UNIVERSITY OF EDUCATION, WINNEBA

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THE PERCEPTION OF ENGINEERS ON THE USE OF OFFSITE CONSTRUCTION METHODS IN GHANA

ACHEAMPONG DUAH FRANK

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THE PERCEPTION OF ENGINEERS ON THE USE OF OFFSITE CONSTRUCTION METHODS IN GHANA

BY

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DECLARATION

STUDENT'S DECLARATION

I, ACHEAMPONG DUAH FRANK, declare that this Dissertation with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE: ……

DATE: ……

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidance for supervision of Dissertation as laid down by the University of Education, Winneba.

NAME OF SUPERVISOR: DR. PETER PAA-KOFI YALLEY

SIGNATURE: …….....

DATE: ….....

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DEDICATION

This work is specially dedicated to two of the numerous blessings that have come my way: Ama Agyapomaa Oheneba-Acheampong and Yaw Baffuor Oheneba-Acheampong

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ABSTRACT

Off-site construction methods have played an important role in the construction sector the world over in the past few decades, having been touted as offering a more sustainable solution to the building industry especially in areas of cost, safety, meeting time lines, and waste reduction. But developing countries still rely on vernacular practices for design and construction. In the Ghanaian construction industry, most contractors are still used to the traditional system of building construction. This attempt is to find out the perception of engineers on the use of offsite construction methods in Ghana. To achieve this, the objectives were to find out engineers knowledge on offsite construction methods, the readiness to use offsite construction methods and the associated cost benefits in using offsite construction method. Survey research design was used for this study. In determining the sample size, purposive sampling technique was used to select 12 engineers of registered construction firms undertaking active projects in the Kumasi Metropolis. Data was collected through interview and the themes analyzed. The study showed that the engineers know that reduction of overall construction costs, shortened construction time, increased efficiency and improved health and safety of workers are benefits of applying off-site construction methods. The dominant challenges were capital-related issues, low level of expertise and negative perception. It was recommended that professional bodies such as Ghana Institute of Architecture and Ghana Institute of Engineers should expose members to the innovation and other new technological advancements. Government on its part must also play a leading role in the training of artisans and the promotion of off-site construction as that is the way forward for any construction industry that aspires to meet the housing challenge of its populace.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The construction industry has not made many improvements when it comes to productivity in the past 40 years; whereas other industries have continuously made advances in productivity (McGraw-Hill, 2011). Several factors have contributed to limited advance in productivity in construction industry. Poor site conditions have an effect on labourers and assist in decreasing their productivity. The continuous changing in weather conditions, dust and airborne particles, and high levels of noise are some of the factors that lead to fatigue and injuries. Fatigue leads to laborers slowing down and also injuries, which all attribute to a decline in efficiency and productivity (The Modular Building Institute, 2009). When productivity is low, project schedules begin to be of concern. Assaf and Al-hejji (2006) stated that poor labor productivity is one of the top factors that cause project delays.

As a way forward in resolving the problem of productivity limitations to traditional on-site construction has been the introduction of off-site construction methods such as prefabrication and modularisation with a view to increase efficiency and standardise the management of quality (Alazzaz & Whyte, 2012). A main reason for industry's endorsement of off-site production methods has been a perceived improvement in productivity (Bernstein, Morton, Gudgle & Russo, 2011). Indeed, Eastman and Sacks (2008) shows off-site production (fabrication of sub-element components) has resulted in an efficiency gain of up to 40% per employee. Prefabrication plays an important role in the modern world construction today, it refers to the making of parts in an offsite workshop or factory prior to the installation at the

site (Baghchesaraei, Kaptan & Baghchesaraei, 2015). “The primary purpose of prefabrication is to produce building components in an efficient work environment with accesses to specialized skills and equipment in order to reduce cost and time expenditures on the site while enhancing quality and consistency” (Anderson & Anderson, 2007).

Prefabrication can be used as a means to help reduce many of the forms of waste (Osmani et al. 2008). Prefabrication, if efficiently implemented, can help lower project costs, shorten project schedules, improve quality of work, assist in more efficient use of labor and improves safety (The Modular Building Institute, 2009). These positive effects of construction all help alleviate construction waste and help make construction sites more sustainable. Along with reducing construction waste, 0ffsite construction increases recycling and allows for the selection of sustainable materials (McGraw-Hill, 2011). This means financial, time, and material waste can all be reduced significantly by using the offsite approach, as a construction method.

In a report produced by McGraw-Hill (2011) on prefabrication, it was stated that in two-thirds of companies that use prefabrication experienced reduced project schedules. Out of those companies 35% reported decreasing schedules by as much as four or more weeks (McGraw-Hill, 2011). This is significant not only because it proves prefabrication reduces project schedules but also because it can yield significant cost savings. Many projects take place on active sites, where business is negatively impacted when construction is occurring. When schedules can be reduced by a month or more, businesses can return to normalcy sooner and help minimize negative impacts to business (McGraw-Hill, 2011).

Several developing countries are still not familiar with this off-site construction. Because those countries have different social and economic systems from modern

countries, they tend to use more actual personals for constructions rather than prefabrication methods (Arieff & Burkhart, 2002). ‘’Designers should carry out prefabricated buildings by the usage of different technologies and systems, however these technologies need high level of knowledge and experience and high quality of application on site, so prefabricated construction technologies are preferred in many developed countries’’ (Kim, 2009). Construction methods that require a lot of physical labor such as masonry, hand paint or cast-in-place concrete are common in several countries. Furthermore, unlike the modern countries, a lot of countries in Africa have fewer concerns in many important aspects of building construction, such as preciseness, on-site safety, energy saving and waste management during a construction.

According to Doloi (2007), lack of knowledge and experience account for the decline in the use of prefabrication construction technologies in many developing countries, but with time several developing countries will start using prefabrication by importing its knowledge and technologies. Another problem might be the fact that, according to Gibb and Isack (2003), off-site construction itself suffers from supply shortages. Lack of availability is the reason why building companies in the developing countries did not use pre-assembly methods of off-site construction. This is supported by Goodier and Gibb (2007), where only about 40 per cent of off-site suppliers supply enough to meet demand for off-site construction.

1.2 Statement of the Problem

Off-site construction methods have played an important role in the construction world in the past few decades (Bernstein, Morton, Gudgle, & Russo, 2011) and is

increasingly becoming a major alternative technique and strategic direction. It produces a significant amount of value for the construction industry and the economy more generally. According to Gibbs et al. (2001), much research has been done in ways of incorporating offsite production into the construction industry with the aim of improving higher quality standards and reducing construction duration and cutting down material waste on site.

The Ghanaian construction industry has been characterized by high construction cost, untimely delivery, poor financial performance, material waste, and decreased value in end product and its inability to move with the changing tides and introducing a better and more effective and efficient construction methods like off-site construction are making them less competitive.

Previous studies on offsite construction methods have mainly focused on the benefits and the future application of offsite construction (Alazzaz & Whyte. 2014; Baghchesaraei, Lavasani & Baghchesaraei, 2016). The reason for this research is to establish what has accounted for the Ghanaian construction industry's inability to adopt offsite construction as a means to dealing with the numerous challenges they face with respect to the use of traditional built-on-site construction method.

1.3 Purpose and Objectives

Offsite construction is touted as offering a more sustainable solution to building, but developing countries already rely on vernacular practices for design and construction. Largely, this work seeks to investigate the lesser use of off-site construction methods in the Ghanaian construction industry. This goal is to be achieved by concentrating on the following specific objectives:

1. To find out engineers knowledge on off-site construction in Ghanaian construction industry
2. To find out the readiness of Ghanaian construction industry to use off-site construction method.
3. To determine the cost benefits for the use of off-site construction over the traditional in-situ method.

1.4 Research Question

The following research questions were developed to guide the study.

1. What is the knowledge level of engineers on off-site construction?
2. How ready is the Ghanaian construction industry to use off-site construction method?
3. What are the cost benefits for the use of off-site construction over the traditional in-situ method in the Ghanaian context?

1.5 Significance of the Study

The outcome of this study would provide information on off-site construction as a building and construction technology to Ghanaians, who have practiced the vernacular 'brick-mortar' method of construction over the centuries. This work will expose the practice of off-site construction methods, which has become a major component in the building industry in other parts of the world. This will give construction industry in Ghana the insight and the advancement of off-site construction in the world today and hence its adoption.

The study is justified for the reason that it might be a good source of information for further studies by researchers and improve the adoption of off-site construction in

Ghana. The study will provide a source of guidance to policy makers, the government and administrators as well as all other stakeholders who find off-site construction useful.

Finally, this work would be beneficial these to contractors. Their exposure to off-site construction method of building will help them seek knowledge and skills and adopt for the means to help reduce many of the forms of waste lower project costs, shorten project schedules, improve quality of work, assist in more efficient use of labor and improves safety. Moreover, the study is significant as it could enhance the knowledge of the general public about the off-site site construction method.

1.6 Limitations of the Study

This study attempted to shed more light and deepen the understanding of the issues on off-site construction method. That notwithstanding, the reasons outlined below may affect the findings of this study.

The study was restricted to construction industries in Ashanti Region. The study is intended to take place at only registered construction industries in Ashanti Region, therefore the results however are not suitable for generalization of all the construction industries in Ghana since the modus operandi of the construction industries are not the same with all the firms all over the country.

The study encountered certain problems like hesitation of the data provisions and collection, and wrong information that might affect the validity of the findings and recommendations. The usual problems of respondents' bias and lack of co-operation could not be avoided completely, thus limiting the scope and results of the study.

1.7 Delimitation of the Study

The work was focus on players and stakeholders involved in the building industry. That will include state institutions, estate developers and building contractors. The findings and fieldwork was limited to construction industries in Ashanti Region, Ghana. The study covers the building expert knowledge on off-site construction, readiness on the use off-site construction method and the cost benefits for the use of off-site construction over the traditional in-situ method in Ghana.

1.8 Organization of the Study

The research has been organized into six chapters. The first chapter essentially introduces the research, identifies the key problem under investigation and asks the relevant questions. It outlines the objectives, both general and specific, makes known the significance of the research and states the limitation and delimitation of the study. This chapter is relevant to the study because it puts the study into perspective and helps to check deviation.

The second chapter presents a review of relevant literature on off-site construction method. It takes a looks into the concept of off-site construction and benefits association with off-site construction adoption. It further concentrates on conceptual framework of the study.

Chapter three provides information on participants, sampling techniques, procedures and equipment used in both data collection, and analysis. It also deals with the research design, description and distribution of instruments

The fourth chapter is dedicated to the presentation and explanation of the research outcome. Chapter five discusses the significant findings relative to the study. Chapter six gives a summary of the findings, draws conclusions and offer

recommendations and any other limitations of the study. This is very relevant because it brings to bare information previously unavailable, thus expanding the frontiers of existing knowledge.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter sets a basic framework for the study by giving a general review on the concept of off-site construction, perception on its use as an alternative method for construction and knowledge level on the adoption of offsite construction. In doing the research, the study strived to find out the benefits of offsite construction over traditional construction methods and challenges associated with off-site construction.

2.2 The Concept of Off-Site Construction

The concept of offsite and simplification of tasks applied to the construction sector are not new, having been discussed extensively since 1950s (Branson et al, 1990). Off-site construction is a development industry term used to depict assemblies that are fabricated under processing factory conditions and afterward transported to development destinations for joining into building and structural designing works (Jaillon & Poon, 2008). Operationally, off-site construction is a construction innovation, which aims to take as much as possible the construction activities away from the project site to the factory to ensure better quality under controlled working conditions (Shahzad et al, 2014). The process is employed in the building and civil engineering works of structures like bridges, tunnels, culverts, and water supply systems. In the construction field, prefabrication is regarded as the first level of industrialization, which is followed by mechanization, automation, robotics, and reproduction (Richard, 2005).

Previous studies have used various terms and acronyms that are associated with offsite construction. This include off-site prefabrication (OSP), precast concrete building (Kale & Arditi, 2006), off-site manufacturing (OSM), industrialized building (Jonsson & Rudberg, 2013; Meiling et al, 2013), modern methods of construction (MMC) (Goodier & Gibb, 2007), and pre-assembly, to name a few, and these terms are used interchangeably (Arif & Egbu, 2010; Goulding & Arif, 2013; Goulding et al, 2014; Taylor, 2010). Nadim and Goulding (2010) argued that, offsite manufacturing falls under the broad umbrella of Modern Methods of Construction (MMC).

Over the years, quite a number of definitions have been used to describe offsite manufacturing (Taylor, 2010). Off-Site Manufacturing (OSM) can be defined as processes that incorporate prefabrication and pre-assembly to produce units and or modules that are then transported to site and positioned to form a permanent work (Emmitt & Gorse, 2010; Gibb & Isack, 2003; Jaillon & Poon, 2008). In the opinion of MBI (2010), OSM refers to any part or aspect of a construction process that is carried out in a controlled condition away from the actual site where the building is or will be situated. But Gibb and Pendlebury (2006) went a step further to defining it as a term used to describe a range of applications where structures, buildings or parts are manufactured and assembled away from the site before they are finally installed into positions. In the nutshell, OSM involves moving operations that are traditionally completed onsite to a manufacturing environment (Gibb & Pendlebury, 2006) and this in turn improves quality, customer satisfaction, efficiency, predictability of delivery timescale and sustainability of project (Nadim & Goulding, 2010).

