONTINUED: USE OF PREFABRICATED COMPONENTS.

This part of the questionnaire deals with the use of prefabricated components by Construction professionals.

1. As a Construction professional, how will you rate your knowledge in off-Site production (Prefabrication).

   Very High [ ],   High [ ],   Average [ ],   Below Average [ ]

2. Name some building components that lend themselves easily to prefabrication.

   …………………………………………………………………………………………

   …………………………………………………………………………………………

3. How often do you recommend the use prefabricated components in your consultancy to Contractors?

   …………………………………………………………………………………………

4. State some of the advantages and disadvantages associated with the use of prefabricated building components in relation to;

PLANT	LABOUR	FINANCE	TECHNOLOGY

5. On the basis of a financial analysis, which one is more expensive; prefabricated components or in-situ / conventional means of construction.

   …………………………………………………………………………………………

6. Which will you go in for, *Prefabricated Components* [ ]   *Conventional* [ ]

APPENDIX 5 D

PART ONE CONTINUED: USE OF PREFABRICATED COMPONENTS.

This part of the questionnaire deals with the use of prefabricated components by Contractors and Real Estate Developers.

1. As a Real estate developer or building contractor, name some building components that lend themselves easily to prefabrication.

   ……………………………………………………..

2. How often do you use prefabricated components in your construction work

   ……………………………………………. …...

3. State some of the advantages and disadvantages associated with the use of prefabricated building components in relation to your available workforce?

   ………………………………………………………………………………………

4. State some of the advantages and disadvantages associated with the use of prefabricated building components in relation to available plant?

   ………………………………………………………………………………………

5. State some of the advantages and disadvantages associated with the use of prefabricated building components in relation to available Technological knowhow?

   ………………………………………………………………………………………

6. Name some challenges you face in the use of prefabricated components in the area of finances.

   ……………………………………………………………………………………...

7. On the basis of a cost analysis, which one is more expensive; prefabricated components or in-situ / conventional means of construction.

   ……………………………………………………………………………………….

8. Which of these do you prefer , *Prefabricated Components* [ ] *Conventional* [ ]

APPENDIX 5 E

PART ONE CONTINUED: MANUFACTURE AND SUPPLY OF PREFABRICATED COMPONENTS.

This part of the questionnaire deals with the manufacture and supply of prefabricated components.

1. As a manufacturer or supplier of prefabricated components, name some building components that lend themselves easily to prefabrication

……………………………………………………………………..

2. Which of these components do you manufacture or supply

i. ………………………… ii. ………………………… iii. ………………….............

iv ………………………… . v. …………………………. vi. …………………………..

3. How do you mobilize capital for the manufacture or supply of your prefabricated components?

ii. ………………………… ii. ………………………… iii. ………………….............

4. Name some of the challenges you face in your supply business

……………………………………………………………………………………………...

5. How soon are you able to dispose of manufactured components

……………………………………………………………………………………………

6. Do you sell your components based on orders from contractors or you pre-finance hoping people will come in and buy

………………………………………………………………………………………………

7. What are some of the advantages you enjoy in your manufacture or supply of prefabricated components

……………………………………………………………………………………………

APPENDIX 5 F

PART TWO: ADVANTAGES OF OFF-SITE PRODUCTION (PREFABRICATION)

This part of the questionnaire provides some advantages of the use of off-site production (prefabrication) identified by earlier researchers. From your own experience, please rate them in order of significance; from

Least Significant – LS, Fairly Significant – FS, Significant – S

Very Significant – VS, and Extremely Significant – ES

	LS	FS	S	VS	ES
Minimise on site operation (better supervision)					
Produce high quality/integrity of the building					
Reduce construction cost					
Minimise number of site personnel					
Minimise construction time					
Increase efficiency					
Improve health and safety					
Improve environmental performance					
Aesthetic issues					
Ease of placement					
Enables existing business continuity					
Reduces congested work area and multi trade interfaces					

APPENDIX 5 G

PART THREE: DISADVANTAGES OF OFFSITE PRODUCTION (PREFABRICATION)

This part of the questionnaire provides some disadvantages of the use of Off-Site

Production (prefabrication) identified by earlier researchers. From your own experience, please rate them in order of significance; from

Least Significant – LS, Fairly Significant – FS, Significant – S

Very Significant – VS, and Extremely Significant – ES

	LS	FS	S	VS	ES
Inflexibility for changes in design					
Higher initial construction cost					
Time consuming in initial design development					
Limited space for placing prefabricated building components					
Lack of experience on the part of contractors					
Monotony in aesthetics					
Leakage problem at joints of prefabricated components					
Inadequate background research information					
Lack of demand for off-site produced (prefabricated)					

APPENDIX 5 H

PART FOUR: BAD BUILDABILITY (CONSTRUCTION FAILURE)

This part of the questionnaire provides some causes of bad buildability (construction failure) identified by earlier researchers which will go a long way to affect the outcome of any construction project. From your own experience, please rate them in order of significance; from

Least Significant – LS, Fairly Significant – FS, Significant – S

Very Significant – VS, and Extremely Significant – ES

	LS	FS	S	VS	ES
Fundamental errors in concept.					
Site selection and site development errors					
Programming deficiencies					
Design errors					
Construction errors					
Material deficiencies					
Operational errors					

APPENDIX 5 I

PART FIVE: PROBLEMS OF THE GHANAIAN CONSTRUCTION INDUSTRY

This part of the questionnaire provides some problems facing the Ghanaian Construction Industry. From your own experience, please rate them in order of significance; from

Least Significant – LS, Fairly Significant – FS, Significant – S

Very Significant – VS, and Extremely Significant – ES

	LS	FS	S	VS	ES
Use of expensive building materials					
Lack of adequate mechanization in the housing construction industry					
Lack of adequate qualified construction manpower and skilled artisans					
Land tenure and cost					
Shortage of housing finance					
Low income of prospective buyers					

Please state any other problems you believe is facing the Ghanaian construction industry not captured above and rate it.

