UNIVERSITY OF EDUCATION, WINNEBA

MATERIAL WASTE MINIMISATION AT THE CONSTRUCTION PHASE OF A BUILDING PROJECT THROUGH THE IMPLEMENTATION OF LEAN CONSTRUCTION PRINCIPLES

ADDI ALUU

2022

UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

FACULTY OF TECHNICAL EDUCATION

MATERIAL WASTE MINIMISATION AT THE CONSTRUCTION PHASE OF A BUILDING PROJECT THROUGH THE IMPLEMENTATION OF LEAN CONSTRUCTION PRINCIPLES

ADDI ALUU

190012356

A THESIS TO THE DEPARTMENT OF CONSTRUCTION AND WOOD TECHNOLOGY, FACULTY OF TECHNICAL EDUCATION, SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, UNIVERSITY OF EDUCATION, WINNEBA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF MASTER'S DEGREE IN CONSTRUCTION AND WOOD TECHNOLOGY EDUCATION (MTECH)

2022

DECLARATION

Student's Declaration

I **Addi Aluu** declare that this thesis, except for quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

Signature: …………………………...

Date: ……………………………….

(ADDI ALUU)

Supervisor's Declaration

I hereby declare that the preparation and presentation of this project report were supervised under the guidelines for supervision of thesis/dissertation/project as laid down by the University of Education, Winneba.

Signature: …………………………….

Date: ……………………… ………

(DR. NONGIBA ALKANAM KHENI)

ACKNOWLEDGEMENT

I am grateful to my Supervisor, Dr. Nongiba Alkanam Kheni for his guidance, directions, and patience towards me throughout the writing of this dissertation.

My sincere gratitude goes to Mr. Kusi Elijah who made the necessary corrections and criticisms to enable me to complete this dissertation. His guidance and constructive criticisms would never be forgotten.

I wish to express my profound appreciation to my wife and children for their advice, assistance, encouragement, and support throughout my life.

DEDICATION

I dedicate this work to my dear wife Awombanoiya Esther for her spiritual, financial, emotional, and moral support.

TABLE OF CONTENTS

CONTENTS **PAGES**

LIST OF TABLES

TABLES **PAGES**

LIST OF FIGURES

FIGURES **PAGES**

ABSTRACT

Material waste is made up of unwanted materials generated during construction, such as rejected structures and materials, materials that have been over ordered or are surplus to requirements, and materials that have been used and discarded. In Ghana, between 5% and 27% of the materials acquired for construction projects are wasted. Ghana's construction business finds it challenging to compete globally due to the current free global economic order. The study sought to assess material waste minimisation at the construction phase of a building project through the implementation of lean construction principles. The objectives of the study include; to assess the level of contribution of some waste minimization measures to waste reduction in the Ghanaian construction industry, to determine the level of understanding of the lean concept among construction practitioners in Ghana, and to determine the obstacles to successful lean construction implementation in the Ghanaian construction industry. Quantitative was used as the research design. A questionnaire survey was adapted to get feedback on the opinions of respondents about the wastage of building materials and the implementation of lean principles in the Ghanaian construction industry. The study adopted a census approach in the first stage in which the population of D1K1 contractors operating in the study area was determined. In the second stage, systematic random sampling was adopted to select the construction professionals covered in the survey using the sampling frame compiled for the list of professionals. Out of the total construction professional population of 105 in the study area, 83 of them representing 79.05% were chosen as the sample size for the study. The findings from the study revealed that purchasing just enough raw materials, using materials before they expire, good coordination between store and construction personnel to avoid overordering, using more efficient construction equipment, and using proper site management

techniques are the five most important measures that can reduce material waste on construction sites. The study further found that there is some level of understanding of the idea of lean construction among experts in the Ghanaian construction industry. Construction organisations' actions, such as delivering what the client wants, developing continuous improvement, "constantly finding better ways to do things, waste minimization, and minimising errors in completed work, are reported to be usually aligned with lean construction practices. The study recommends that the government pass legislation and establish regulations that encourage good attitudes toward waste minimization at all levels of a construction project to aid the construction industry in reducing material waste. Construction firms should modify organisational cultures that do not favour lean construction and promote the concept of lean construction through workshops and conferences, among other things, to bridge the knowledge gap on the use of LC.