Offsite construction plays an important role in the modern world of every building today. Lamb (2010) refers “Off-Site Construction" to the several different types of building systems in which a home is partially or entirely constructed,

manufactured, or assembled in a factory, assembly plant, or lumber". The conventional method of building house has been to transport bricks, timber, cement sand, steel and aggregates to the site, and to construct the house on the site from these materials. In prefabrication construction, only the foundations are constructed in this way while sections of walls, floors and roof are assembled in a factory, transported to the site, lifted into place by a crane and bolted together: with the primary purpose of producing building components in an efficient work environment with specialized skills and equipment in order to reduce cost and time expenditures on the site while enhancing quality and consistency (Anderson and Anderson, 2007). Prefabrication "need only affect the construction process and not the end-product" (BRE certification, 2001; Craig et al, 2000). Typically, four stages make up a prefabricated construction project;

1. Design development by developer and plan approval by regulating authorizes
2. Assembly of module components in a factory
3. Transportation of modules to the project site
4. Erection of modular units to form the building

Prefabrication can be divided into five main building methods (CABE, 2004; Ross, 2005; National Audit Office, 2005; Burwood et al, 2005; Goodlier et al, 2005; Ely, 2004)

- Volumetric systems: this system is also known as modular construction (Burwood et al., 2005). In a volumetric system, three-dimensional units are completed, either in isolation or in multiples, to form the structure of the building. These modules can be prefinished in the factory to include all fixtures and fittings, requiring a very limited amount of installation work on site. (Ross, 2005; National Audit Office, 2005; Ross et al, 2006). In this system about 85-90 per cent of the process is completed in the factory (Burwood et al, 2005)

- Panelised systems: panel systems include walls, floors and roofs, which are made from flat, pre-engineered panels and are assembled on site. Panel systems can be divided into two main categories of Open and Closed systems. In open systems structural components are taken to site where the rest of work is done on site and in closed system which is more complex and different components such as windows , doors, internal finishes, external cladding, insulation etc. can be fitted in factory (Ross, 2005; National Audit Office, 2005; Burwood et al, 2005; Ely, 2004, Ross et al, 2006).
- Hybrid system: this is also known as the semi-volumetric system. In this system panelized and volumetric systems are combined, with the volumetric system frequently being used in kitchens and bathrooms and other highly serviced places. The volumetric systems for kitchens and bathrooms are also known as pods (Ross, 2005; National Audit Office, 2005; Burwood et al, 2005; Ely, 2004).
- Sub-assemblies: sub-assemblies mainly include floor or roof cassettes and pre-cast foundations which are made in factory but do not form the primary structure of the building (Ross, 2005; national audit office, 2005; Burwood et al, 2005)
- Components: these are non-structural elements that are assembled offsite. Although currently less common than structural elements, components such as mechanical and electrical services infrastructure are being developed with significant assembly being carried out offsite.

While this building method is becoming popular, there are other new ways builders are using factory precision and efficiencies to create quality structures. In the book ‘prefab prototypes: site-specific design for offsite construction, Jaillon and Poon (2008) detailed six different types of prefabricated systems

- Panelized wood framing
- Sandwich paneling
- Steel framing
- Timber framing
- Concrete systems
- Modular systems

All of these prefab building systems provide durable construction components that can save both time and money. Prefabricated construction, as a modern construction technology replacing conventional cast-in-situ concrete construction, has attracted immense attention from many countries over the past two decades. This wide spread interest can be largely explained by the inherent superiority of the technology, including construction waste reduction (Baldwin et al, 2009; Tam et al, 2007), improved quality control (Jaillon & Poon, 2008), noise and dust reduction (Pons & Wadel, 2011), higher standards for health and safety (Lopez-Mesa et al., 2009, Pons & Wadel, 2011), time and cost savings (Chiang et al 2006, Gibb & Isack, 2003), reduced labour demand (Nadim & Goulding, 2010), and low resource depletion (Aye et al, 2012; Won et al, 2013).

2.3 Types of Off-site Construction Components usage in Buildings

The composite construction method and fully off-site construction method was adopting into current Industrialised Building System (IBS) construction projects. The concept of partial industrialized system is derived from the composite nature of full industrialization, and is used to describe a manufacturing strategy that selectively uses some industrializing aspects (Nurul et al, 2005).

Nurul et al (2005) further stated that, the fully prefabricated construction method will involve on the manufacture, assembly and connect concept. All of the designed fabrication components of the building will be manufactured off-site, assembly off-site and be delivered to the stated site on planned period. Both of the type of construction method is specifically aimed to increase productivity and quality of work. There are various types of prefabricated components that have been designed and manufactured for construction project. There are factors that need to be considered on the adoption of the prefabricated components in the usage of warehouse buildings. The components which are commonly used in local warehouse buildings construction are:

- Steel framing systems
- Panel system

2.3.1 Steel Framing Systems

Frame system may be defined as the structures that carry the loads through their beams and girders to column and finally to footing or pilecap. In such system, the skeletal structures will help to reduce the number and sizes of load carrying members. The important feature is the capacity to transfer heavy loads over large spans. Therefore, it is used in the construction of bridges, parking lots, warehouses, industrial buildings and etc (Junid, 1986). Frame system is a system that use beam and column as the main structure member due to the function that support all of the building weight. The walls have to be light for easy installation to support the building (Badir et al., 1998).

In the development of construction industry, the usage of light steel trusses increased due to cost effective which profiled steel portal frame and cold-formed channels system as alternative choice for traditional hot-rolled sections. It is commonly

used with precast concrete slab, steels columns and beams. Steel framing systems have always been the popular choice that used widely in the construction of skyscrapers (CIDB, 2003). The framing system is prefabricated in factory and delivery to the site with stated schedule. It is erected to the final location by using machinery, such as mobile crane and be join by special bolts, plates and welded with the structure.

The products of steel framing systems are included steel beams and columns, portal frame, roof trusses and etc (Industrialised Building System (IBS) Survey, 2003). These systems especially steel beams and columns are commonly used in construction industry in order to speed up the construction works.

2.3.2 Panels system

Panel system may be defined as the structures that carry load through large floor and wall panels (Junid, 1986). This system probably would be the most widely used prefabricated system which employed planar or panel-shaped elements for floor slabs, vertical supports, partitions and exterior wall. Depending on the scale of projects, some panels may be fabricated at site for easy transportation. Other panel systems available are such as wood, plastic, light weight metal and ferrocement materials.

In panel system, loads are distributed through large floor and wall panels where walls support the building weight. This system is applicable to building which functionally require a large number of walls such as apartment house, hotel and hospital. This system is not applicable to buildings with large spans or many stories (Badir et al, 1998).

According to Junid (1986), panel system may be defined as those structures that carry the load through large floor and wall panels. The panels can be made in various forms and materials and are normally prefabricated at factory. Concrete panel systems

are extensively used in Europe for high rise building for ease of construction purpose. In Malaysia, this system is slowly gaining popularity in terms of low rise buildings. The products of steel wall panels are included lightweight steel wall panel, metal wall panel and etc. There are another different concept in classifying the building that the components shold be used as a basis for building classification hot-rolled steel sections which consists of frame system, panel system and box system (Majzub, 1977).

2.4 Issues of Prefabricated Components usage in buildings

The adoption of prefabricated system which introduced in industrialized building system is still very low in construction industry. Particularly, there are issues regarding the usage of prefabricated components in warehouse buildings. The implementation of prefabrication system in local construction industry is still very low and this causes issues in the usage of prefabricated components. This is because of several reasons in the construction industry.

2.4.1 Lack of skill and exposure to prefabricated technology

Skilled workers in local labour forces still lack the implementation of prefabricated system, and even so with superior construction technology where highly skilled workers are required to replace foreign workers. Due to the issue of low wages on occupational safety and health, the construction parties are still refusing to join the industry (IBS Steering Committee, 2006). Besides, specialist skills such as system integrator or assemblers require intensive training which required more time and investment (Thanoon et al, 2003).

Knowledge in construction technology is equally important. Lack of knowledge in design of prefabricated components discourages further the implementation of prefabricated system. Fully prefabricated construction system requires high

construction precision. Building projects that were awarded and constructed using prefabricated system were carried out with many mistake and the most common problems faced are improper assembly of the components connections.

2.4.2 Financing issues

Contractors lack capital backup and are not able to set up their own manufacturing company as this involves high initial investment. In this case, financial issue becomes the main reason for lower class contractors not to move forward with the prefabricated system (Rahman & Omar, 2006). Prefabricated system is also an unattractive choice due to wide swing of property demand, high interest rate and improper economic condition (Thanoon et al. 2003).

2.4.3 Planning and the control of organization

The changing in design or variation works required a lot of further adjustment and this will raise up the initial cost and time for prefabricated system to be adopted during design stage. Although the possibility to prefabricate any kind of building design is high, but if the design stage is taken into account by manufactured construction, it can resolve the issues relating to manufacturing, final assembly and transportation (Pan et al, 2008). The most common problems encountered are improper assembly of the prefabricated components that normally involved the connections due to the underestimate of importance of accuracy in setting out the alignment and leveling. Accuracy of setting out the alignment and leveling are the most important aspect for the successful rapid erection of prefabricated components (Rahman & Omar, 2006).

Prefabricated system design needs to be addressed and planned from the beginning of design stage for successful implementation through the integration of

designer and contracting firm. In Malaysia, contracting firms are only involved after tender stage and this causes many prefabricated system projects, which has become the alternative design for traditional method, not cost effective.

2.4.4 Negative perception and low quality

The term prefabricated system is often misunderstand with negative image due to its past failures and unattractive architecture (Rahman & Omar, 2006). These buildings are normally associated with prefabricated mass construction method, low quality buildings, abandoned projects, and poor aesthetic and other drawbacks. Due to poor architectural design, old prefabricated buildings have given the public bad impression. Furthermore, among the designers, it is always not popular as they realize that their creativity in design process has limitation in prefabrication (Hamid et al, 2008). The development of prefabricated system in other countries such as Japan and Sweden are very successful due to high quality and high productivity, unlike Malaysia which the development of prefabricated system is still very low. In conclusion, developers are encouraged to adopt prefabricated system utilization as is it important for better customer perception and this will create better understanding and demand for prefabricated system.

2.5 Usage of Prefabricated Components in Warehouse buildings

The needs for increased efficiency in construction have been discussed widely among construction players and also academicians. However, the efforts have shown to be slower and the practice less successful (Winch, 1998). The general view of the construction process is that it is in ordered, linear phenomenon, which can be organized, planned and managed top down. The frequent failures to complete construction projects

on budget and schedule give rise to the thinking that the process maybe is not as ordered and predictable in its nature as it may look (Bertelsen, 2002). With the usage of prefabricated components in warehouse construction, the delays, cost overruns, and etc can be prevented. Construction of warehouse buildings which use this prefabricated components offers minimal wastage, reduce site material, clean and safe environment, controlled quality and lower construction cost.

2.5.1 Level of Prefabricated Components usage in Construction Projects

A survey by IBS (2003) indicated that companies with zero usage of prefabricated system in construction projects were recorded to be steadily decreasing from 1998 (74%) to 2002 (48%). Hence, more companies are starting to accept and applying prefabricated system in their construction projects. 81% to 100% of the projects are utilized by a number of companies and a steady increase shown in the record (IBS Survey, 2003).

According to the record shown above, the usage of prefabricated system in construction projects is in an increasing trend. Besides, the rising usage of prefabricated system in construction industry can be attributed to increasing usage of prefabricated components which most of the companies are accepting and applying in their construction projects. As the usage of prefabricated system becomes more pervasive, it is expected to extend further across the construction industry. The adoption of prefabricated components in construction project will help to improve the construction progress in terms of improving the planning, management and production process of construction works. Construction wastage will be reduced for increasing in the construction profit. Besides, the labours consumption on construction industry will be reduced by adopting this system (Shaari, 2003).

2.6 Innovation Adoption

2.6.1 Innovation diffusion theory (IDT)

The innovation diffusion theory has remained one of the strong theories to predict the diffusion of innovations in a social system. Introduced in 1962, the innovation diffusion theory was fine-tuned by Rogers (1995). Innovation diffusion theory focuses on understanding how, why and at what rate innovative ideas and technologies spread in a social system (Rogers, 1962). Fichman (2000) defines diffusion as the process by which a technology spreads across a population of organisations, and Ismail (2006) divide the whole theory into four elements.

Rogers and Shoemaker (1971) observed that five attributes are largely involved to influence the adoption of an innovation: relative advantage, compatibility, complexity, trialability and observability and continued to argue that the individuals' perceptions of these five characteristics predict the rate of adoption of innovations (Rogers, 2003). Rogers believed that these five qualities determine between 49 and 87 percent of the variation in the adoption of a new product (les Bobinson, 2009).

1. **Relative advantage:** a simple yet a powerful concept for diffusion of an innovation. It is common sense term that a person will only adopt a new idea, a new product or a service if he perceives it to be a better option than the one in practice. If a user finds a new innovation more advantageous than the operational one, he will be compelled to adopt the new innovation. Thus the more advantageous the new innovation, the quickly will it diffuse in a social system. The degree of relative advantage is often expressed by a pot of sub-dimensions (economic profitability, low initial costs, decreases in discomfort,

social prestige, saving time and effort immediacy of rewards) (Francesco, 2012).

2. **Compatibility:** it is the extent to which adopting the innovation is compatible with what people do (Kaasinen, 2005). It is the degree to which an innovation is perceived as consistent with consumer needs, values and beliefs, previous ideas and past experiences. It helps give meaning to the new idea and regard it as more familiar (Francesco, 2012). The more compatible the innovation the better chances of adoption.
3. **Complexity:** It is the degree to which an innovation is perceived as relatively difficult to understand and use (Rogers, 2003). To Rogers, the simpler the innovation, the greater the rate of adoption. This may not be true in all situations as some high tech products are perceived more advantageous because of their complexity but quite often the rule of simplicity does help the diffusion of innovation.
4. **Observability:** it is the easiness with which the results of an innovation are not only visible but their communication to the prospective users. Moore and Benbasat (1991) found the observability construct quite complex, so they divided into two thus, result demonstrability and visibility constructs. While demonstrability means the ease of presentation of working and features of an innovation, visibility defines the degree of exposure to public notice. Result demonstrability is the tangibility of results of using the innovation. Visibility is the degree to which others can see that an innovation is been used (Moore & Bensabat, 1991; Benham & Raymond, 1996).
5. **Trialability:** it is the degree of examining or testing a new innovation before actually adopting to it. An example is seen where automobile companies allow

customers to test drive vehicles to have real life feel before actual purchase. It gives the prospective users a sense of sureness to adopt a new innovation.

2.6 Ways towards successful implementation of Prefabricated System

Various parties have making an effort in order to achieve the targeted goals in construction industry for the process to successful implementation of prefabricated system in local construction industry. Many countries have played an important role in order to successfully implementation of this system. This system was highlighted into national Budget in pass few years and into Malaysia Plans and etc.