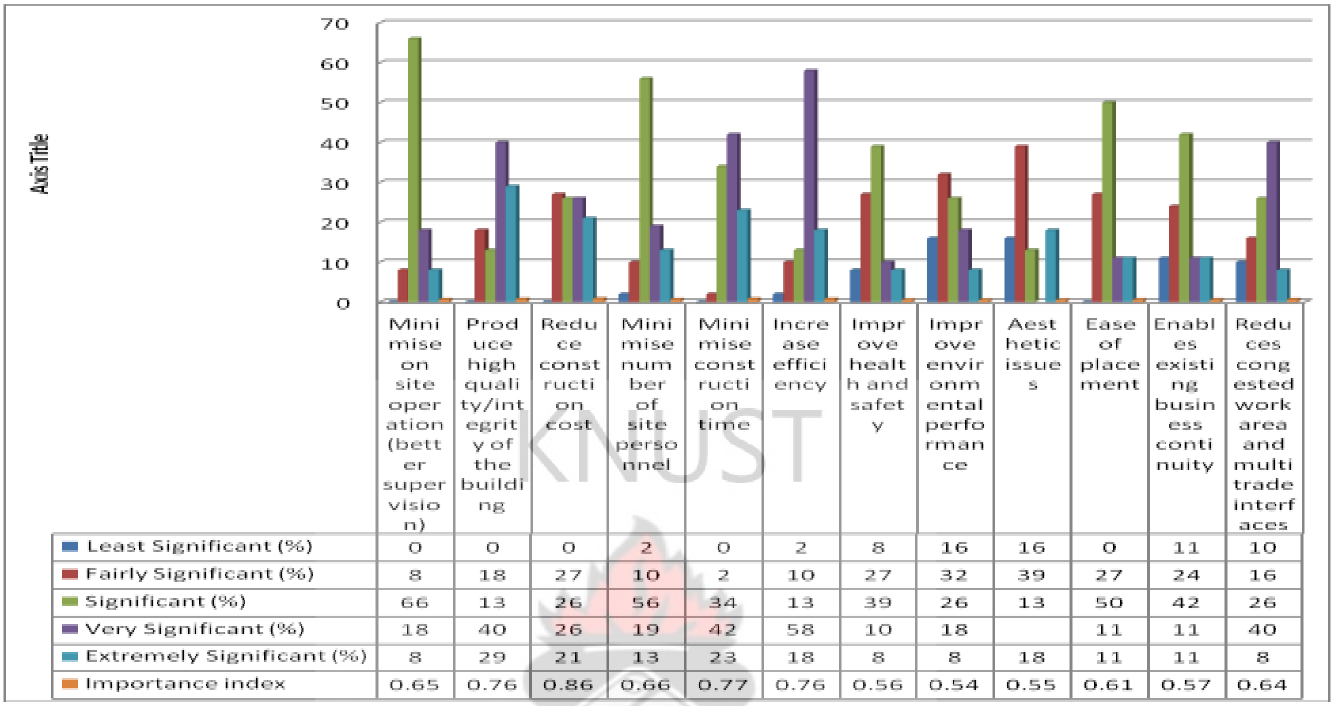
APPENDIX 5 J

PART SIX: CONVENTIONAL CONSTRUCTION OR OFF-SITE PRODUCTION

This part of the questionnaire provides construction methods for the development of building projects. Please tick the method, that is, conventional or prefabrication you would like to apply for the construction of the under listed elements.

TRADE	ELEMENT	CONVENTIONAL (IN-SITU)	OFF-SITE PRODUCTION (PREFABRICATION)
substructure	Foundation		
	Basement		
Structural frame	Column		
	Beam		
	Bearing wall		
	Slab		
	Stairs		
External works	External wall		
	Roof system		
Internal works	Partition wall		
	Tiling		
Building services	Ductwork		
Others	Frames		
	Doors		
	Windows		
	Kerbs		
	Septic tanks		
	Furniture		