CHAPTER ONE

INTRODUCTION

1.1 Background

Increased productivity has resulted in significant performance improvements in the manufacturing industry during the last few decades. The application of the new manufacturing philosophy known as "Lean Production" was a crucial component in this success. This method allows for continuous improvement in the manufacturing process by eliminating various sorts of waste (Aziz & Hafez, 2013; Koskela et al., 2013; Lee et al., 1999). While manufacturing has achieved remarkable accomplishments, the building industry continues to face serious challenges as a result of massive volumes of waste (Ogunbiyi, 2014; Polat & Ballard, 2004), necessitating the use of lean construction to assist reduce waste.

Waste, according to Koskela (1992), is "any inefficiency that results in the usage of equipment, materials, labor, or money in greater quantities than are considered required in the development of a facility." Unavoidable waste (or natural waste) is defined as waste for which the investment required to reduce it is greater than the economy's output, whereas avoidable waste is defined as waste for which the cost of disposal is greater than the cost of prevention (Formoso et al., 1999; Polat & Ballard, 2004). The percentage of unavoidable waste is determined by the company's technological development level (Renuka et al., 2017; Womack & Jones, 1996). According to Angalekar et al. (2017) and Formoso et al. (1999) waste can also be classified by its source or the point at which the waste's root causes manifest. Waste can be generated throughout the materials manufacture, design, material supply, and planning stages, as well as during the building stage (Formoso et al., 1999). However, only materials wasted during the construction stage of projects will be evaluated for this study. This is because of two key factors: Materials make up the greatest portion of construction costs, accounting for 50-60% of the entire cost of a project (Babalola et al., 2018; Ganesan, 2000; Ibn-Hamid, 2002). Furthermore, the raw materials used to make construction inputs are sourced from nonrenewable resources. As a result, once these materials have been discarded, they are rarely replaced (Babalola et al., 2018; Ekanayake & Ofori, 2000).

Materials waste, according to Hong Kong's Environmental Protection Department (EPD), is made up of unwanted materials generated during construction, such as rejected structures and materials, materials that have been overordered or are surplus to requirements, and materials that have been used and discarded (EPD, 2000). Building material waste is also defined as the difference between the value of 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 materials waste may result in unnecessary cost and time (Enshassi, 1996; McDonald & Smithers, 1998; Pheng & Tan 1998; Shen et al., 2003). Furthermore, material waste is defined as "any material, other than earth materials, that needs to be transported elsewhere from the construction site or used within the construction site itself for landfilling, incineration, recycling, reusing, or composting, other than the intended specific purpose of the project due to material damage, excess, non-use, or non-compliance with the project's specifications, other than the intended specific purpose of the project due to material damage, excess, non-use, or non-comply (Ekanayake & Ofori, 2000). Despite the differences in construction projects, inefficiencies in design, procurement, material handling, operation, or residual on-site waste such as packaging all contribute to potential material waste (Formoso et al., 1993; Gavilan & Bernold, 1994).

1.2 Problem Statement

According to research, between 5% and 27% of all materials purchased for construction projects in Ghana are wasted (Babalola et al., 2018). The existing free global economic order makes it difficult for Ghana's construction sector to compete globally (Pate & Vasatkar, 2018). To stay in business, the sector must aim to provide valuable products and services to clients at the lowest possible cost (Bipin et al., 2019). To attain the lowest possible construction costs, the Ghanaian construction sector must understand the distinction between waste and value, as well as how to minimize waste in current projects (Khan et al., 2019). Lean construction considers construction materials waste as potential waste that hinders the flow of value to the client and should be eliminated (Stevens, 2014). The creation of this waste can be prevented by applying lean construction principles. The question now arises as to whether professionals in the building industry in Ghana are aware of the amount of materials waste generated on-site. What measures have they put in place to deal with the situation?

Past studies into the causes of waste in construction projects indicate that waste can arise at any stage of the construction process from inception, right through the design, construction, and operation of the built facility (Craven et al., 1994; Faniran & Caban, 1998; Gavilan & Bernold, 1994; Spivey, 1974). Waste in the construction industry has been the subject of several research projects around the world in recent years (AlMoghany, 2006; Chen et al., 2002; Ferguson et al., 1995; Formoso et al., 1999; McDonald & Smithers, 1996; Shen et al., 2000, 2002; Smallwood, 2000; Teo & Loosemore, 2001; Wong & Tanner, 1997). According to Polat and Ballard (2004), it is commonly acknowledged that a very high level of waste exists in construction. Since construction has a major and direct influence on many other industries utilizing both purchasing inputs and providing the products to all other industries, eliminating or reducing waste in the construction industry could yield great cost savings for society.