Construction Industry Development Board (CIDB) has been delegated for the implementation of prefabricated system in local construction industry. CIDB is an agency under the Ministry of Works which is a regulated body entrusted with the responsibility of coordinating the needs of the Malaysia construction industry, making recommendations in the formulation of policies for the construction industry. It is also addressing the pertinent issue and problems faced by the local construction (Construction Industry Development Board, 2003).

2.61 Adoption of prefabricated components for warehouse buildings

Many countries have introduced and encouraged the adoption of prefabricated system in construction industry. According to IBS Centre (2012), the most common types of prefabricated components are precast concrete framing, steel framing system, panel system, block work system and etc. Among all of the types, steel framing system and panel system are most suitable to utilize in warehouse buildings.

The Government through CIDB has embarked the IBS Roadmap (2003-2010) that outlines several well-thought strategies and aggressive steps to promote the use of

prefabricated system in Malaysia. To facilitate further, the Government has encouraged the use of prefabricated components for the construction industry. Contractors adopting prefabricated system are given incentives such as levy exemption based on the percentage of prefabricated components usage in a project. The Government is taking the leading role in persuading the construction industry to apply a more systematic construction method in construction industry. The effort that started is a strategic change in the construction industry.

Construction industry which is adopted using prefabricated system is efficient, clean, safe and innovative which are the new attributes that will be related. With these outstanding features, with attributes such as professionally managed and handled, workers with relevant skills, proper coordination and management as well quality will inevitably make prefabricated system an excellent option for those involved in the industry to become global industry players in the international arena that demands high quality, efficient and professional services (CIDB 2003).

2.6.2 Modular Coordination (MC)

Modular Coordination introduced in the construction industry improves in productivity and quality that act as a tool towards industrialization and rationalization of the construction industry. The application of MC can be adopted into the design, manufacture and assembly of the buildings, their components and installations (CIDB, 2007). It also can be used to coordinate the position and dimensions of components and spaces in buildings design (Sharul, 2003).

Besides, modular coordination is a coordinated unified system for dimensioning spaces, components, fitting and etc so that all of the elements fit together without extending or cutting when the components and fittings are manufactured by different

manufacturer (Trikha, 1999). The objective of modular coordination is to allow interchangeability of prefabricated components within the building and an easy adoption of any layout of prefabricated components (Warszawski, 1999).

According to CIDB (2005), practical approaches related to set-up coordination and measurement of components with the introduction of MS 1064, as a certain geometric discipline and spaces in the building design (IBS Digest, 2005). Modular coordination which was introduced in Malaysia since 1986 has not been implemented successfully in the construction industry. The main reasons limiting the usage of MC in the construction industry is lack of knowledge in MC concept and proper planning which requires precision dimensioning.

The proper characteristics of Modular Coordination are (Thanoon et al. 2003): The module is small in terms of odd size which provides design flexibility, and large enough to promote simplification in the variation in size of the components. It provides industry friendly features for manufacturing but also for requirements of transportation and assembly.

The reason for implementing modular coordination is to reduce wastages in production, installation process, improve quality in productivity and open system is encouraged. With the approach of Open System, building components could combine in a variety of individual building projects while ensuring architectural freedom in their designs. MC is an important factor in application of prefabricated system with the standardization of building components and production time which the installation of building components will be reduced, this achieving a repeatability and able to construct building in a lower cost.

2.7 Perception on prefabrication as an alternative method for construction

Given that construction clients bring their idea of a building to construction professionals with a clear definition of its purpose (Schexnayder & Mayo, 2004), they also have their expectations and specific requirements that have to be met regardless of the complexity and nature of construction sites. Consequently, the construction project team meets to prepare a suitable package of strategies to satisfy these requirements. This package may involve the preparation of feasibility studies, drawings and planning, contract and tender documents including the selection of a suitable construction method. These activities were governed by the project and client requirements, where time, cost, quality, value, trust and security were mostly considered (Smallwood, 2000).

Cost, time and quality have been the priority of construction clients for many previous decades (Smallwood. 1999; Musonda & Haupt, 2008). Bikitsha and Ndihokubwayo (2009) found that construction clients were still influenced by time, cost and quality when selecting prefabrication as an alternative construction method. However, Pasquire and Gibb (2002) indicated that clients resisted the use of prefabrication and pre-assembly since they were unfamiliar with the benefits associated with off-site manufacturing. Abdallah (2007) compared prefabrication and in-situ construction methods and found that the prefabricated concrete structure was cheaper. Unfortunately, there is little willingness to change from in-situ construction to off-site manufacturing in the form of prefabrication and pre-assembly in the construction industry (Gibb, 2001).

The experience of clients in the construction industry contributes to resistance to prefabrication and pre-assembly. For example, inexperienced clients relied on recommendations of consultants to take most decisions in a project, unlike experienced clients who knew what construction was all about. The resistance of inexperienced

construction clients may be attributed to designers not proposing off-site manufacturing processes in their designs. Gibb (2001) argued that these advisors remained the main barrier to further implementation of prefabrication, even though clients had the last say. Experienced construction clients were familiar with construction methods and therefore made more decisions. Although the designer might advise on particular matters, Bikitsha and Ndihokubwayo (2009) in their study found that designers rarely proposed the use of prefabrication as alternative construction methods. The primary drivers and motivators for or barriers to the adoption of manufacturing include

- Clients and the project team;
- Procurement methods and supply chain relationships;
- Formal/contractual requirements;
- Legislation;
- Changing construction to a manufacturing process;
- Whole life costing,
- Sustainability and waste reduction;
- People issues, skills and training;
- New materials and technologies;
- Information and communications technology;
- Pre-assembly; and
- The measurement of success (Gibb, 2001).

Glass and Pepper (2006) emphasized that client resistance to the use of prefabrication could be attributed to the following initial cost;

- Inhibition of design creativity (Pasquire & Connolly, 2002);
- Lack of understanding the product by the SMME's (Gibb,2001); and
- Client requirements.

Although clients might reject the use of prefabrication due to negative perceptions about its initial cost implication, the reduction of labour, waste and many construction site operation related cost would enhance profitability in a construction project. Unfortunately, in developing countries like Ghana, the in-situ construction method was regularly a preferred method for project construction. It was possible that the resistance to the use of prefabrication as a construction method might be caused by its perceived reduction of labour since many developing countries have high rates of unemployment.

2.8 Knowledge level on the Adoption of Offsite Construction

In the construction industry's quest to address problems associated with late delivery of projects, cost overruns, quality and general management of the facility throughout its lifecycle, have led to the development of offsite construction. According to Ibrahim and Bishir (2012), construction industries awareness on offsite construction is low. Ibrahim and Bishir indicated there is no best ways to communicate all information required by all the different stakeholders in discharging their professional duties with on offsite construction with much ease and high accuracy.

According to American Institute of Architects (2007), low level of knowledge has caused decreasing in prefabrication construction technologies in many developing countries, that is, the design, fabrication information, erection instructions, and project management logistics. Chewlos, Benbasat, and Albert (2001) on the other hand identified construction companies not mandating the use of off-site construction due the generally low level of awareness on its application and lack of knowledge on use, the general conception that the current technology in use is enough and the lack of inter-agency collaboration for the adoption and use of offsite construction as the factors

militating against late delivery of projects and cost overruns. Other identified factors include: lack of Government support for the adoption of offsite construction, high cost of implementation, concerns about its complexity, lack of educational facilities to support its use and lack of laws and policies mandating the application of offsite construction.

Furthermore, Andy et al. (2011) in comparing the implementation of offsite construction in some countries including Finland, Denmark, Norway, Japan, USA, Singapore, UK and other African countries observed that offsite construction is regarded as the driving force towards higher utilization in those countries. Andy et al. noted that the importation of knowledge helps in the adoption of offsite construction in such countries. Also, Andy et al. suggested that the developing countries have failed to employ knowledge on offsite construction.

Situations to this scenario, Goss (2006) noted that the implementation of offsite construction in Finland, Denmark, and Norway and to certain extent in Singapore were the support of the government. He further argued that if the government's support for off-site implementation in a country is not strong then market forces could be dominant on off-site implementation. However, this scenario could result in uncertain outcomes. Even if the market conditions depict a booming economy especially in the building sector, there would be non-uniformities in the nationwide implementation of off-site as each market stakeholder would implement its own off-site system. Also, Ibrahim and Bishir (2012) suggests; that the Federal Government through the legislative arm should enact a law, making the application of off-site construction in construction projects a necessity, construction companies should embark on training and retraining of their staff and engineers abroad so that skills and construction methods like can be acquired, construction companies and relevant government agencies should procure all necessary

equipment for off-site construction and there should be increased research and development in evolving construction methods to promote the adoption of off-site construction.

2.9 Benefits of Offsite Construction over Mass Construction

Off-site construction can be used as a means to help reduce many of the forms of waste (Osmani et al. 2008). Prefabrication, if efficiently implemented, can help lower project costs, shorten project schedules, improve quality of work, assist in more efficient use of labor and improves safety (The Modular Building Institute 2009). These positive effects of construction all help alleviate construction waste and help make construction sites more sustainable. Along with reducing construction waste, prefabrication increases recycling and allows for the selection of sustainable materials (McGraw-Hill, 2011). This means financial, time, and material waste can all be reduced significantly by using the offsite approach, prefabrication, as a construction method.

Many researchers have outlined the numerous benefits of offsite construction method, and hence its comparative advantage over the conventional site built method of construction. Almost all sources reviewed assert more or less similar advantages and barriers (Bagenholm et al, 2001; Burwood et al, 2005; FMB, 2004; Goss, 2006; Harris, 2006; Pan et al, 2006; Post, 2003; National Audit Office, 2005).

2.9.1 Cost Benefits of Offsite Construction

Usage of prefabricated components result in cost savings due to a greater productivity and less wastage of materials during the production of the building components offsite and deliver to site for assembling (Bing et al, 2001). Besides, it reduces cost in site supervision which most of the output are similar, skilled labour

required on-site for installation, wastage of materials, formworks, scaffolding, and etc. The usage of system formwork made up of aluminum/steel, scaffolding and etc provide a considerable cost savings (Bing et al, 2001).

While economic justification is often dependent on high volume and repetition (Davies, 2005; Fawcett & Allison, 2005; Lessing, 2006), the potential for offsite construction methods to reduce costs and cost uncertainty may be a clear driver for uptake (Nadim & Goulding, 2011). The repeated use of moulds through standardization reduces formwork materials, preliminaries, site storage and onsite facilities, leading to costs cuts. Preliminaries in construction provide a description of a project that allows the contractor to assess costs which, whilst they do not form a part of any of the package of works required by the contract, are required by the method and circumstances of the work. Harris (2006) describes preliminaries as "the cost of administering a project and providing general plant, site staff, facilities, and site based services and other items not included in the rates". Costs emanating from the provision of shuttering and scaffolding are saved as these are not necessary in the prefabrication construction process.

According to Harris (2006), offsite construction saves a lot of money on the construction project. By using standard patterns, the building materials are saved at the manufacturing factories. This helps reduce the waste in formwork and other materials that can occur during traditional building procedures. Savings is made as a result. Unlike site-built homes that are constructed one at a time and with no place to store excesses, modular manufacturers create multiple homes every month, and so are able to order items they need in bulk, reducing the cost per item (Lessing, 2006). Lessing mentioned that some manufacturers go the extent of getting a deal to get a set of discount on items produced by the company. This may mean that a more premium brand will be available at reduced prices.

Traditional building methods utilising large numbers of sub-teams and individual contractors operating onsite, do not promote efficiency in terms of process, nor do they facilitate accumulation of lessons learnt within the business. Prefabrication on the other hand has the potential to centralize repeatable processes that accumulate knowledge to improve efficiency and quality, and ensuring the on-going success of the house construction industry (Halman, Voordijk, Reymen, 2008). Increases in labour efficiency and associated decreases in onsite time have been frequently raised as benefits of offsite construction. In inclusion are the greater quality and higher levels of precision allowed with factory built or automation housing (Bildsten, 2011; Elnaas et al., 2009; Gibb & Isack, 2003; Lu, 2009). With the current state of skilled labour shortage, factory built is the perfect alternative means of production. Since the factory environment allows better safety than the construction site, there is increased job safety and corresponding lower insurance premiums (Jaillon & Poon, 2010).

2.9.2 Time Benefits of Offsite Construction

Delay is one of the biggest problems often experienced on construction project sites. Delays are insidious often resulting in time overrun, cost overrun disputes, litigation, and complete abandonment of projects (Sambasivan & Soon, 2007; Aibinu & Jagboro, 2002). Many projects are of such nature that the client will suffer hardship, expenses, or loss of revenue if the work is delayed beyond the time specified in the contract (Clough, 1986). Delays in the construction industry is a global phenomenon, and are attributable to various factors and causes. The problem of delays in construction is one that has attracted the attention of many researchers and practitioners (Odeyinka & Yusif,1997; Chan & Kamaraswamy, 1997; Mansfield et al, 1994; Odeh & Battaineh, 2002; Battaineh, 1999; Momani, 2000; Mohammed & Isah, 2012; Divakor &

Subramanian, 2009; Toor & Ogunlana, 2008)- partly due to its dire consequences on projects.

Usage of prefabricated components reduced the construction duration in which most of the products and components are completed offsite in factory before deliver to site. Besides, it can reduce the onsite labour works duration of construction work. Prefabricated components for on-site construction and off-site assembly can perform as parallel activities, which the operations are not affected by the weather condition. Prefabricated components are standardized and the installation procedures are simplified. Therefore, the usage of prefabricated components will result in reduce of construction time (Kim, 2009). Prefabricated system which gives faster construction time because of the construction element that manufactured in factory and foundation work can occur at site in the same time. This provides earlier occupation of the building, thus reducing interest payment or capital outlays (Peng, 1986).

In the construction industry, delay refers to the time overrun either beyond completion date specified in a contract or beyond the date that the parties agreed upon for delivery of a project (Assaf & Al-Hejji, 2006). According to Assaf and Al-Hejji (2006), 70 per cent of construction projects experienced time overrun and the average time overrun was between 10 to 30 per cent of the original duration. For the client, construction delay refers the loss of revenue, lack of productivity, dependency on existing facilities, lack of rentable facilities etc. For the contractor, construction delay refers to higher costs, longer work duration, increased labour cost, high material and equipment costs etc. Meeting construction project deadline indicates the work and construction efficiency.