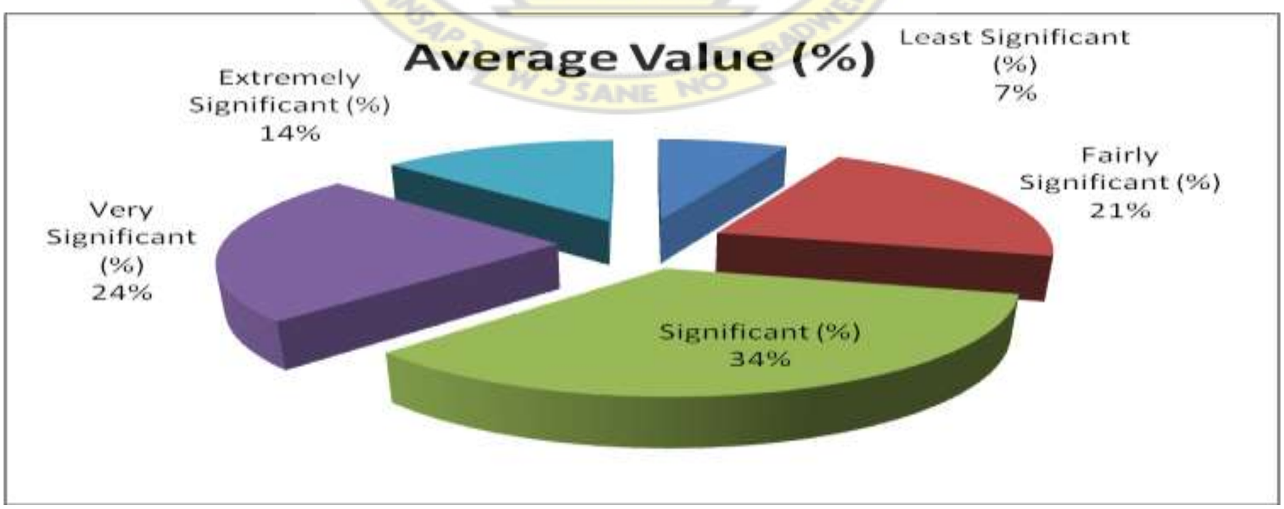
APPENDIX 6 A



	Minimise on site operation (better supervision)	Produce high quality/integrity of the building	Reduce construction cost	Minimise number of site personnel	Minimise construction on time	Increase efficiency	Improve health and safety	Improve environmental performance	Aesthetic issues	Ease of placement	Enables existing business continuity	Reduces congested work area and multi trade interfaces
Least Significant (%)	0	0	0	2	0	2	8	16	16	0	11	10
Fairly Significant (%)	8	18	27	10	2	10	27	32	39	27	24	16
Significant (%)	66	13	26	56	34	13	39	26	13	50	42	26
Very Significant (%)	18	40	26	19	42	58	10	18		11	11	40
Extremely Significant (%)	8	29	21	13	23	18	8	8	18	11	11	8
Importance index	0.65	0.76	0.86	0.66	0.77	0.76	0.56	0.54	0.55	0.61	0.57	0.64

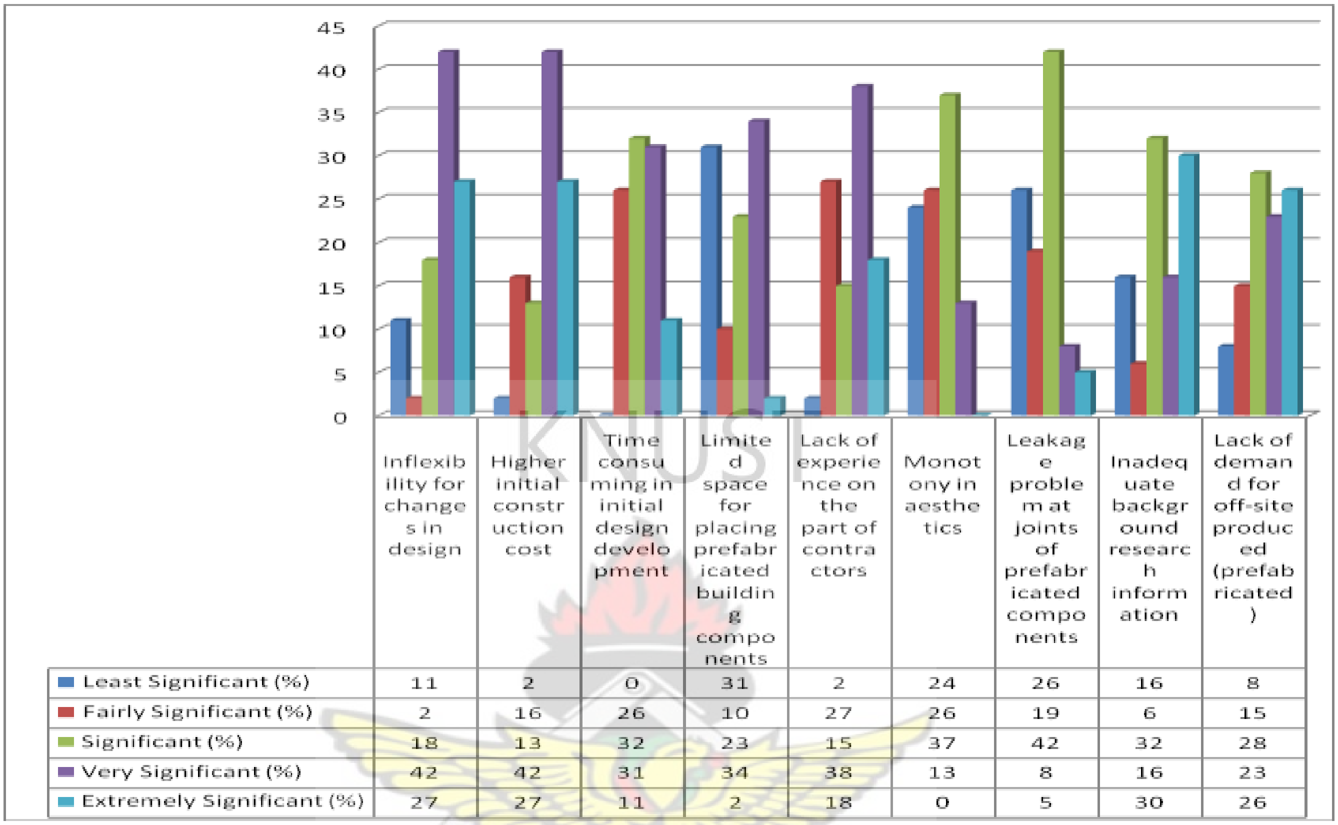
Advantages in Adopting Prefabrication (significance table)

APPENDIX 6 B



Average Value of Significance for Advantages of Adopting Offsite Production (Prefabrication)