“Lean management in construction sites” was evaluated by Bipin et al. (2019). The study focused on several lean management projects that have been implemented on construction sites around the world. The studies' outputs were examined. The conclusion was reached that lean theory increases performance by reducing overall time and increasing efficiency. The last planner and improved visualizations were used to achieve the best results. Human performance can help to increase labor productivity. Khan et al. (2019) investigated “Lean technology and waste minimization in the construction industry.” The study used lean construction techniques to reduce construction waste and increase site productivity. The activities have been planned out. Physical mapping of the current state and future state maps are part of this process, and they serve as the foundation for other lean initiatives. The lean concepts are investigated in-depth here, and it is clear that the lean construction approach is beneficial in reducing waste and increasing production. “Lean design strategy of waste minimization in construction industries” was discussed by Prasanna et al. (2018). The goal of this study is to discover a solution to the building industry's waste problems. To detect the issues, the last planner system is employed. When compared to other approaches, the indicated method produces better outcomes, resulting in increased productivity and a better trade-off between time and cost due to improved workflow.

The goal of Pate and Vasatkar (2018) is to "use lean building techniques." The project's main goal is to use lean construction technologies in a project in Rahatani, Pune, to analyze waste in construction operations and improve process flow by eliminating inefficient activities. The topic of productivity is also briefly discussed.

The "Application of lean construction to improve material management in construction projects" was discussed by Kumar et al. (2018). Therefore, the study sought to use lean technologies to improve material management in the Ghanaian construction industry.

1.3 Aim of the Study

The study sought to assess material waste minimisation at the construction phase of a building project through the implementation of lean construction principles.

1.4 Objectives of the Study

- To assess the level of contribution of some waste minimization measures to waste reduction in the Ghanaian construction industry.
- To determine the level of understanding of the lean concept among construction practitioners in Ghana.
- To determine the obstacles to successful lean construction implementation in the Ghanaian construction industry.

1.5 Research Questions

- What is the contribution of some waste minimization methods to waste reduction in the Ghanaian construction industry?
- What are the perceptions of construction professionals on the concept of lean construction?
- What are some of the potential barriers to lean construction implementation in Ghanaian construction companies?

1.6 Significance of the Study

The construction industry involves different processes and utilizes huge quantities of resources that have impacts on the environment (Horsley et al., 2003). According to DETR (2000), in some more advanced countries, the concern for the effect of Man's endeavours on the environment and rising project costs has increased the drive for the application of Construction Waste Management. This study sought to bring to the notice of contractors, engineers, foremen in the construction industry and especially the Assemblies some of the factors that cause waste at the construction stage which shoot up the cost of construction and also address construction materials waste reduction which can improve productivity.

The study also intends to make some contributions to the understanding of construction waste management through the application of some important but neglected principles such as the '3R' which talks about reduce, reuse and recycle. This will help subsequently reduce contamination in the environment and reduce cost overrun arising from wastage on construction sites. The research would add to the body of knowledge about the factors that influence material handling on construction sites. It would once again aid in the better handling of materials on building sites. The study would also serve as a guide for construction industry workers, building construction company directors, project managers, and site supervisors, to help improve material handling on construction sites by making better decisions to complete quality work.

1.7 Scope of the Study

This study was limited to consultants in the building construction industry and covered only the construction stage of building projects. The construction stage refers particularly to the building or construction of sub-structures, super-structures, and architectural elements such as finishes. Surveys carried out at these phases enabled on-site observations to be conducted simultaneously. The materials considered were timber, cement/mortar, concrete, and blocks. The research focused on the flow activities of these materials (storage and handling). Surveys in the forms of questionnaires and personal interviews were conducted with the proponents who were undertaking referenced projects. Proponents mentioned referring precisely to the engineers concerned with such projects.