Researchers (Chan & Kumaraswmy, 1997; Manfield, 2002; Odeyinka & Yusif,1997; Assaf, Alkhalil & Al-Hazmi, 1995) cited many noteworthy causes of

delays such as weather conditions, shortage of resources, shortage of material and equipment, financial difficulties faced by clients and contractors, poor contract management, design errors, poor skills etc. Construction delay is a major problem confronting the Ghana construction industry. It is endemic and its economic and social impact is often discussed (Fugar & Agyakwah-Baah, 2010). Delays in governmental projects are no exception. Very few government construction projects are completed on time or deadline specified in the contract. Many large projects have suffered delays, suspension and or abandonment. This includes the affordable housing projects across the country. Frimpong and Oluwoye (2003) investigated the significant factors causing delay and cost overruns of underground projects in Ghana and outlined four major categories as 1) project financing 2) economic conditions 3) natural conditions and 4) material supply.

According to Divakor and Subramanian (2009), the potential for prefabrication methods to reduce the overall time consumptions on construction projects, and meet timelines has been described as a hallmark. Toor and Ogunlana, 2008) on the other hand emphasized that a unique feature of prefab building method is the ability to simultaneously construct a building's floors, walls, ceilings, and roofs. During site-built construction, walls cannot be set until floors are in position, and ceiling and rafters cannot be added until walls are erected. Conversely, with prefabrication, walls, floors, ceilings and rafters are all brought together in the same factory to form a building. This process often allows modular construction times half of that of conventional, stick-built construction. Thus program savings due to the ability to progress work as a parallel operation in a factory and on a construction site is reaped.

Time savings also means cost savings. As this process contributes to a much shorter overall construction period, there is a corresponding reduction in labour,

financing and supervision costs, and earlier building occupancy (Divakor & Subramanian, 2009; Manfield, 2002; Toor & Ogunlana, 2008).

2.9.3 Quality Control Benefits of Offsite Construction

Several definitions of quality given by companies have been described as vague and general, rather than specific, and that words like "goodness", or "luxury", or "fitness for use" does not lend itself to measurable or controllable terms, and in order to have a more befitting definition (Adam, 1994) considered various definitions provided by several quality "expects" and came up with a consolidation. He however argued that quality should include the following aspects:

- Freedom from defects
- Meeting specifications and standards as set by the consumer, the industry, and the company
- Meeting consumer expectations and needs
- Exceeding consumer expectations and needs
- Affordability and competitive price.

Better performance and component fit between parts for prefabricated system, which the components required more accurate profile and dimension of components that manufacture in factory. Prefabricated components can easily be controlled and monitored in factory for critical factors such as temperature, stripping time, and etc. Quality is the main factors in prefabricated system, the components that are manufacture off-site are better in quality control. A Quality Assurance Department is to ensure that there is a complete quality procedure and maintained regularly will be well set-up by manufacturer to ensure strict compliance throughout the manufacturing processes (NSL Eastern Pretech, 2005). It is much easier to control the quality in the

factory compared with casting at site. Prefabrication produced higher quality components, attainable through specific selection and the use of advance technology with strict quality assurance control (Din, 1984).

Generally, the quality achievable with factory prefabrication is higher than can be achieved on site. Tolerances and workmanship is of higher quality and consistency to that achieved on site. Factories employ quality control and quality assurance programs that would be difficult to execute on site. In the factory, inspection and testing protocols promote superior quality of construction throughout each step of the assembly process. The National Audit Office (2005) argues that offsite construction method meets the three quality requirements of durability, whole life cost and performance. In researches conducted in India, Australia and UK respectively (Arif et al, 2012; Fussell et al., 2007; Gibb and Isack, 2003), it was realized that achieving greater quality was one of the major benefits of offsite construction and also one of the key drivers to its adoption in those countries. Quality can better be achieved within a factory and also products consistency can be better achieved while working in a controlled environment (Gibb & Isack, 2003). Evidence from Sweden has indicated a lower level of defect in industralised timber houses in comparison to site-built homes (Jonsson & Meiling, 2009). In India, for instance, prefabrication is synonymous with durability.

For quality control, traditional building techniques, quality manufacturing and third-party administered random inspections are combined with testing and certification services. This assures that permanent modular buildings are built in strict accordance with appropriate local, state and national regulations and codes. Due to the extra durability needed for travel, factory-built buildings are built better than conventional structures. As a result of meeting and exceeding site-built standards, modular

construction has the same life expectancy as traditional built buildings, and can, with proper maintenance, last indefinitely.

2.9.4 Waste Reduction benefits of Offsite Construction

Construction materials are a valuable resource, yet it is common place to see high levels of waste through damage on site, off-cuts, over-ordering and need for rework. Reducing, reusing and recycling waste can help to reduce cost on construction projects. It is believed that building material wastage on construction sites account for cost overruns and any improvement in building materials management on construction sites has the potential to enhance the construction industry's performance with cost-saving benefits (Ameh & Itado, 2013). Teo, Abdelnasar and Abdul (2009) observed that extra construction materials are usually purchased due to material wastage during construction.

Prefabricated components reduce the wastage of construction material and this will provide a safe working platform for the workers in construction site due to the reduction of construction debris, site worker and materials. Fewer mistakes, misalignments and deviations will be made by applying prefabricated system in construction industry, this will result in less waste, reduces costs on materials, handling, dumpster and etc. With the reduction of construction material wastage, this will lead to the decrease in overall construction cost. According to Best and De Valence (2002), off-site construction components offer minimal wastage, because the components such as precast columns were being prefabricated off-site. The entire component has been manufactured on the required sizes. Besides, the repetitive use of the construction material, for example, steel system formwork provides considerable cost savings (Bing et al, 2001; Thanoon et al, 2003). Higher degree of precision and accuracy in the

production of prefabricated components with the utilization of machine will lead to reduction of material wastage (CIDB, 2003).

Previous studies from various countries have confirmed that waste represent relatively larger percentage of production cost. For example, Skoyles in Tam et al., (2007) in a UK study reported an additional cost of 15 per cent to construction project cost overruns as a result of material wastage is observed, as cited in Ameh and Itado, (2013). A study conducted by the Hong Kong polytechnic and the Hong Kong construction association (1993) put material waste contribution to cost overruns at 11%. Similar study in the Netherlands concluded that material wastage accounted for between 20-30 per cent of project cost overrun (Bossink & Bounwers, 1996). Hore, Kehoe, McMillan and Penton (1997) as cited in Ajayi, Koleoso, Sonyingbe and Oladiran (2008) opined that in every 100 houses built; there is enough waste material to build another 10 houses. In another study in Hong Kong, Chu (2004) identified the contribution of the following materials waste to the total project cost: concrete 4%, blockwork 10%, waste from screeding and plastering 15%, packaging 5% and that of formwork is based on the number of times it is reused. There is a growing consensus within the build environment in Nigeria that building materials account for over 50 per cent of the total cost of a building project (Akinkurolere & Franklin, 2005) as cited in Ameh and Itodo (2013). Ayarkwa and Adinyira (nd) reports of a wide variation in wastage rates of between 5-27 per cent of total materials purchased for construction projects in Ghana, as cited in Agyekum, Ayarkwa and Adinyira (2012).

There are different views held by researchers as to what constitutes construction waste. Formoso, Isatto and Hirota (1999) defines construction waste as any inefficiency that results in the use of equipments, labour, materials, or capital in large quantities other than those considered in the production of a building. According to Shen et al.

(2002), building material wastage is defined as the difference between the value of the materials delivered and accepted on site and those properly used as specified and accurately measured in the work, after deducting the cost savings of substituted materials transferred elsewhere, in which unnecessary cost and time may be incurred by material wastage.

Keal (2007) further stressed that any substance or object that are discarded, intend to be discarded, or are required to be discarded is waste and such is subject to a number of regulatory requirement. Dania et al (2007) asserted that construction and demolition waste is a complex waste stream, made up of a wide variety of materials which are in the form of building debris, rubble, earth, concrete, steel, timber, and mixed site clearance materials, arising from various construction activities including land excavation or formation, civil and building construction site, clearance, demolition activities, roadwork, and building renovation. According to Formoso et al (2002) the concept of material wastage in lean production paradigm is seen as resources that do not add value to the final product.

Waste management, thus, have become an important issue in the construction industry. In traditional construction, the majority of waste is generated from the concreting process and the related wet trades, which constitutes over 80% of construction waste. Concrete waste is generated mainly from both the direct works, steel from the cutting of reinforcement bars, surplus and spilled concrete, etc. rework, the need to replace, remove or extend work previously considered completed also results in construction waste. One way of reducing construction waste is by precasting or creating repeatable forms in the factory (Baldwin, 2009; Dainty & Brooke, 2004).

In recent years, construction waste reuse and recycle have been promoted in order to reduce waste and protect the environment. Waste management in construction

activities had been promoted for protecting the environment in line with the recognition that the waste from construction works contribute significantly to the polluted environment (Dainty & Brooke, 2004). The conventional construction method consisting of extensive cast-in-situ activities being widely used, is now been criticized. Huge quantities of unwanted but useful surplus materials are running out of space to dispose, thus conventional method is quite difficult and not effective to control wastage of building materials on construction site. For sustainable development and to conserve landfill capacity, there is an urgent need for the industry to adopt certain new construction methods or technologies, which can reduce waste effectively.

Goss (2005), for instance, observed that 11 per cent of primary materials is wasted on site, but was quick to add that that can be reduced to 1.8 per cent in factory. In agreement, AMA research report (2007) mentions that construction waste is substantially reduced from 10-15% in a traditional building to less than 5% in a factory environment. It is estimated, the report continues, that, modular construction can achieve the highest level of waste reduction relative to both traditional construction and any other modern construction techniques (AMA Report, 2007). Thus Prefabrication is regarded as an effective and efficient procedure for waste minimization (Dainty & Brooke, 2004). Consequently, prefabrication is being widely used in European countries, Japan and Singapore.

2.9.5 Safety benefits of Offsite Construction

The construction industry has one of the worst occupational safety and health records. Persistent endeavours have been made to promote construction safety, but fatalities still plaque the industry. Recently there had been an emergency of variety of

construction safety research focusing on topics such as safety competency, accident statistics, design for safety, and safety culture.

The first written record concerning safety management in the construction domain was in 2200BC (Perezgonzalez, 2005), when King Hammurabi of Babylon passed a law stipulating penalties for houses falling down and killing their inhabitants (Clarke et al, 1999). In contrast to other industries with high safety risks, the construction industry has the characteristic of small scale of accidents with high frequency, and diverse hazard sources. The trend of construction accidents has decreased steadily, thanks to the continuous efforts from researchers and practitioners (Huang & Hinze, 2006; Hallowell, 2012). However, much can be done about construction safety, because the construction industry is still regarded as one of the most unsafe industries at present (Perttula et al, 2006; Pinto et al, 2011). Construction has about 5% of US workers, but 18% of the fatalities – the largest number of fatalities reported for any industry sector (Bureau of Labour Statistics, 2009). Transferring much of the construction program from an open site to a controlled factory environment reduces the potential for site-based accidents and ill health

Offsite construction method offers an opportunity for greater workplace health and safety outcomes by reducing exposure to heights and weather and hazardous tasks such as cutting (Luo, Riley & Horman, 2005). Safety on site and in the factory is greatly improved and it is estimated that reportable accidents are reduced by over 80 per cent relative to site intensive construction (Lawson, 2011). Theft is also greatly reduced as most finishes and expensive exterior elements are set in the factory and tied to the module.

2.9.6 Higher Productivity

Prefabricated components are more productive compare with the conventional construction method. The components are assembly on-site which result in better productivity. In addition, it is also convenience for site management and site inspection for the prefabricated method which the components are installed on the construction site. Hence, it reduces in construction time as well as the wastage of materials (Phillipson, Scotland, & Lane, 2001). Local construction industry is driven towards the adoption of an integrated construction industry to produce and utilize prefabricated components of the building at the work sites. This will help to enhance the efficiency of construction process, allowing a higher productivity, time, quality and cost efficiency (CIDB, 2004).

2.10 Challenges of Offsite Construction

Other than the advantages that come with the application of offsite construction method, its disadvantages have equally and aptly been discussed. Hindrances to the application of prefabrication have also been discussed (Ho, 2001; Ting, 1997)

- A mistake in the mass production of prefabricated elements ahead of the measurable site work is a serious risk
- Higher degree of accuracy than is normally associated with onsite building works must be ensured. If this is not observed, difficulty in connecting precast units so as to produce same effect as monolithic will be compromised.
- Handling, transportation, crane age and erection costs of prefabrication having being weighed against in-situ alternatives have been identified to add on cost.
- The difficulties of transporting factory completed building to the site is sometimes cumbersome especially where traffic is immense. Handling and

transportation may also cause breakages of members during the transit and extra provision is to be made.

- There is a great amount of trust given to the manufacturer to produce precisely what is needed. One single error can eventually put the entire building in danger. For instance, they are to be exactly placed in position, otherwise the loads coming on them are likely to get changed and members may be affected (load distribution). The beams, columns and floor plans need to be perfectly aligned and constructed for stability. If a member should get disconnected, the possibility of entire destruction of the building is assured.
- Skilled labour and strict supervision are inevitable requirements to ensuring quality of working and product both at the factory and on site
- Quick production time does not, in any way, mean product instability, thus making prefabricated buildings more likely to collapse. However, workers constructing under an intense time limit in order to complete task quickly can lead to a higher potential of mistakes in bolting pieces together which will have serious consequences on the building.

Dainty and Brooke (2004) added that the use of prefabrication in buildings has the following shortcomings: possibility of damage during transportation - normally it requires lifting equipment, monotony of design unless there are variations in the prefabricated units, and over designs to take care of the loading conditions. The cost of the technologies and equipment is usually high at the beginning. The study by Dainty and Brooke (2004) further found out that large volumes are required in the long run as the production volume must exceed the critical volume and this is not always the case.

2.10.1 Customer Expectation

One particular barrier to adoption of prefabrication systems in housing is the perception that the public want traditional brick finished housing. Timber frame housing systems are usually finished with an outer cladding of brick, other innovative systems include those which have brick slips mechanically fixed to the outer surface of the wall in an attempt to mimic the traditional finish. The masonry industry is developing new factory prefabricated systems that can be delivered to site and which will allow a further route for delivering housing which maintains the traditional masonry appearance whilst being delivered through a prefabrication route.