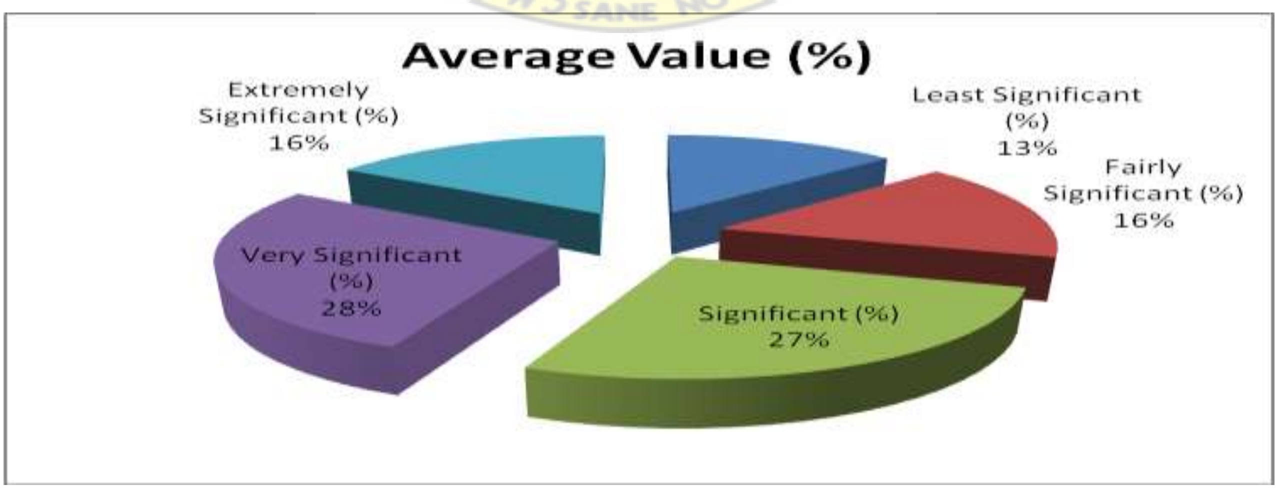
APPENDIX 7A



	Inflexibility for changes in design	Higher initial construction cost	Time consuming in initial design development	Limited space for placing prefabricated building components	Lack of experience on the part of contractors	Monotony in aesthetics	Leakage problem at joints of prefabricated components	Inadequate background research information	Lack of demand for off-site produced (prefabricated)
Least Significant (%)	11	2	0	31	2	24	26	16	8
Fairly Significant (%)	2	16	26	10	27	26	19	6	15
Significant (%)	18	13	32	23	15	37	42	32	28
Very Significant (%)	42	42	31	34	38	13	8	16	23
Extremely Significant (%)	27	27	11	2	18	0	5	30	26

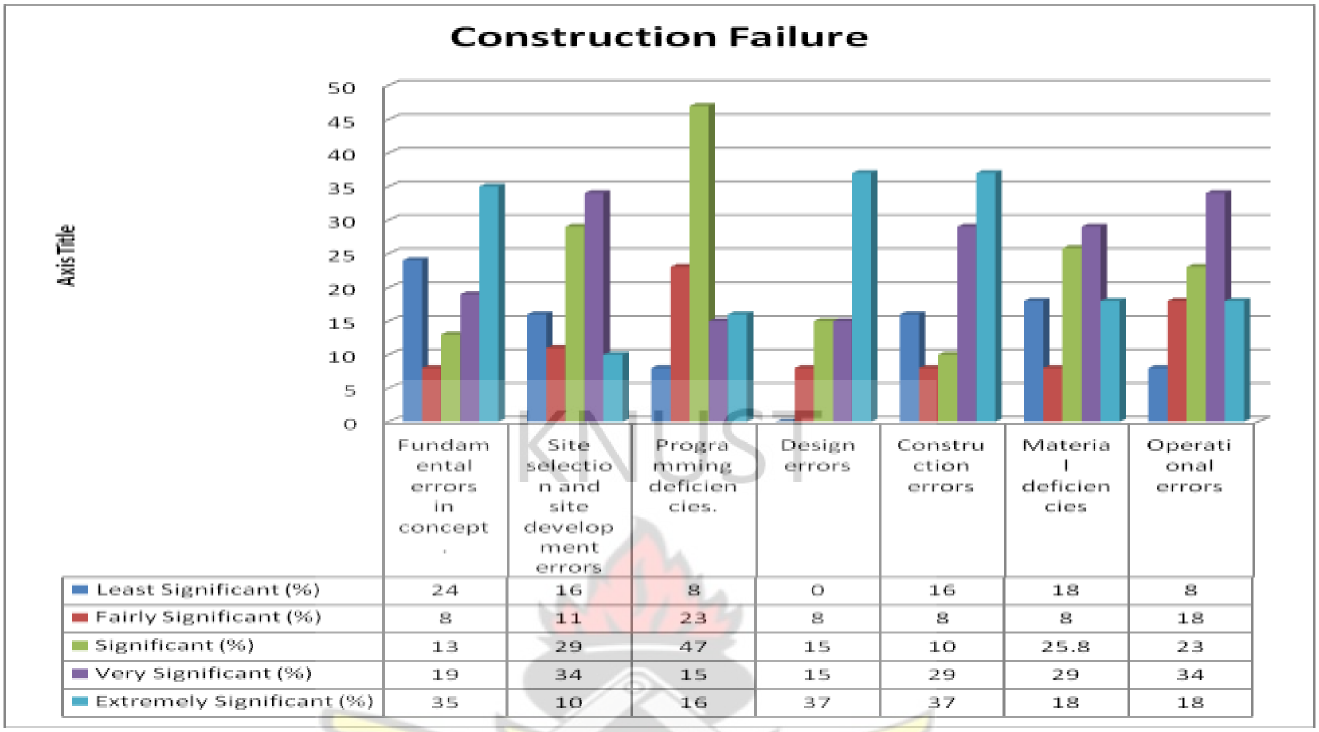
Hindrances in Adopting Prefabrication

APPENDIX 7B



Average Value of Significance for Hindrances of Adopting Offsite Production (Prefabrication)