1.8 Organization of the Study

The study's introduction is found in the first chapter of the research. The problem statement, the study's purpose, the study's aims, and objectives, and the study's importance and scope are all included in this chapter. The second chapter provides an overview of the Ghanaian construction sector as well as the notion of construction material management. The literature on the elements and activities in Ghana's construction industry surroundings, as well as the idea of building materials waste at the construction stage, are the emphasis of this chapter. The study's research technique is discussed in the third chapter. This section covers topics such as research design, research strategy, data collection tools, sample size and sample size determination, and data analysis tools. The study's fourth chapter contains data analysis, results presentation, and discussion. Chapter five of the research contains the study's conclusions and suggestions. This chapter discusses both proposals for the adoption of effective building materials management principles and recommendations for future implementation.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

Many researchers have disputed and researched lean construction since the early 1900s, when Lean Manufacturing Concepts were first introduced (Conway et al., 2005). According to Abdullah et al. (2009), Lean Construction is a concept that needs to be introduced inside the construction industry, primarily to boost the sector's productivity by eliminating activities and actions that cause waste during the construction process. The worldwide construction industry, the Ghanaian construction industry, materials waste, materials waste mitigation measures, and lean principles are all covered in this chapter.

2.1 The Global Construction Industry

All companies primarily engaged in construction, such as general contractors, heavy construction (airports, motorways, and utility systems), and construction by specialty trades, are included in the construction sector. Companies that prepare building sites for new construction and subdivide land for building sites are also featured. New construction, additions, alterations, and maintenance and repairs are all examples of construction work. Construction projects are frequently classified as either residential (house construction) or non-residential (commercial and government buildings and infrastructure projects), as well as by funding source (public or private) (Conway et al., 2005).

For many countries, the building industry is a primary source of revenue. The building industry does not only serves as the foundation for all other businesses, but it is also one of the largest single industries in the economy. Governments have relied on the construction sector as a strategically vital industry for producing jobs and sustaining growth since it is closely related to public works. Because of its link to the development of basic infrastructure, training of local workers, technology transfer, and increased access to communication channels, the construction sector is particularly important for developing economies (International Institute for Sustainable Development, 1999).

Construction services are typically provided by establishing service suppliers on or near the job site for work by local or regional operators in a significant number of nations. On-site presence is typically limited to the period of a single project, whereas regional or local presence can be maintained on a long-term basis to serve or promote multiple projects. Joint ventures between international and domestic enterprises are prevalent, often as a result of a need for project funding, knowledge transfer, and support in complying with local laws, rules, and norms (IISD, 1999).

In many countries, construction services may be carried out by general contractors who complete all the work for the proprietor of the project, or by specialized sub-contractors who undertake parts of the work. Analysis by the World Trade Organization Secretariat indicates that most countries have a small number of large firms, a moderate number of medium-sized firms, and a large number of small firms who specialize in certain fields or who operate in small geographical areas (IISD, 1999).

2.2 The International Supply of Construction Services

The worldwide construction industry is the world's largest single industry. The worldwide construction business was valued at about four trillion dollars in 2004. (Gary, 2004). Even more significant, 25% of the global workforce worked directly for the construction industry or a company that supported construction. Building is an instrument for stimulating economies and projecting foreign policy. The global construction business rose by 6.6 percent between 2003 and 2004. (Conway et al., 2005). Vinci of France ($12 billion (B) domestic revenue/$8 billion international revenue) and Skanska of Sweden ($3 billion (B) domestic revenue/$14 billion international revenue) were the two largest worldwide construction corporations in 2003. (Conway et al., 2005). Europe is the world's largest construction market. Asia/Australia is the second largest international building market, with China being the fastest developing market. Transportation accounts for the highest share of the international construction market (27.5%), followed by general construction (25.4%) and petroleum infrastructure (18.7%). (Conway et al., 2005).

According to the World Trade Organization Secretariat, considerable movements of employees at all levels of ability are involved in the international supply of construction services. Although statistics on the movement of workers related to the industry are not readily available, analysts believe that construction is responsible for a large portion of the migration of workers from Asia, Latin America, and other developing regions into industrialized countries and the Middle East (IISD, 1999).

Because of the nature of the work, the majority of construction services are either provided by a foreign company with a commercial presence or by natural persons. Because of technical impossibility, cross-border construction services are thought to be practically non-existent (i.e., construction services cannot be supplied without the movement of service providers). Some services (like land surveying and blueprint design) may, however, become more widely traded over telecommunications infrastructures. There may be some changes in the way construction services are provided as electronic commerce grows (IISD, 1999).