2.10.2 Perceived Value

Mohammed and Isah (2012) suggested that resistance to prefabrication, particularly in the housing sector, is partly caused by the perception that property is an investment and prefabrication is not necessarily seen to be a good investment based on historical experience. As affirmed by Mohammed and Isah (2012), this needs to be considered carefully in the context of the economic aspects of sustainability. In a study by Chan and Kamaraswamy (1997), with perceived performance, the non-domestic client is much more likely to actively evaluate the through life performance of new buildings and have an understanding of the investment value of their developments. Chan and Kamaraswamy further indicated that with housing the effect of prefabrication on the true life environmental value of non-domestic buildings needs further consideration.

2.10.3 Industry Culture

One factor that is restraining the use of some forms of prefabrication in housing applications is the availability of plant for handling the larger prefabricated systems on

site. This is a problem specific to the house building sector as the use of appropriate plant is more widespread in the non-domestic market (Divakor & Subramanian, 2009). In Europe the use of cranes on even modest housing developments is well established and part of site culture. In other countries, lack of this provision makes the installation of panelling systems in housing developments more difficult. Some manufacturers provide cranes with their lorry delivery systems to enable the installation of the prefabricated components, however, where such systems require later adjustment there is a need for site based plant (Hallowell, 2012).

According to Battaineh (1999), construction industries are addressing this to some extent by modifying existing plant (usually excavators) so that prefabricated components can be slung under digger arms for movement around site. A change in site culture and industry use of plant would enable better ability for developments to use panel prefabrication systems. As indicated by Odeh and Battaineh (2002), the attitude of the construction industry has suggested that the industry is reluctant to try new methods and believes that offsite manufacture cost more than traditional methods of construction. Despite evidence to the contrary, this attitude still found in some parts of the industry is difficult to counter.

2.10.4 Product Awareness

The procurement of prefabricated components for a project is often a matter of designers being aware of the availability of a given system (Odeyinka & Yusif, 1997). Designers are unlikely to use a system for which they do not appreciate the benefits for the construction, or for which they do not understand how the system impacts on the design process. Manufacturers are producing innovative prefabricated products, they consider that it is the designers that are conservative and reluctant to try out new systems (Mansfield et al., 1994).

According to Toor and Ogunlana (2008), the challenges of prefabrication are often based on a perception of difficulties that have arisen from past experience, rather than from actual technical constraints. For systems correctly specified and used none of the challenges should exist, the construction industry needs to be educated of the merits and benefits of using prefabrication.

Prefabrication is a well-established procurement option in the UK. There are, however, a range of barriers to its full potential use which stem from past experience of prefabrication which have left it labelled as a poor quality product with associated social stigma. Prefabrication within the housing market is most affected by this perception, yet offers considerable opportunity for those willing to use it properly (Momani, 2000). Prefabrication has the capability to make a difference within the Ghanaian construction industry in economic, social and environmental terms. It is important that how much of a potential difference it can make is established so that appropriate development can be implemented.

2.11 Conceptual Framework

Bradley (2008) defines conceptual framework as a visual or written product that explain either graphically or in a narrative, the main things to be studied, the key factors, concepts or variables and the presumed relationship among them. It is therefore a model used in research to outline possible courses of action or to present a preferred approach to an idea or thought. A conceptual framework is very important in any research study being undertaken. It shows the relationship between variables. The variables are the stages of prefabrication, readiness of prefabrication, challenges of prefabrication, knowledge level of contractors on prefabrication. It further shows the benefits of prefabrication after effective adoption of off-site construction. Figure 2.1 depicts the conceptual basis of the study.

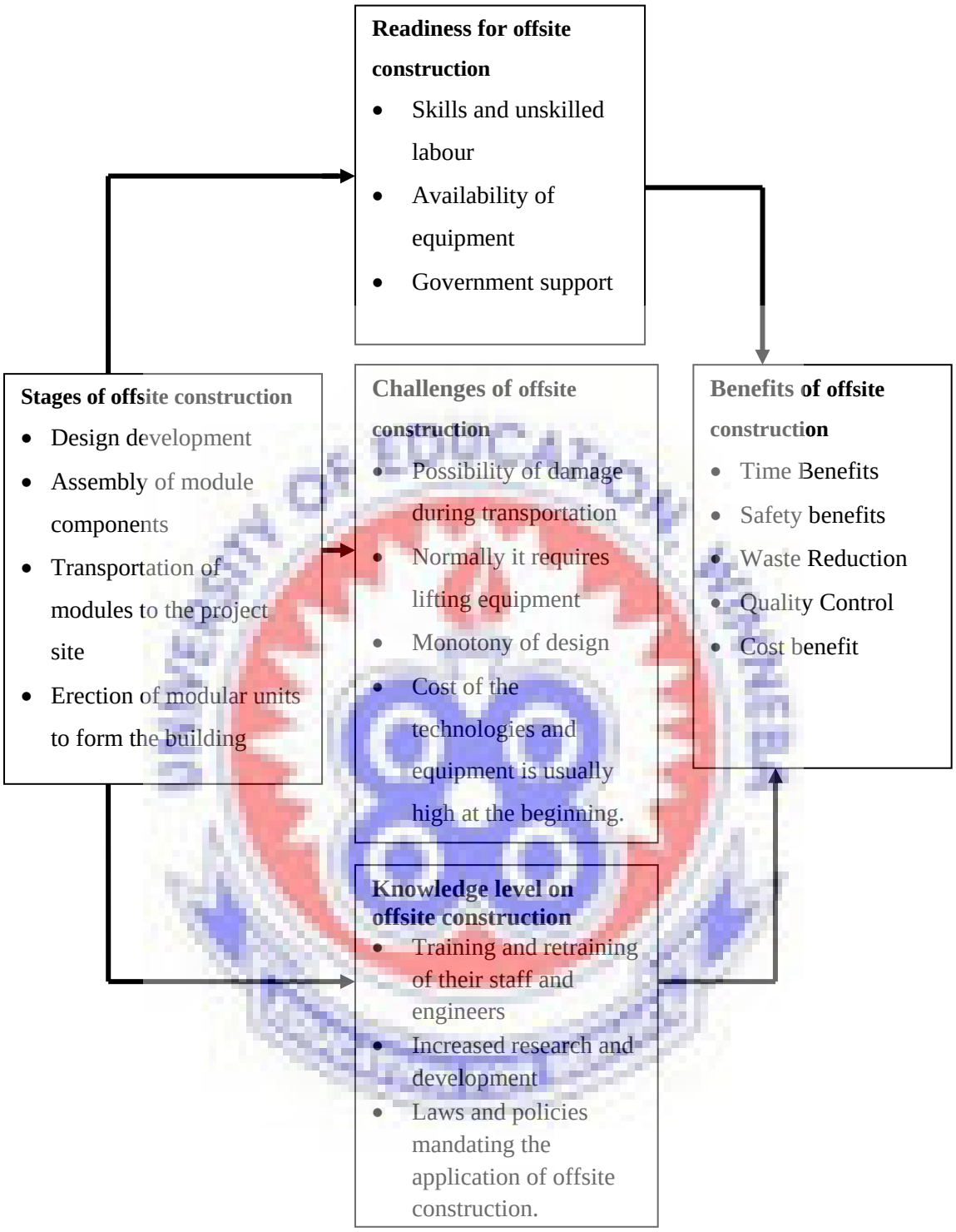

Figure 2. 1: Conceptual Framework of Off-site construction
Source: Researcher Field Construct, 2017

Offsite construction, if efficiently implemented, can help lower project costs, shorten project schedules, improve quality of work, assist in more efficient use of labor and improves safety (The Modular Building Institute, 2009). Based on the literature review the four main stages of prefabrication were identified as follows:

- Design development
- Assembly of module components
- Transportation of modules to the project site
- Erection of modular units to form the building

The framework depicted readiness of prefabrication, knowledge of contractors and challenges of prefabrication as the influence of non-use of off-site construction. The readiness of prefabrication is an important and integral part of non-use of off-site construction. This involves the skills and unskilled labour available, government support and availability of equipment for erecting off-site construction.

Knowledge of contractors on prefabrication variables includes training and retraining of staff and engineers, increasing research and development, and laws and policies mandating the application of offsite construction. According to Doloi (2007), lack of knowledge and experience has caused decreasing in prefabrication construction technologies in many developing countries. As indicated by Gibb and Isack (2003), off-site construction itself suffers from supply shortages. Lack of availability is the reason why building companies in the developing countries did not use pre-assembly methods of off-site construction.

The challenges of prefabrication as the influence of non-use of off-site construction variables are the possibility of damage during transportation, requiring of lifting equipment, the monotony of design and high cost of the technologies and equipment at the beginning. According to Dainty and Brooke (2004) the use of prefabrication in buildings hast its shortcoming. The hindrances of off-site construction restrain the use of some forms of prefabrication in housing applications.

In general, proper utilization of off-site construction help alleviate construction waste and help make construction sites more sustainable. Along with reducing

construction waste, off-site construction ensures safety, reduces time, quality and also increases recycling and allows for the selection of sustainable materials (McGraw-Hill, 2011). This means financial, time, and material waste can all be reduced significantly by using the offsite approach, prefabrication, as a construction method.

2.12 Conclusion

The chapter provides an overview of literature relative to the non-use of offsite construction methods in Ghana. The literature argues that the adoption of offsite construction as an alternative construction method would result in less hazards and less risks than where construction work is traditionally done on sites. A traditional construction method presents major threats to health and safety of workers. The traditional construction method health hazards were material handling hazards, ergonomic and musculoskeletal disorders hazards. The concept of Off-Site construction, perception on prefabrication as an alternative method for construction, knowledge level on the adoption of offsite construction, and challenges of offsite construction were reviewed.

The use of prefabrication and preassembly on site could lead to potential reduction of cost in the long run, health and safety hazards since most of construction works would be carried out under factory conditions off site. The chapter also reviewed the benefits of offsite construction as an alternative construction method.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter gives in-depth details of the method and procedure of the study. A list of offsite factors as well as problems facing the Ghanaian construction industry and some factors of construction failures were collated from literature review, internet search, preliminary survey and developed into questions for the main survey. A review of literature also indicated the importance of offsite production and construction. In order to establish the authenticity or otherwise of issues emanating from literature, the survey sought the views of respondents on the industry's inability to adopt offsite construction methods. To determine the perception of engineers on the use of offsite construction methods in Ghana, the most significant among the data collection was use of interview as the views of respondents can be best gathered through this process. Data gathering was limited to Kumasi, where major construction activities were centered.

3.2 Research Design

A research design is a collection of guides or rules or data collection (Adams & Schvaneveldt, 1985). This pacts with the structure for data collection and analysis; the structure that influences the technique for collection and analysis of data and provides the connection between empirical data as well as its conclusions in a logical sequence to the initial research question of the study (Yin, 2003; Bryman, 2004).

The researcher found it appropriate to use survey in order to get a detailed description of the study. The descriptive research design was used for this study because in the words of Creswell (2005), it is used to answer descriptive research questions such as 'what is happening?', 'how is something happening?' and 'why is something happening?' As a widely accepted method in educational research, the

descriptive method of research is a fact-finding study that involves adequate and accurate interpretation of findings.

3.3 Population

A research population can be defined as the totality of a well-defined collection of individuals or objects that have a common, binding characteristics or traits (Polit & Hungler, 1993). The population comprised all engineers of registered construction firms undertaking active projects in the Kumasi Metropolis. There were thirteen (12) of such companies as at the time of conduct of this work.

3.4 Sample Size and Sampling Techniques

Creswell (2005) stated that, sample refers to a sub-group of target population that the researcher plans to study for the purpose of making generalization about the target population. Sample as a small group of larger and identifiable groups, Avoke (2005) continued that, samples usually reflect subset of the entire population of interest to the researcher.

In determining the sample size, the researcher adopted purposive sampling technique to select 12 engineers of registered construction firms that were undertaking active projects in the Kumasi Metropolis. This technique was adopted based on the researcher's judgment in respect of the respondents' competency to provide detail and appropriate responses to the research instruments. Purposive sampling is used in qualitative research to focus on the perspectives of those who are known to experience the phenomenon of interest.

3.5 Data Collection Protocol and Instrument

Interviews provide researchers with rich and detailed qualitative data for understanding participants' experiences, how they describe those experiences, and the meaning they make of those experiences (Rubin & Rubin, 2012). The interview protocol framework is comprised of 4 phases, thus:

1. Ensuring interview questions align with research questions
2. Constructing an inquiry-based conversation
3. Receiving feedback on interview protocols
4. Piloting the interview protocol

These phases culminate into a systematic framework for developing a well-vetted interview protocol that can help the researcher obtain robust and detailed interview data necessary to address research questions (Castillo-Montoya, 2016). Jones et al (2014) state that each phase helps the researcher take one step further toward developing a research instrument appropriate for their participants and congruent with the aims of the research.

A purposive sampling method was used in this qualitative research. Data was collected through semi-structured interviews conducted. The questions were prepared in accordance with the guidelines suggested in the relevant literature. Before using it in the study, the questions were reviewed to determine legibility, clarity and consistency (Castillo-Montoya, (2016); Merriam, (2009)). The final version of the form was a result of the criticisms and suggestions made during the review process.

The interview consisted of 4 sections with questions and sub-questions soliciting engineers' perspective on the use of offsite construction methods in Ghana. Section "A" contains the socio-demographic characteristics of the respondents (i.e sex, education level, etc.). Section "B" reveals the knowledge level of the engineers on off-

site construction. Section "C" presents the readiness of the contractors on off-site construction. Section "D" gives the cost benefit analysis of employing off-site construction method.

3.6 Data Collection Procedure

The interview was conducted at the beginning of April, 2017. The researcher interviewed the engineers personally and the interviews were audio-recorded. It took three weeks (21 days) to complete the interviews. Before the interviews began, permission was obtained from the engineers, with further arrangements and bookings all done to ensure an effective and successful exercise. The interviews were conducted mainly in their offices. To eliminate biases and influences, the interview protocol was followed. Where responses triggered follow-up question(s), care was taken to be as neutral as possible in asking the questions. Individual interview sessions lasted between 30 to 40 minutes. The audio recordings were diligently transcribed afterwards.