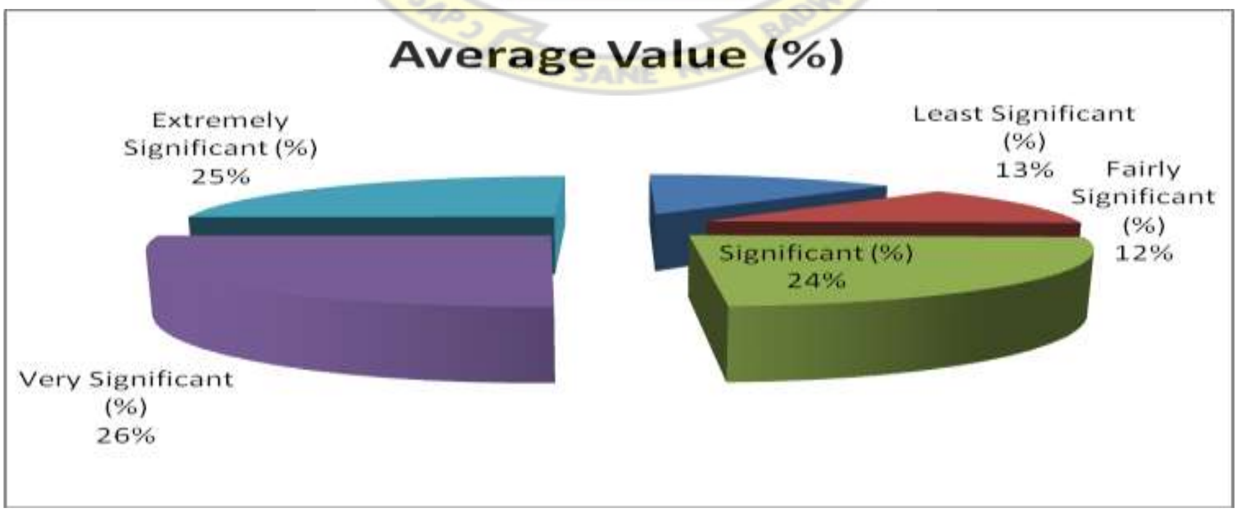
APPENDIX 8 A



	Fundamental errors in concept.	Site selection and site development errors	Programming deficiencies.	Design errors	Construction errors	Material deficiencies	Operational errors
Least Significant (%)	24	16	8	0	16	18	8
Fairly Significant (%)	8	11	23	8	8	8	18
Significant (%)	13	29	47	15	10	25.8	23
Very Significant (%)	19	34	15	15	29	29	34
Extremely Significant (%)	35	10	16	37	37	18	18

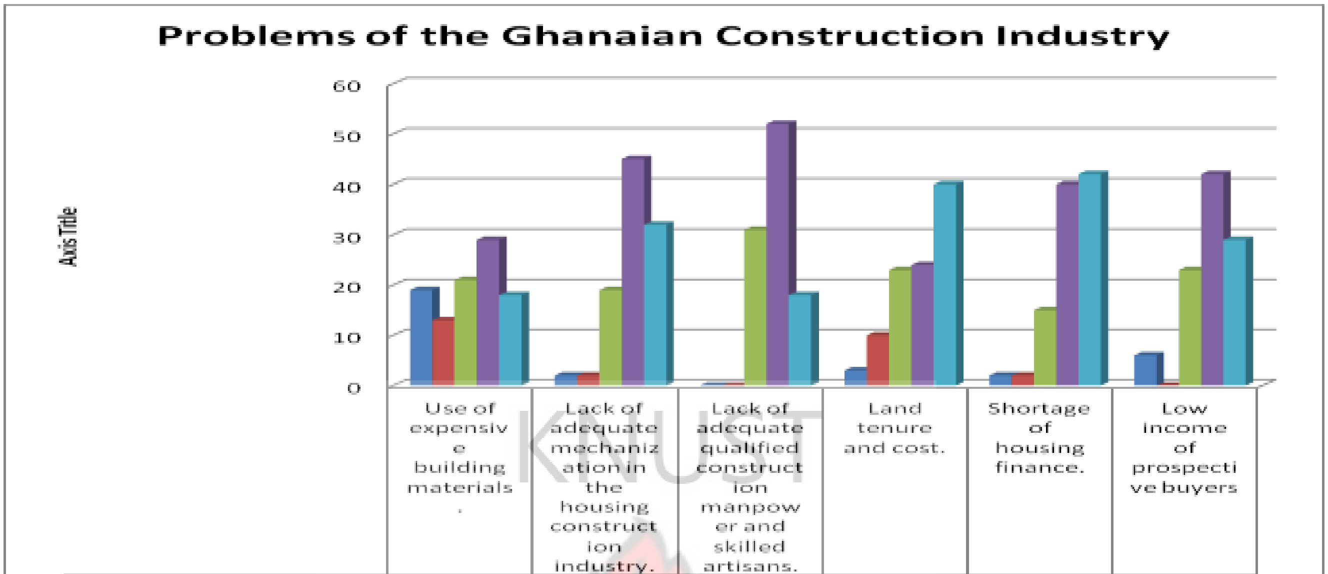
Factors of Bad Buildability (Construction failure)

APPENDIX 8 B



Average Value of Significance for Bad Buildability (Construction Failure)