2.3 The Ghanaian Construction Industry

Construction is a big sector in Ghana, as it is in other parts of the world, and it is an important aspect of economic development. Construction is present in every area, regardless of what one performs. Its importance cannot be overstated, as it is one of the top drivers of the Ghanaian economy, which includes agriculture, manufacturing, and mining. Ghana is one of the most active economies in West Africa. Construction's share of GDP has risen steadily since its low point in the 1970s and 1980s, from 4.5 percent in 1975 to 8.5 percent by the turn of the century, and has remained relatively constant since then. Due to the worldwide economic slump, the sector increased by 10% in 2008 but experienced a negative growth rate of 1% in 2009. (Gyadu-Asiedu, 2009). Clients, professional consultants, and contractors are the most important stakeholders in Ghana's building sector (Gyadu-Asiedu, 2009). Typically, these take out loans and construct speculative structures for resale. Their performance is usually influenced by the country's lending position.

2.4 Wastes in the Construction Industry

This part begins with a survey of the literature on waste in construction, then goes on to define waste in greater depth, discussing construction waste, forms of construction waste, materials waste, and the magnitudes of waste in construction. During the construction process, construction managers must deal with a variety of elements that might have a negative impact on the production process' performance, as well as the generation of various types of waste. Mistakes, working out of order, duplicated activity and movement, delayed or premature inputs, and products or services that do not fulfill consumer expectations are all examples of waste (CIB, 1998).

2.4.1 Definition of construction waste

Different studies have characterized waste in construction in various ways. Waste, according to the new production philosophy, is defined as any inefficiency that results in the use of more equipment, materials, labor, or capital than is thought required in the construction of a building. Both the occurrence of material losses and the execution of needless work, which generates additional costs but adds no value to the result, are examples of waste (Polat & Ballard, 2004). Waste should be defined as any losses incurred as a result of operations that incur direct or indirect costs but add no value to the product from the client's perspective (Alwi et al., 2002; Formoso et al., 1999). A simple definition of waste, according to Polat and Ballard (2004), is "that which can be eliminated without lowering consumer value." It could be activities, resources, rules, or anything else. The common sense understanding of waste, according to Macomber and Howell (2004), is that anything has no worth. Waste is defined as the use of resources or the expenditure of effort without providing value. After Ohno (1994) classified waste into seven kinds, Womack and Jones (1996) defined waste as any action that consumes resources without contributing value.

2.4.2 Construction waste

Waste has long been regarded as a serious issue in the building sector, as well as in many large cities throughout the world (Al-Moghany, 2006; Chen et al., 2002; Shen et al., 2002; Teo and Loosemore, 2001; Smallwood, 2000; Wong and Tanner, 1997; Ferguson et al., 1995). Waste in the construction sector has been the focus of various study initiatives around the world in recent years, according to Formoso et al. (1999). Some of them have concentrated on the environmental harm caused by the production of material waste. On the other hand, a number of studies have been conducted, the most of which have focused on the economic aspects of waste in the building industry. Building site trash is defined as a non-hazardous by-product of activities such as new construction and rehabilitation. It is produced as a result of variables such as site preparation, material use, material damage, material non-use, excess procurement, and human error throughout the construction process (Mocozoma, 2002). Waste is defined by Hong Kong's Environmental Protection Department (EPD) as undesirable items generated during construction, such as rejected buildings and materials, overordered or surplus-to-requirements materials, and materials that have been utilized and discarded. Wood from formwork and false work, material and equipment wrappings, useless or surplus cement/ grouting mixtures, and damaged/surplus/contaminated construction materials are all examples of waste generated by the contractor during construction and maintenance.

2.4.3 Types of construction waste

Waste in construction can be divided into three categories: material waste, time waste, and machinery waste (Al-Moghany, 2006; Ekanayake and Ofori, 2000). However, the focus of this study is on waste materials.

2.4.3.1 Material waste

Construction material wastes are materials from construction sites that are no longer useable for construction purposes and must be discarded for various reasons (Yahya and Boussabaine, 2006). Construction material waste, according to Ekanayake and

Ofori (2000), is defined as any material, other than earth materials, that must be transported away from the construction site or used on the site for purposes other than the project's intended specific purpose due to damage, excess, or non-use, or that cannot be used due to non-compliance with the specifications, or that is a by-product.