3.7 Data Analysis

Analyzing data in a qualitative study essentially involves synthesizing the information obtained from various sources such as observation, interviews and document analysis (Patton, 1990) into a coherent description of what is observed and discovered (Katlu & Korkmaz, 2014). Qualitative analysis involves obtaining information about phenomenon being studied and establishing patterns and trends from the information gathered (Best & Kahn, 2006). This also involves giving meaning to the mass information collected by organizing the data and creating categories and themes. In this study, excerpts were used to give representative information required. First, the audio recordings of the interview were transcribed. This was done by listening

to each tape repeatedly then carefully writing down, as much as possible, the exact words of the interviewee. Second, the common answers were identified, then data grouped for effective management and comparison. The data was then thematically analysed question by question and categorized (Yildirim & Simsek, 2008).

CHAPTER FOUR

RESULTS OF THE STUDY

4.1 Introduction

The chapter presents results emanating from the study. The study focused on exploring the non-use of off-site construction method in Ghana. The data was gathered through structured interviews with construction professionals. Results were obtained and interpreted accordingly.

4.2 Analysis of Qualitative Results

Structured interviews were conducted with twelve (12) engineers of registered construction firms undertaking active projects in the Kumasi Metropolis. This study examined construction professional knowledge on off-site construction, the readiness of Ghanaian construction industry to use off-site construction method and the cost benefits for the use of off-site construction over the traditional in-situ method in the Ghanaian context. The interviews were conducted face-to-face and responses were recorded and later transcribed. For the purpose of anonymity the respondents were given pennames, i.e. ENG 1 – ENG 12.

4.3 Background Information of Respondents

The interviewees represented construction companies undertaking works in Kumasi Metropolis. The years of experience of the various professionals ranged from 1 year and above. One out of the 12 construction professionals interviewed, representing 8.3% has been in the construction industry for 0-5years, whilst 2, representing 16.7% had entered the industry between 6-10years. In addition, one of the

respondents constituting 8.3% had gained over 11-15 years working experience in the construction industry. The results further indicated that 5 respondents representing 41.7% have had 16-20 years of work experience, making them knowledgeable and qualified enough as respondents for the study. Moreover, 3 respondents constituting 25.0% have worked for more than 20years. These experienced respondents have managerial responsibilities in their respective organizations, as only 2 respondents forming 16.7% of the 12 respondents stated they were not part of the project management team.

The educational level of the engineers of registered construction firms undertaking active projects in the Kumasi Metropolis was ascertained. The results show that all the engineers have tertiary educational background. According to Benson, Finegold and Mohrman (2004), the educational level of employees improves the efficiency and the technological way of managing labourers. Statistically, the study shows 6 (50.0%) of the selected engineers were graduates, 4 (33.3%) were post graduates, while 2 (16.7%) held professional qualifications. This implies that with the knowledge and skills gained through formal education, they might heard about new technologies and systems of building by the making of parts in an offsite workshop or factory prior to the installation at the site. They are therefore in good standing to argue professionally on the issue been considered in the study. Figure 4.1 and Figure 4.2 show the gender and age of the respondents respectively.

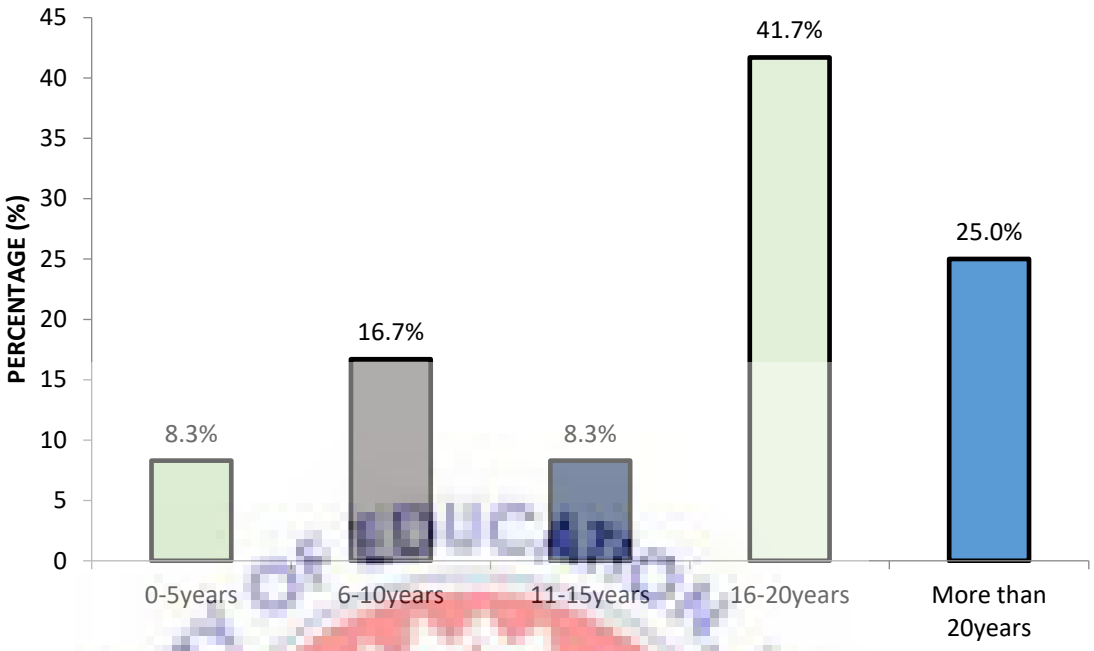

Figure 4. 1: Working experience of respondents

Source: Field Survey, 2017

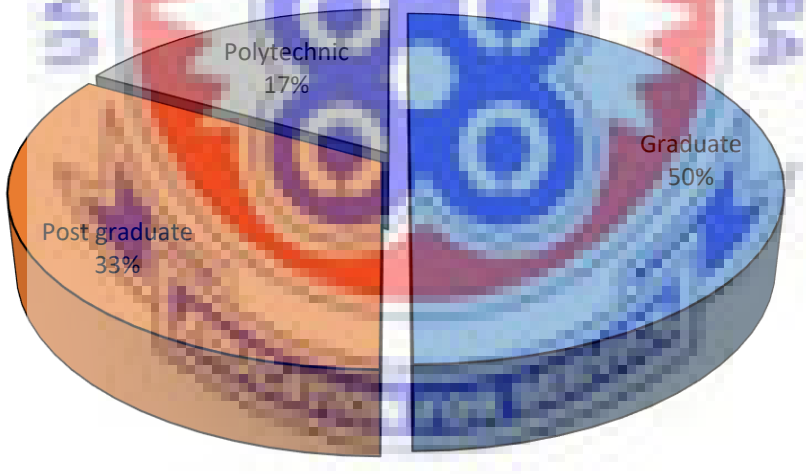

Figure 4. 2: Educational Background of the respondents

Source: Field Survey, 2017

4.4 Knowledge level of construction professional on off-site construction

The knowledge level of construction professionals has caused decreasing in prefabrication construction technologies in many developing countries, that is, the design, fabrication information, erection instructions, and project management

logistics. In determining the knowledge level of the engineers on off-site construction in Kumasi Metropolis, the view of the respondents on off-site construction, awareness on building units are/can be made offsite, awareness of any benefits associated with off-site construction and training received on offsite construction were sought.

4.4.1 View of respondents on off-site construction

This question was posed to ascertain the construction professional's understanding on off-site construction. On this issue, majority of the respondents affirmed that off-site is the assembly of buildings or parts of buildings ahead of time. They further indicated that off-site construction plays an important role in the modern world construction today, it refers to the making of parts in an offsite workshop or factory prior to the installation at the site. The smaller section could not explain vividly what off-site construction is.

Some of the noticeable views express by the respondents are:

> *"It is where building units are made in factory and assembled. Off-site construction plays an important role in the modern world construction today" (ENG 2, 2017).*
>
> *"……Off-site construction refers to the making of parts in an offsite workshop or factory prior to the installation at the site. The primary purpose of off-site construction is to produce building components in an efficient work environment with accesses to specialized skills and equipment in order to reduce cost and time expenditures on the site while enhancing quality and consistency……"* (ENG 1, 3, 2017).

"……In prefabrication construction, the establishments are developed thusly, while segments of dividers, floors and rooftop are assembled in a processing factory, transported to the site and lifted into spot by a crane to join together……" (ENG 4, 2017).

"…….offsite construction method is the process of building parts outside the site where the project is taking place. The prefabrication technologies try to reduce costs and time……with prefabrication method designers can assembles their favorite structures in a short period of time……"(ENG, 7, 2017).

"…….traditional construction methods require the overall construction work to be carried out on site as opposed to prefabrication. Prefabrication is where sub- elements are constructed remotely then transferred to and installed on site……" (ENG, 8, 9, 2017).

"……offsite construction is about constructing building components in a factory before being shipped to a building site in pieces, where they're then assembled on-site in a matter of days…." (ENG 10, 2017).

"……I know prefabrication is where components are built off site in controlled environments. The *prefabricated construction is major components of the developed countries construction and almost all building construction in Europe utilizes prefabricated materials but in developing countries like Ghana are in progress…." (ENG 12, 2017).*

"……am not familiar with this method. This country has different social and economic systems from modern countries. We use more actual personals for constructions rather than offsite methods……."(ENG 5, 6, 11, 2017).

4.4.2 Awareness on building units are/can be produced offsite

The respondents were asked whether they know the building units that can be produced in the factory to be assembled onsite. Majority of the respondents know that the entire building can even be made offsite. As a result of in-depth interviews, the following interviewee's profile emerged:

ENG 2 said:

"Factory-made building units such as door, roof and walls can be made in a shorter time for lower cost than a similar element fabricated by highly paid skilled labourers at a building site.

ENG 3 commented that:

"Factory production controls construction costs by economizing on time, wages, and materials. ……units may include: doors, stairs, window walls, wall panels, floor panels, roof trusses, room-sized components, and even entire buildings".

"…….doors, walls, floor panels, and roof are the building units can be produced in the factory……." (ENG 1, 7, 2017). "……The quality of factory produced building units have increased to the point that they may not be

distinguishable from traditionally built units to those that live in them…….(ENG 1, 2017).

"…..the building units usually come with doors, closets, and stairs – so there's little finishing work to be completed when the home is assembled……" (ENG, 8, 2017).

"…….The technique is used in building units like doors, walls, stairs, and even the whole buildings. Prefabricated can also be used for the exterior of large buildings……."(ENG 12, 2017).

"……am not aware of the specific building units that cannot be produced offsite….. I know the units are masterpieces that are also high-tech and hard-wearing - and the exterior at least can usually be installed on-site (ENG 5, 2017).

"……the entire building, I must say…. (ENG, 6, 2017).

"…….we have been in the industry for the past 4 years……We are an established construction company with an excellent track record for best customer satisfaction……..but the idea and choice of offsite construction has not come up….."(ENG 11, 2017).

4.4.3 Awareness of any benefits associated with off-site construction

Further to finding out the knowledge level of construction profession on off-site construction was on the awareness of any benefits associated with it. The respondents view that the benefits associated with off-site construction identified minimization on site operation (better supervision); reduction of overall construction costs; minimization of number of site personnel; shortening of construction time; increasing efficiency; and improving health and safety of workers as the benefit of applying off-site production in construction. Some section of the respondents requests for improving the awareness of offsite construction as they are not aware of the benefits associated with offsite construction method. The salient points expressed by the selected interviewees are:

ENG 3 commented:

> *"……..there is the need for specialised knowledge of artisans to aid in the adoption of off-site production and assembly which the local labour lacks. As most of the components are manufactured under factory conditions, work on site is reduced thereby leading to the need for fewer worker on-site……"*

ENG 2 affirmed:

> *……..there will be a reduction in construction hazards leading to improvement in the workers' site safety and health.*

> *"……..it would naturally require companies to look at reducing material and labour waste.....(ENG 4, 2017)"……by making material use more efficient, the impact on the earth's resources will be reduced. Construction sites*

do not make the best manufacturing sites, yet everything happening there is about production. Anything that can improve that production without just transferring the problems and waste should be recognized." (ENG, 7, 8, 2017).

"……..offsite construction typically brings manufacturing insight to the building process which identifies and eliminates wastage of material and labour. Offsite production will gain grounds due to its cost saving……."(*ENG* 1, 9, 2017).

As affirmed by *ENG* 12

"……..new technologies in building need high level of knowledge and experience and high quality of application on site, so offsite construction technologies are preferred in many developed countries not in Ghana……".

…….I know off-site construction is associated with many benefits ……..but there is a need to Increase the awareness on the use and benefit of off-site through increased research and development, increased government support and relevant professional bodies ensuring the training……..." (*ENG*, 5, 6, 11, 2017)

4.4.3 Training received on offsite construction

In response to whether the Ghanaian industry players have received any training on offsite construction processes and production, majority of the respondents indicated that they have not received any such training. ENG 12 confirmed that training on offsite construction is important, especially in era where technology is considered crucial in addressing the housing shortage in Ghana. The respondents indicated that there is the

need for construction professional to be educated and trained on offsite construction methods as a new technology model in building houses.

"……..I have not received any training on prefabrication……..the use of offsite technologies need high level of knowledge and experience and high quality of application on site, so the knowledge should be imported from the developed countries that have adopted it….." (ENG, 4, 2017).

"……..There has not been any training for construction professionals in the industry on the subject (ENG, 1, 2, 10, 2017). "……..offsite construction is a technology that will solve housing deficit in Ghana……(ENG, 10, 2017).

"……there has not been any seminar or training of on offsite construction for us……. Ghana as a country have fewer concerns in many important aspects of building construction, such as preciseness, on-site safety, energy saving and waste management during a construction. All these issues can be resolved by using offsite construction methods……" (ENG, 7, 2017).

"……..the subject isn't new. In fact, most of the things around were manufactured in factory…… I have attended workshops and seminar on the subject but personal though……" (ENG, 6, 2017).

"……..I know components are pre-assembled in a factory before the final product reaches the site. I have attended seminars and received some training on offsite construction of building units/components……." (ENG, 9, 2017).