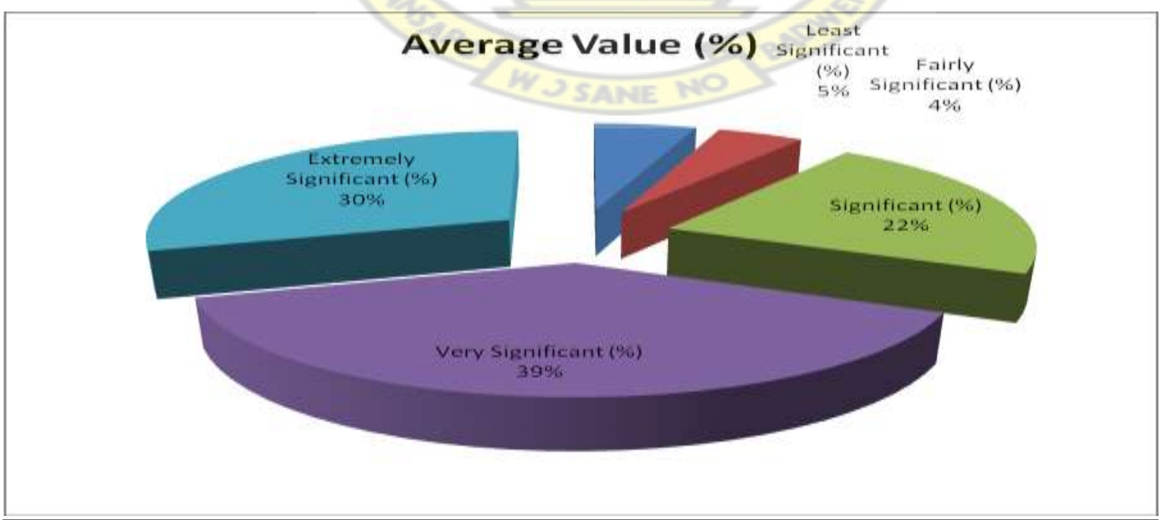
APPENDIX 9 A



	Use of expensive building materials.	Lack of adequate mechanization in the housing construction industry.	Lack of adequate qualified construction manpower and skilled artisans.	Land tenure and cost.	Shortage of housing finance.	Low income of prospective buyers
Least Significant (%)	19	2	0	3	2	6
Fairly Significant (%)	13	2	0	10	2	0
Significant (%)	21	19	31	23	15	23
Very Significant (%)	29	45	52	24	40	42
Extremely Significant (%)	18	32	18	40	42	29

Problems facing the Ghanaian construction industry

APPENDIX 9 B



Average Value of Significance for problems facing the Ghanaian Construction Industry

APPENDIX 10

A typical calculation for the level of significance for advantages of adopting of prefabrication is illustrated by Reduction in construction time which had the second highest importance index

$$\frac{5(23)+4(42)+3(34)+2(2)}{5(23+42+34+2)}$$

$$= \frac{115+168+102+4}{5(101)}$$

$$= \frac{389}{505}$$

$$= 0.77$$

APPENDIX 11

A typical calculation for the level of significance for hindrances towards the adoption of prefabrication is illustrated by 'Higher Initial Construction Cost' which had the highest importance index.

$$\frac{5(27)+4(42)+3(13)+2(16)+2}{5(27+42+13+16+2)}$$

$$= \frac{135+168+39+32+2}{5(100)}$$

$$= \frac{376}{500}$$

$$= 0.75$$

APPENDIX 12

A typical calculation for the level of significance for construction failure in the Ghanaian construction industry is illustrated by Site selection and site development errors which had the lowest importance index.

$$\frac{5(10)+4(34)+3(29)+2(11)+16}{5(10+34+29+11+16)}$$

$$= \frac{50+136+87+22+16}{5(100)}$$

$$= \frac{311}{500}$$

$$= 0.62$$

APPENDIX 13

A typical calculation for the level of significance for problems facing the Ghanaian construction hindrances towards the adoption of prefabrication is illustrated by Shortage of housing finance which had the highest importance index is given as below:

$$\frac{5(42)+4(40)+3(15)+2(2)+2}{5(42+40+15+4+2)}$$

$$= \frac{210+160+45+4+2}{5(103)}$$

$$= \frac{421}{515}$$

$$= 0.82$$

APPENDIX 14

Correlations for advantages in the adoption of prefabrication

Variables		Minimise on site operation	Produce high quality buildings	Reduce cost	Minimise site personnel	Minimise construction time	Increase efficiency
Minimise on site operation (better supervision)	Pearson Correlation	1	.351**	.205	.295*	.376**	.251*
	Sig. (2-tailed)		.002	.078	.010	.001	.030
	N	75	75	75	75	75	75
Produce high quality building	Pearson Correlation	.351**	1	.224	.109	.284*	.171
	Sig. (2-tailed)	.002		.054	.354	.013	.142
	N	75	75	75	75	75	75
Reduce construction cost	Pearson Correlation	.205	.224	1	.275*	.163	.080
	Sig. (2-tailed)	.078	.054		.017	.161	.497
	N	75	75	75	75	75	75
Minimise number of site personnel	Pearson Correlation	.295*	.109	.275*	1	.298**	.338**
	Sig. (2-tailed)	.010	.354	.017		.009	.003
	N	75	75	75	75	75	75
Minimise construction time	Pearson Correlation	.376**	.284*	.163	.298**	1	.440**
	Sig. (2-tailed)	.001	.013	.161	.009		.000
	N	75	75	75	75	75	75
Increase efficiency	Pearson Correlation	.251*	.171	.080	.338**	.440**	1
	Sig. (2-tailed)	.030	.142	.497	.003	.000	
	N	75	75	75	75	75	75
Improve health and safety	Pearson Correlation	.359**	.151	.424**	.548**	.192	.482**
	Sig. (2-tailed)	.002	.205	.000	.000	.106	.000
	N	72	72	72	72	72	72
Improve environmental performance	Pearson Correlation	.494**	.315**	.514**	.277*	.503**	.230*
	Sig. (2-tailed)	.000	.006	.000	.016	.000	.047
	N	75	75	75	75	75	75
Aesthetic issues	Pearson Correlation	.562**	.315*	.481**	.459**	.272*	.478**
	Sig. (2-tailed)	.000	.010	.000	.000	.027	.000
	N	66	66	66	66	66	66
Ease of placement	Pearson Correlation	-.016	-.063	.037	-.318**	.046	.142
	Sig. (2-tailed)	.893	.591	.752	.005	.695	.223
	N	75	75	75	75	75	75

Enables existing business continuity	Pearson Correlation	.507**	.459**	.445**	.312**	.349**	.314**
	Sig. (2-tailed)	.000	.000	.000	.006	.002	.006
	N	75	75	75	75	75	75
Reduces congested work area and multi trade interfaces	Pearson Correlation	.407**	.178	.430**	.196	.303**	.355**
	Sig. (2-tailed)	.000	.126	.000	.092	.008	.002
	N	75	75	75	75	75	75

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Variables		Improve health and safety	Improve performance	Aesthetic issues	Ease of placement	Enables existing business continuity	Reduces congested work area and multi trade interfaces
Minimise on site operation (better supervision)	Pearson Correlation	.359**	.494**	.562**	-.016	.507**	.407**
	Sig. (2-tailed)	.002	.000	.000	.893	.000	.000
	N	72	75	66	75	75	75
Produce high quality/integrity of the building	Pearson Correlation	.151	.315**	.315*	-.063	.459**	.178
	Sig. (2-tailed)	.205	.006	.010	.591	.000	.126
	N	72	75	66	75	75	75
Reduce construction cost	Pearson Correlation	.424**	.514**	.481**	.037	.445**	.430**
	Sig. (2-tailed)	.000	.000	.000	.752	.000	.000
	N	72	75	66	75	75	75
Minimise number of site personnel	Pearson Correlation	.548**	.277*	.459**	-.318**	.312**	.196
	Sig. (2-tailed)	.000	.016	.000	.005	.006	.092
	N	72	75	66	75	75	75
Minimise construction time	Pearson Correlation	.192	.503**	.272*	.046	.349**	.303**
	Sig. (2-tailed)	.106	.000	.027	.695	.002	.008
	N	72	75	66	75	75	75
Increase efficiency	Pearson Correlation	.482**	.230*	.478**	.142	.314**	.355**
	Sig. (2-tailed)	.000	.047	.000	.223	.006	.002
	N	72	75	66	75	75	75
Improve health and safety	Pearson Correlation	1	.636**	.714**	-.239*	.581**	.508**
	Sig. (2-tailed)		.000	.000	.043	.000	.000
	N	72	72	63	72	72	72
Improve environmental performance	Pearson Correlation	.636**	1	.575**	-.039	.715**	.677**
	Sig. (2-tailed)	.000		.000	.739	.000	.000
	N	72	75	66	75	75	75
Aesthetic issues	Pearson Correlation	.714**	.575**	1	.013	.615**	.648**
	Sig. (2-tailed)	.000	.000		.918	.000	.000
	N	63	66	66	66	66	66

Ease of placement	Pearson Correlation	-.239*	-.039	.013	1	.006	.276*
	Sig. (2-tailed)	.043	.739	.918		.956	.017
	N	72	75	66	75	75	75
Enables existing business continuity	Pearson Correlation	.581**	.715**	.615**	.006	1	.804**
	Sig. (2-tailed)	.000	.000	.000	.956		.000
	N	72	75	66	75	75	75
Reduces congested work area and multi trade interfaces	Pearson Correlation	.508**	.677**	.648**	.276*	.804**	1
	Sig. (2-tailed)	.000	.000	.000	.017	.000	
	N	72	75	66	75	75	75

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX 15

Correlations for hindrances of adopting Off- site production

Variables		Inflexibility for changes in design	Higher initial construction cost	Time consuming in initial design developme nt	Limited space for placing components	Lack of experience of contractors	Monotony in aesthetics	Leakage problem at joints	Inadequate research information	Lack of demand
Inflexibility for changes in design	Pearson Correlation	1	.080	.339**	.116	-.149	-.174	-.338**	-.147	.055
	Sig. (2-tailed)		.495	.003	.321	.202	.136	.003	.209	.640
	N	75	75	75	75	75	75	75	75	75
Higher initial construction cost	Pearson Correlation	.080	1	.698**	-.069	.466**	.326**	.296**	.501**	.545**
	Sig. (2-tailed)	.495		.000	.558	.000	.004	.010	.000	.000
	N	75	75	75	75	75	75	75	75	75
Time consuming in initial design development	Pearson Correlation	.339**	.698**	1	-.297**	.386**	.204	.005	.402**	.469**
	Sig. (2-tailed)	.003	.000		.010	.001	.080	.967	.000	.000
	N	75	75	75	75	75	75	75	75	75
Limited space for placing prefabricated building components	Pearson Correlation	.116	-.069	-.297**	1	-.207	.191	.275*	-.027	.099
	Sig. (2-tailed)	.321	.558	.010		.075	.101	.017	.816	.397
	N	75	75	75	75	75	75	75	75	75
Lack of experience on the part of contractors	Pearson Correlation	-.149	.466**	.386**	-.207	1	.151	.383**	.762**	.579**
	Sig. (2-tailed)	.202	.000	.001	.075		.197	.001	.000	.000
	N	75	75	75	75	75	75	75	75	75
Monotony in aesthetics	Pearson Correlation	-.174	.326**	.204	.191	.151	1	.573**	.324**	.268*
	Sig. (2-tailed)	.136	.004	.080	.101	.197		.000	.005	.020
	N	75	75	75	75	75	75	75	75	75
Leakage problem at joints of prefabricated components	Pearson Correlation	-.338**	.296**	.005	.275*	.383**	.573**	1	.336**	.298**
	Sig. (2-tailed)	.003	.010	.967	.017	.001	.000		.003	.010
	N	75	75	75	75	75	75	75	75	75
Inadequate background research	Pearson Correlation	-.147	.501**	.402**	-.027	.762**	.324**	.336**	1	.644**
	Sig. (2-tailed)	.209	.000	.000	.816	.000	.005	.003		.000

information	N	75	75	75	75	75	75	75	75	75
Lack of demand for off-site produced	Pearson Correlation	.055	.545**	.469**	.099	.579**	.268*	.298**	.644**	1
	Sig. (2-tailed)	.640	.000	.000	.397	.000	.020	.010	.000	
	N	75	75	75	75	75	75	75	75	75