As commented by ENG 3 and 11:

Offsite construction have been around for decades and construction professional are not prepared to acquire training on it……because clients are not aware or do not believe in the quality of buildings produced that way. Meanwhile prefabrication is incredibly waste-efficient as compared to the on-site building processes of today, which can exhaust more than 30% of building materials.

4.5 Readiness of Ghanaian construction industry to use off-site construction

When opinions were sought on the readiness of Ghanaian construction industry to use off-site construction, all the responses signified that the Ghanaian construction industry was not ready to employ off-site construction. The respondents revealed that they have not thought of adopting Off-Site Construction (OSC) method as part of their construction methods because of the low quality of available artisans, and unavailability of needed tools and equipment. They further mentioned that due to *inadequate capital backup and not able to set up their own factory and* negative image attached to off-site construction due to its past failures and unattractive architecture, and lack of knowledge in designing off-site construction components.

The respondents further reveal that the construction industries in the world today are undergoing changes from an industry which employs conventional method to a mechanized and systematic system which utilizes the latest technologies. Offsite construction technology is a new method in the construction industry. This is vital for the future growth of the industry, but the Ghanaian construction industry do not have the requisite skilled labour and the resources to undertake such technology.

According to ENG 2:

"……..The question as to whether the Ghanaian construction industry is ready for the adoption of offsite construction method currently is one that cannot be answered easily…….There are some problems facing the Ghanaian construction industry like low levels of industrialization 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…."

As affirmed by ENG 4:

With the ongoing construction trend in Ghana, the industry is not ready to use off-site construction as we are very still comfortable using labour intensive and low technology methods of construction. ……the high dependency on conventional building system and unskilled workers have contributed to non-readiness of Ghanaian construction industries to use off-site construction, although the off-site construction is efficient and reduce high wastage.

"……..for now, No. However, the contemporary architectural firms and design companies are now thinking what offsite consruction means for today's waste-conscious and energy-savvy homebuyers. Many are combining traditional modular concepts with a customized approach, allowing clients to select a basic design and alter it according to their tastes……." (ENG 1, 2017).

"……Although the Off-site construction has promised to solve and improve the current construction method, the method has been low in gaining popularity in Ghana, partly due to lack of awareness and coordination among the relevant parties in the country……" (ENG 5, 2017).

"……The readiness of Ghanaian construction industry to use off-site construction is low due to the low popularity of the usage of Off-site construction components……off-site construction is often misconceived by clients as a typical building should necessarily be 'block and mortar'…."(ENG, 3, 2017)

"……The implementation of Off-site construction system in local construction industry is very low and this raises issues in the readiness of the construction industry in Ghana in adopting the method……"(ENG *7, 2017).*

ENG 9 indicated that:

Fully off-site construction system requires high construction precision, and skilled workers which the current labour force lack ……..superior construction technology requires highly skilled workers. Besides, specialist skills such as system integrator or assemblers require intensive training which required more time and investment.

ENG 10 commented that:

Players in the industry lack the experience and technical knowledge in this new technology of assembling components that made in a factory before delivery to the construction site.

As per ENG 6:

> *Lack of knowledge in the design of off-site construction components discourages further the implementation of this system……..Knowledge in construction technology is equally important. Building projects constructed using this system without indepth knowledge will lead to many mistakes and the most common problems to be faced will be improper assembly of the components connections.*

ENG 11 said:

> *Ghanaian construction companies are not able to set up their own manufacturing plants due to inadequate capital backup. In this case, financial issue becomes the main reason for lower class contractors to move forward with the off-site construction……..for this company, we are not ready because off-site construction system is an unattractive choice due to wide swing of property demand, high interest rate and improper economic condition.*

4.6 Cost benefits of using off-site construction over the traditional method

Respondents were asked to do a cost analysis by comparing by comparing the cost benefits of the use of offsite construction methods over the tradition construction method. Generally, respondents agreed that the choice of offsite construction yielded much benefits in term of cost when factors such as waste management, labour on site, time expenditures, efficiency, and site safety were considered.

However so, since most of the off-site construction units and materials were imported, some respondents expressed mixed feelings and reactions, especially given the current rate of high uncertainties with respect to constant and persistent fall of the

local currency against the major trading currencies, it was anticipated that the cost of manufactured components/units could rise to surpass the cost of meter square of using the traditional construction method, within the coming days. This means that offsite production will be very cost effective when issues relating to high import duties and the depreciation of the cedi against the major currencies are given needed attention and addressed accordingly.

According to ENG 3:

"……..when you look at factors such as project completion time, labour, waste issues and safety among others, then it is true that the use of offsite construction methods is cost effective than the traditional construction method. ……. Offsite construction enhances mass production and duplication of components.

Presently, we are not implementing offsite construction fully. We only use prefabricated components and these components that we use are a bit cheaper comparatively. But this is seen when you buy many and in bulk (ENG 4, 6, 2017)

……..for instance, for a storey building with many floors (ENG 4, 2017).

We do not produce the prefab components that we use. We buy or import some. Prices on the international market have been stable for some time now, and that is good news to us in the industry but because of the cedi's persistent depreciation, costs keep increasing by the day. Thus, prefab components have become expensive (ENG 1, 7, 2017).

ENG 2 indicated that:

As I indicated earlier, you will have to establish a plant or factory, get the necessary equipment or machinery and the skilled personnel. These are prerequisite for the adoption and implementation of full offsite construction. So you see, it is capital intensive initially and not many of the companies can afford. This means that the use of offsite construction is not necessarily cheaper.

……..because we do not have all the necessary equipment and tools already in place, the practice of offsite construction cannot be cheaper……. (ENG 9, 5, 2017)

According to ENG 12:

Offsite construction methods have a number of advantages and these advantage ultimately lead to cost savings that in turn lead to increased profit. Ideally, this should be the case.

……..So if there is a system that can reduce material waste, mitigate delays in project timelines, use a few hands on site, enhance quality of product, reduce the risk and increase safety on site, then it is in to solve the challenges in the construction industry. At the end of it all, it will lead to increase in profit which is the aim of every establishment (ENG 8, 11, 2017)

ENG 10 said:

All things being equal, offsite construction is cost effective compared to the tradition method of construction currently practiced. There is cost savings on material use and reuse, few hands used cuts cost on labour, the possible elimination of time overruns also means cut on cost. I mean it is an advantage using offsite construction.

CHAPTER FIVE

DISCUSSION OF RESULTS

5.1 Introduction

This chapter discusses the major findings that emerged from the study. The discussions were carried out with the objective and research questions set out in chapter one as the basis. For in-depth understanding, the discussions on the findings from the current study were linked to the related literature. The discussions are structured into the knowledge level of construction professionals on Off-site construction, readiness of Ghanaian construction industry to use off-site construction and the cost benefits of using off-site construction over the traditional method

5.2 Knowledge level of construction professionals on Off-site Construction

The study revealed that walls, ceiling, roof, and windows are the building units that can be prefabricated as indicated by the respondents. The view of the respondents supports Toor and Ogunlana (2008) who emphasized that a unique feature of prefab building method is the ability to simultaneously construct a building's floors, walls, ceilings, and roofs. During site-built construction, walls cannot be set until floors are in position, and ceiling and rafters cannot be added until walls are erected. Conversely, with offsite production, walls, floors, ceilings and rafters are all brought together in the same factory to form a building. This process often allows modular construction times half of that of conventional, stick-built construction.

Further to finding out the knowledge level of construction profession on off-site construction was the awareness of any benefits associated with it. The respondents observed that reduction of overall construction costs, minimization of number of site

personnel, shortening of construction time, increasing efficiency, and improving the health and safety of workers are the benefits of applying off-site production in construction. The view of the respondents on cost benefits concurs with the study by Nadim and Goulding (2011), that, potential for offsite construction methods to reduce costs and cost uncertainty may be a clear driver for uptake. According to Harris (2006), offsite construction saves a lot of money on the construction project. By using standard patterns, the building materials are saved at the manufacturing factories. This helps reduce the waste in formwork and other materials that can occur during traditional building procedures. Savings is made as a result.

The respondents view that off-site construction increases efficiency at workplace is in line with the study by Bildsten (2011) that increasing in labour efficiency and associated decreases in onsite time have been frequently raised as benefits of offsite construction. In inclusion are the greater quality and higher levels of precision allowed with factory built or automation housing (Elnaas et al., 2009; Gibb & Isack, 2003; Lu, 2009). With the current state of skilled labour shortage, factory built is the perfect alternative means of production.

The view of the of the respondents on shortening of construction time as a benefit of off-site construction agrees with Divakor and Subramanian (2009) that the potential for prefabrication methods to reduce the overall time consumptions on construction projects, and meet timelines has been described as a hallmark. As affirmed by Divakor and Subramanian (2009), Manfield (2002), Toor and Ogunlana (2008), off-site construction contributes to a much shorter overall construction period, there is a corresponding reduction in labour, financing and supervision costs, and earlier building occupancy.

The respondent's assertion on improving health and safety of workers are the benefit of applying off-site production in construction buttresses Luo et al. (2005) that off-site construction method offers an opportunity for greater workplace health and safety outcomes by reducing exposure to heights and weather and hazardous tasks such as cutting. Safety on site and in the factory is greatly improved and it is estimated that reportable accidents are reduced by over 80 per cent relative to site intensive construction (Lawson, 2011). Theft is also greatly reduced as most finishes and expensive exterior elements are set in the factory and tied to the module.

In addition to discovering the knowledge level of construction profession on off-site construction was on whether the respondents have received any training on off-site construction. It was not surprising that the majority of respondents have not received any training on off-site construction. Ibrahim and Bishir (2012) indicated that construction industries have not received training on off-site construction and suggests that, the Federal Government through the legislative arm should enact a law, making the application of off-site construction in construction projects a necessity, construction companies should embark on training and retraining of their staff and engineers abroad so that skills on construction methods can be acquired, construction companies and relevant government agencies should procure all necessary equipment for off-site construction and there should be increased research and development in evolving construction methods to promote the adoption of off-site construction.

In short, off-site construction system offers economization of design, site work and materials, provides shorter construction time, saving in labour, better quality control, immunity to weather changes and the most importantly, the cost factor. It has been proven successful in some countries, namely Singapore, Japan, England, and the United States (CIDB, 1998). This implies that the shorter construction time offered by

ABS seems to be the panacea for the housing demand in Ghana. It is hoped that the widespread understanding on the offsite production can further help to develop and promote prefabricated system as an innovative construction method in Ghana.

The overall knowledge level of the respondent in off-site production is generally above average which brings to the fore the need to intensify the education on this important technological advancements in a bid to help tackle the issue of housing deficit. The study indicated that majority of the respondents understand off-site construction, aware of the building units that be produced as a result, and the numerous associated benefits. On the other hand, the study indicated that most of the respondents have not received any training on offsite production. This leads one to conclude that even the respondents who are major stakeholders of the Ghanaian construction industry have limited knowledge on its application, which in one way or the other can contribute to the huge deficit in the housing delivery system in Ghana. This supports the assertion by Boadu (1992) on the overreliance on the traditional in-situ construction systems over the use of off-site produced building components in the Ghanaian construction industry. 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.

Respondents' knowledge level on off-site construction, awareness on manufactured components and the associated benefits of off-site construction contradicts the findings by Ibrahim and Bishir (2012) who indicated that construction industries awareness on offsite construction is low, and that there is no best ways to

communicate all information required by all the different stakeholders in discharging their professional duties with much ease and high accuracy.

Furthermore, Andy et al. (2011) comparing the implementation of offsite construction in some countries including Finland, Denmark, Norway, Japan, USA, Singapore, UK and other African countries observed that offsite construction is regarded as the driving force towards higher utilization in those countries. Andy et al. noted that the importation of knowledge helps in the adoption of offsite construction in such countries, but suggested that the developing countries have failed to employ knowledge on offsite construction.

On the same issue, Chewlos, Benbasat, and Albert (2001) observed the non-use of off-site construction as due to the generally low level of awareness on its application and lack of knowledge on use, the general conception that the current technology in use is enough and the lack of inter-agency collaboration for the adoption and use of offsite construction as the factors militating against late delivery of projects and cost overruns. Other identified factors include: lack of Government support for the adoption of offsite construction, high cost of implementation; concerns about its complexity, lack of educational facilities to support its use and lack of laws and policies mandating the application of offsite construction.

5.3 Readiness of Ghanaian construction industry to use off-site construction

The second research objective was to find out the readiness of Ghanaian construction industry to use off-site construction method. The respondents revealed that the Ghanaian construction industry was not ready in adopting Off-Site Construction (OSC) method as part of its construction methods because of reasons such as low level of expertise, perception, very high cost of implementation, financial strength of

contractors and clients alike and the unavailability of requisite tools and equipment needed for OSC. The respondents explained that due to inadequate capital backup of the companies as against the huge sum of money needed to set up their own factory has been a big challenge. They again explained that OSC is still new to the Ghanaian construction industry. As a result, not much training has been given to professionals in the industry. The problem of after-sale services, that is, repairs (minor and major) and replace of units/parts has been contemplated by clients especially as many, if not all, artisans lack that expertise. Not many people (clients) are aware of OSC as a method of building. However, the few that know still hold on to the perception that has given the method a bad image and so would not opt for it given the choice. This perception has defeated the purpose of sale and resale of manufactured houses given the Ghanaian situation where a building is supposed to be 'mortar and block'. These finding on the readiness of Ghanaian construction industry to use off-site construction agrees with studies in the literature. According to Hamid et al. (2008), contractor's lack of experience in prefabricated system and lack of technical knowledge in this industry discourages further the implementation of prefabricated system.

The view of the respondents on inadequate capital backup and not able to set up their own factory confirms the study by Rahman and Omar (2006) that financial issue becomes the main reason for lower class contractors to move forward with the off-site construction system. According to Thanoon et al. (2003), off-site construction system is also an unattractive choice due to wide swing of property demand, high interest rate and improper economic condition.

According to Arditi and Pattanakitchamroon (2006), the construction industry is still applying labour intensive and low technology methods for construction due to low knowledge in designing off-site construction components and the negative image

attached to off-site construction which initially lead towards low productivity and inefficiency of work at construction site. The intensive use of unskilled workers and low technology equipment has eventually affected the quality of work which results in defects, structural failures and design inadequacies of the construction projects. As a result, this has led to unproductive practices and initially contributes to the late delivery of work.