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX 16

Correlations for causes of construction failure

Variables		Fundamental errors in concept.	Site selection and site development errors	Programming deficiencies	Design errors	Construction errors	Material deficiencies	Operational errors
Fundamental errors in concept.	Pearson Correlation	1	.000	.131	.106	.469**	.303**	.409**
	Sig. (2-tailed)		1.000	.261	.440	.000	.008	.000
	N	75	75	75	55	75	75	75
Site selection and site development errors	Pearson Correlation	.000	1	-.206	.099	.250*	.001	-.086
	Sig. (2-tailed)	1.000		.076	.471	.031	.996	.462
	N	75	75	75	55	75	75	75
Programming deficiencies	Pearson Correlation	.131	-.206	1	-.071	.361**	.221	.480**
	Sig. (2-tailed)	.261	.076		.605	.001	.057	.000
	N	75	75	75	55	75	75	75
Design errors	Pearson Correlation	.106	.099	-.071	1	.178	.472**	-.006
	Sig. (2-tailed)	.440	.471	.605		.193	.000	.964
	N	55	55	55	55	55	55	55
Construction errors	Pearson Correlation	.469**	.250*	.361**	.178	1	.625**	.469**
	Sig. (2-tailed)	.000	.031	.001	.193		.000	.000
	N	75	75	75	55	75	75	75
Material deficiencies	Pearson Correlation	.303**	.001	.221	.472**	.625**	1	.295*
	Sig. (2-tailed)	.008	.996	.057	.000	.000		.010
	N	75	75	75	55	75	75	75
Operational errors	Pearson Correlation	.409**	-.086	.480**	-.006	.469**	.295*	1
	Sig. (2-tailed)	.000	.462	.000	.964	.000	.010	75
	N	75	75	75	55	75	75	

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX 17

Correlations for problems facing the Ghanaian construction industry

Variables		Use of expensive building materials	Lack of adequate mechanization in the housing construction industry	Lack of adequate qualified construction manpower and skilled artisans	Land tenure and cost	Shortage of housing finance	Low income of prospective buyers
Use of expensive building materials	Pearson Correlation	1	-.056	-.168	.036	-.084	-.070
	Sig. (2-tailed)		.635	.149	.756	.476	.553
	N	75	75	75	75	75	75
Lack of adequate mechanization in the housing construction industry	Pearson Correlation	-.056	1	.350**	.080	.173	-.025
	Sig. (2-tailed)	.635		.002	.493	.138	.832
	N	75	75	75	75	75	75
Lack of adequate qualified construction manpower and skilled artisans	Pearson Correlation	-.168	.350**	1	.326**	.144	.435**
	Sig. (2-tailed)	.149	.002		.004	.219	.000
	N	75	75	75	75	75	75
Land tenure and cost	Pearson Correlation	.036	.080	.326**	1	.590**	.535**
	Sig. (2-tailed)	.756	.493	.004		.000	.000
	N	75	75	75	75	75	75
Shortage of housing finance	Pearson Correlation	-.084	.173	.144	.590**	1	.456**
	Sig. (2-tailed)	.476	.138	.219	.000		.000
	N	75	75	75	75	75	75
Low income of prospective buyers	Pearson Correlation	-.070	-.025	.435**	.535**	.456**	1
	Sig. (2-tailed)	.553	.832	.000	.000	.000	
	N	75	75	75	75	75	75

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX 18

Concordance of response

Kappa statistics for multiple raters using categorical classifications was employed to test the level of agreement among respondents. This was done for all the components of the questionnaire. The calculation on the advantages in the adoption of prefabrication can be tested by reference to section 3.4.2 and Table 4.1, as follows:

$$m = \sum_{j=1}^{k} x_{ij} = 900 \qquad (1)$$

$$\bar{m} = \frac{\sum_{i=1}^{n} m_i}{n} \qquad (2)$$

$$\Rightarrow \quad \sum_{i=1}^{n} m_i = n \times \bar{m} = 900$$

$$\bar{P}_j = \frac{\sum_{i=1}^{n} x_I}{n \times \bar{m}} \qquad (3)$$

$$\hat{k}_j = 1 - \frac{\sum_{i=1}^{n} x_{ij}(m - x_{ij})}{nm(m-1)\,\bar{p}_j \bar{q}_j} \qquad (4)$$

where $\bar{q}_j = 1 - \bar{p}_j$

Hence the overall kappa value for occurrence = $\hat{k} = \dfrac{\sum_{j=1}^{k} \bar{p}_j \bar{q}_j \hat{k}_j}{\sum_{j=1}^{k} \bar{p}_j \bar{q}_j}$ (5)

From table 4.7,

$\sum_{j=1}^{k} \bar{p}_j \bar{q}_j \hat{k}_j = 0.722$ and

$\sum_{j=1}^{k} \bar{p}_j \bar{q}_j = 0.917$

$$\hat{k} = \frac{0.722}{0.919} = \mathbf{0.787}$$

Based on the same calculation, the kappa values for;

Hindrances towards the adoption on prefabrication was given as **0.782**

Problems facing the Ghanaian construction industry **0.772**

Construction failure is **0.775**