Chewlos, Benbasat and Albert (2001) identified that construction firms are not ready in adopting off-site construction due to the generally low level of awareness on its application and lack of knowledge on use. In other words, the awareness of current trends and latest construction technology and innovation is essential.

Amankwah (2013) indicated that due to the fact that most of the local construction workforces in Ghana 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 conditions, 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.

The low productivity of the local construction industry can be attributed 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 industry has led to the situation where most of the tradesmen are not abreast with new technologies like off-site construction.

5.4 Cost benefits of using off-site construction over the traditional method

The last research question sought to identify, if any, the cost benefits for using offsite construction over the traditional construction method in the Ghanaian situation. The study revealed that traditional method is about 12.1% over off-site construction in terms of cost. Respondents indicated that off-site construction method is cost effective when compared with the traditional built-on-site construction method. In a report produced by McGraw-Hill (2011), it was noted that two-thirds of companies that used offsite construction experienced reduced project schedules and cost. Out of those companies 35% reported decreasing schedules by as much as four or more weeks. This is significant not only because it proves OSC reduces project schedules but also because it can yield significant cost savings. Many projects take place on active sites, where business is negatively impacted when construction is occurring. When schedules can be reduced by a month or more, businesses can return to normalcy sooner and help minimize negative impacts to business. A good example of an active site would be a new building being constructed in a hospital complex (McGraw-Hill 2011).

According to Rosenfeld (1994), as most of the work is carried out in the factory leaving little to be done on-site, it 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. 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 due to its cost reduction.

According to Amankwah (2013), the current use of offsite method is still not strongly encouraged by the Ghanaian construction industry. 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 OSC in the near future as all stakeholders believe it will cut down cost, 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 to reduce cost.

Osei-Hwedie (2010) in his study mentioned that 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 cost 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. While economic justification is often dependent on high volume and repetition (Davies, 2005; Lessing, 2006), the potential for offsite construction methods to reduce costs and cost uncertainty may be a clear driver for uptake (Nadim & Goulding, 2011).

As per Bing et al. (2001), usage of off-site construction components result in cost savings due to a greater productivity and less wastage of materials during the production of the building components. Besides, prefabricated components reduce

construction cost in site supervision, skilled labour required on-site for installation, wastage of materials, formworks, scaffolding, and etc. The usage of system formwork made up of aluminum, steel, scaffolding and etc provides a considerable cost savings. Harris (2006) on his part, confirmed that offsite construction saves a lot of money on the construction project. By using standard patterns, the building materials are saved at the manufacturing factories.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

The chapter presents the summary of the major findings of the study, and the relevant conclusions drawn from the findings indicating how the study has contributed to knowledge. In addition, it presents the recommendations made based on the findings of the study and the suggestions for future studies.

6.2 Summary of Key Findings

This section presents the summary of the major findings of the study under suitable themes developed from the respective research questions as follows:

6.2.1 Knowledge level of construction professional on off-site construction

- It was observed that respondents know that every member - wall, ceiling, roof, floor, doors and windows, etc can be prefabricated. Thus, the entire building can be made off site.
- The reduction of overall construction cost, reduction of number of site personnel, shortening of construction time, increasing efficiency and improving the health and safety of workers are benefits of applying off-site production in construction.
- The study found that most of the respondents have not received training on the application of off-site construction.

6.2.2 Readiness of Ghanaian construction industry to use off-site construction

- It appeared from the study that the Ghanaian construction industry is not yet ready to employ off-site construction.
- The respondents revealed that they have not thought of adopting Off-Site Construction (OSC) method as part of their construction methods for reasons such as unavailability of necessary tools and equipment, clients' choice and preferences and unavailability of skilled artisans.
- The study indicated further that inadequate capital backup, inability to set up factories, the perception and misconception about off-site construction and the lack of knowledge in designing off-site construction components have equally contributed to the industry's inability to adopt off-site construction methods.

6.2.3 Cost benefits of using off-site construction over the traditional method

- The study revealed that the use offsite construction methods are cost effective compared and advantageous compared to the traditional method of construction.
- The mass production of components, duplication of parts, reduced onsite personnel and shortened construction time will result further in cost savings, thus, maximizing profit for the use offsite construction method.

6.3 Conclusions

Usage of prefabricated components in buildings is still being developed in the construction industry. New construction methods and technologies are still developing with the aim to improve and achieve an industrialized industry. Besides, the objective of prefabricated components usage in buildings are to reduce the construction time, save in construction cost and produce high quality product.

The overall knowledge level of the respondent on off-site production is good but then it is still very important to intensify the education 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 housing deficit. The study indicated that majority of the respondents understand off-site construction, and its associated benefits. However, the study also indicated that most of the respondents have not received any training on offsite construction. This leads one to conclude that even the respondents who are major stakeholders of the construction industry are themselves deficient with respect to the full implementation of offsite construction method.

The study indicated that the Ghanaian construction industry is not ready to employ off-site construction because of unavailability of required tools and equipment, and skilled labour. The study further indicated that due to inadequate capital backup and not able to set up own factory, the negative image attached to off-site construction due to its past failures and unattractive architecture, and lack of knowledge in designing off-site construction components makes Ghanaian construction industries not ready in adoption off-site construction.

However, it was realised that factors such as reduced construction time, reduced number of personnel on site and the duplication and mass production of prefabricated units all culminated in the overall cost saving of the use of offsite construction.

6.4 Recommendations

The following recommendations are made for the study

- Increased awareness of the use of off-site construction should be made using means suitable and putting into consideration the peculiarities of the Ghanaian

Construction Industry, relevant bodies, agencies and organizations should inform the government on the benefits of the use of off-site construction and together as a team support the adoption of off-site construction in Ghana.

- Local artisans should be trained on off-site construction and its application as that is the way forward for any construction industry that aspires to meet the housing challenge of its populace.
- Estate developers and 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.
- There is also the need for the teaching of the concept of off-site production 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 its familiarity so that when they get out of school, they can easily champion its usage and put it into practice.
- Some simulators are needed in adopting off-site production. These include full mechanisation of the construction process using heavy plants under factory conditions to produce prefabricated components. The government support will help in the introduction of more productive construction methods with the sole aim of reducing housing deficit in Ghana.
- Construction professionals should explore the use of industrialised building techniques and methods as a solution to solving the problems of the Ghanaian construction industry. This will result in using mass production techniques

under factory conditions leading to an increase in productivity, efficiency and quality of the product.

- Enabling environment should 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 by the government.
- Government's incentives to encourage the import, manufacture and use of prefabricated building components can also be a driving force. 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.

6.5 Suggestions for Future Research

In a study like this, recommendations for future research would address the issues generated from this study. Based on these findings, future research may start from a relatively higher level of knowledge. First, a replication of this study would be helpful in reexamining the validity of its findings for which the researcher was not able to investigate. Further empirical studies using different geographical diversity, would be helpful in validating specific parts of the theoretical models proposed in this study.

Second, a study should be conducted on 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.

Also, research should be conducted on the concept to 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. Finally, the influence of external environment should be studied in order to explore how external environment affects the adoption of off-site construction in Ghana.

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APPENDIX A

IMAGES OF OFF-SITE COMPONENTS

APPENDIX B

LIST OF CONTRACTORS IN KUMASI METROPOLIS

LIST OF CONTRACTORS AND PROJECTS UNDERTAKEN

AT KUMASI METROPOLITAN ASSEMBLY

NO.	NAME OF CONTRACTOR	PROJECT UNDERTAKEN
1.	MESSRS ISSAHAKU.L.COMPANY LTD. P.O.BOX 240, WA	CONSTRUCTION AND COMPLETION OF 1No. 6- UNIT CLASSROOM BLOCK AND REHABILITATION OF 2-STOREY 6-UNIT CLASSROOM WITH ANCILLARY FACILITIES AT AL-ZAIAH ISMALIC SCHOOL AT TAFO KUMASI.
2.	MESSRS RICH HOUSE CONSTRUCTION WORKS LTD. P.O.BOX 246 KUMASI	CONSTRUCTION AND COMPLETION OF 1No. 6 UNIT CLASSROOM BLOCK AND RHABILITATION OF 3No. 3-UNIT SCHOOL BLOCK AT OHIM IN KUMASI
3.	MESSRS EMBEGOSAN ENTERPRISE, P.O.BOX 4085 KUAMSI	CONSTRUCTION OF 2No. 6-UNIT CLASSROOM BLOCK AT DOMPOASE M/A AT DOMPOASE IN KUMASI
4.	MESSRS JACOB ABORAH CONSTRUCTION WORKS LTD. P.O.BOX S 1085 SUAME-KUMASI	CONSTRUCTION OF 6-UNIT CLASSROOM BLOCK(GROUND FLOOR) WITH ANCILLARY FACILITIES- ST CYPRIAN ANGLICAN PRIMARY A&B IN KUMASI
5.	MESSRS ABOAGYEWAA VENTURES P.O.BOX 1534 KUMASI	REHABILITATION OF 3No. 3-UNIT CLASSROOM BLOCK WITH ANCILLARY FACILITIES AT OLD TAFO, KUMASI
6.	MESSRS OWUATI CONSTRUCTION LTD. P.O.BOX AH 8716 KUMASI	CONSTRUCTION OF 1No. 6-UNIT AND COMPLETION OF 1No. 6-UNIT CLASSROOM BLOCK WITH ANCILLARY FACILITIES AT ST. HUBERT SEMINARY AT SANTASE, KUMASI
7.	MESSRS GOLD PRINT AND CONSTRUCTION LTD. P.O.BOX AH 8716 KUMASI	CONSTRUCTION OF 1No. 6-UNIT CLASSROOM BLOCK WITH ANCILLARY FACILITIES AT MMBROM-KUMASI

8.	MESSRS OWUATI CONSTRUCTION LTD. P.O.BOX AH 8716 KUMASI	REHABILITATION OF 2-STOREY 12-UNIT CLASSROOM BLOCKS, 1No. 6-UNIT CLASSROOM BLOCK AND 1No. 6-UNIT CLASSROOM BLOCK WITH ANCILLARY FACILITIES AT YAA ACHIAA AKOSA AND OHWIM, KUMASI
9.	MESSRS GOLD PRINT AND CONSTRUCTION LTD. P.O.BOX AH 8716 KUMASI	CONSTRUCTION OF 1No. 6-UNIT CLASSROOM BLOCK AND REHABILITATION OF 2No. 3-UNIT CLASSROOM BLOCK WITH ANCILLARY FACILITIES AT ABOABO, KUMASI
10.	MESSRS OSSIMILLER COMPLEX. P.O.BOX 4701 KUMASI	CONSTRUCTION OF 1No. 6-UNIT CLASSROOM BLOCK (FIRST FLOOR ONLY) WITH ANCILLARY FACILITES AT WEWESO M/A, KUMASI
11.	MESSRS JARTHUR COMPLEX LTD. P.O.BOX 8716 KUMASI	REHABILITATION OF 4No. 3-UNIT CLASSROOM BLOCK AND LIBRARY WITH ANCILLARY FACILITIES AT ANYAANO AND OLD TAFO, KUMASI
12.	MESSRS RICH HOUSE CONSTRUCTION WORKS LTD. P.O.BOX 246, KUMASI	CONSTRUCTION OF 1No. 6-UNIT CLASSROOM BLOCK WITH ANCILLARY FACILITIES AT AYIGYA, KUMASI

D C U
Deputy Dev. Control Engineer
K M A

APPENDIX C

UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

INTERVIEW GUIDE

Preamble: The researcher, a student of University of Education, Winneba seeking information relating to the topic "**THE STUDY INTO THE CHALLENGES OF THE USE OF OFF-SITE CONSTRUCTION METHODS IN GHANA".** Please you have been selected to participate in the research. Kindly provide answers by ticking [√] or completing the blank space. Your response will be kept confidential.

Section A: Socio – demographic characteristics

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 (1)

   b. Senior Secondary (2)

   c. Polytechnic (3)

   d. University (4)

   e. Post graduate (5)

   Area of specialization, please specify

   ……

……..……

2. What is your experience in the construction industry?

a) 0 – 5 years (1)

b) 6 – 10 years (2)

c) 11 – 15 years (3)

d) 16 – 20 years (4)

e) More than 20 years (4)

3. Are you a member of the Project Management team in your Organization?

Yes (1) No (2)

Section B: Knowledge on prefabrication

5. What is your understanding of offsite construction (OSC) method?

……

……

6. Do you know some building units are/can be prefabricated?

No ( ) Yes ( )

If "Yes" can you mention some of them?.....

7. Do you know that the entire building can be prefabricated?

No ( ) Yes ( )

8. Are you aware of any benefits associated with the adoption of off-site construction?

Yes (1) No (2)

If "Yes" please specify:……..

……

9. Have you undergone any training in relation to OSC?

No ( ) Yes ( )

If "No" does your organisation have plans of giving such training?

……

Would you do that on your own either?.....

If "Yes" are you satisfied with the extent of training?.....

10. As a professional, how do you rate your knowledge in OSC method?

Very high ( ) High ( ) Average ( ) Below average ( )

11. Do you believe OSC can be used to reduce housing deficit in Ghana?

……..

Section B: Readiness of Companies in the Adoption of Off-site Construction

12. Has your company employed off-site construction methods for a project before?

a) Yes (1)

b) No (2)

13. Have you recommended OSC method to your organization before?

a) Yes (1)

b) No (2)

If "Yes" what informed that decision?.....

What was the organisation's response/ feedback……

14. Has your organization thought of adopting OSC method as part of its construction methods?

No ( ) Yes ( )

If "Yes" how soon will that be……

15. Can you mention some tools and equipment needed for OSC?

……..

……..

……

16. Does your organization have them?

No ( ) Yes ( )

17. Do you have the requisite skills/skilled personnel for OSC?

Yes ( ), Can you mention some……..

No ( )

If "No" is your company ready to give them training to that effect?

……..

18. Do you perceive any challenges with respect to the adoption and use OSC method.

No ( ) Yes ( )

If "YES", can you share those challenges?

19. Do you perceive OSC as a substitute/replacement to the traditional construction method?

Yes ( )

Any reasons:……..

No ( )

Any reasons:……

Thank you