2.5 Magnitude of waste in construction

In the Netherlands, Bossink and Brouwers (1996) did research on the measurement and avoidance of building waste in order to achieve the sustainability standards set forth by Dutch environmental legislation. Between April 1993 and June 1994, waste from seven different materials was measured in five different house-building projects. All material waste was sorted and weighed during the research. The amount of direct waste by weight ranged from 1 to 10% of the total amount of materials purchased. Furthermore, it was discovered that in the Netherlands, an average of 9% (by weight) of all purchased construction materials end up as site waste.

According to a Malaysian study, the following materials wastes are composed of 27 percent soil, 5 percent wood, 1.16 percent brick and blocks, 1 percent metal product, 0.20 percent roofing material, 0.05 percent plastic and packaging materials, and 65.80 percent concrete and aggregate (Begum et al., 2006). Jones and Greenwood (2003) found that the percentage of waste in ten materials was 36% for plaster board, 23% for packing, 20% for cardboard, 10% for insulation, 4% for lumber, 2% for chipboard, 1% for plastic, 1% for electric cable, and 1% for rubber (Yahya and Boussabaine, 2006).

Sand (25%), Lime (20%), Cement (14%), Bricks (14%), Ceramic Tiles (10%), Timber (10%), Rubble (7%), Steel (7%), Cement Blocks (6%), Paint (5%), and Asbestos Sheets (5%), according to Rameezdeen and Kulatunga (2004)'s study in Sri Lanka (3%).

According to Hong Kong research, roughly 5-10% of building materials end up as waste on construction sites. There are numerous human, mechanical, and other elements that contribute to this statistic (Poon & Jailon, 2004).

Forsythe and Marsden (1999) looked at how construction industry clients in Australia are responding to the requirement to improve the environmental performance of building projects. They created a model for analyzing the cost of garbage, including its collection and disposal, in a project. This model uses waste numbers for six different building materials with weights ranging from 2.5 to 22%. These were created as a consequence of a 15-site empirical research of house-building. The waste was quantified based on the number of materials delivered effectively on site, according to available documentation and conversations with representatives from several trades.

Picchi (1993) also reported on a modest study on material waste that took place between 1986 and 1987 at three home construction sites and tracked the amount of garbage removed. The waste percentage was anticipated to be between 11 and 17 percent of the building's planned weight. This equates to a waste rate of 0.095 to 0.145 t/m2. In the USA, construction activities generate an enormous amount of waste approximately over 29% of overall landfill volumes (Ferguson *et al.*, 1995).

According to Formoso et al. (2002), Pinto conducted one of the first studies on material waste in Brazil (1989). This study focused on a single case study based on data from an 18-story residential building project that was chosen because the construction business kept meticulous records of material supply and use. The direct and indirect wastes of ten building materials were calculated. The waste percentages include both direct and indirect waste. The overall waste accounted for 18% of the total weight of all materials purchased, resulting in a 6% increase in cost. This study made a significant addition by emphasizing the importance of indirect waste in comparison to direct waste. For example, indirect mortar waste accounted for up to 85 percent of the total volume of plaster. This is not only a waste of materials, but it also adds a large amount of needless weight to the construction of the building. This is not only a waste of materials, but it also adds a large amount of needless weight to the construction of the building. According to Datta (2000), construction sites in Tanzania, Zambia, Zimbabwe, and Botswana squander 20-25 percent of materials. According to Fatta et al., (2003), each 1000m2 of construction activity generates 50m3 of garbage in Greece. Ayarkwa and Adinyira (n.d.), observed that there is a wide range of wastage rates in Ghana, ranging from 5% to 27% of total materials purchased for construction projects.

2.6 Sources of materials waste

Construction waste is generated during the construction, renovation, and repair of buildings. During the design and construction stages, several wasteful actions can occur, wasting time and effort while offering no value to the client. Various elements have an impact on the waste stream's generation.

2.6.1 Natural Waste

Natural waste is a type of waste that costs more to prevent than it saves. Waste of materials can only be averted up to a certain point. Any effort done to prevent waste beyond that point will be unsustainable, as the cost of saving will outweigh the value of the resources saved. As a result, natural waste is permitted in the tenders. The amount of natural waste produced is determined by the cost-effectiveness of the management methods employed. The methodologies, as well as the natural waste, differ from one case to the next. For example, the cost of preventing waste in a project with a good material management policy will be lower than in a project that does not have one. Natural waste is a sort of trash that is more expensive to avoid than it is to save. Material waste may only be avoided to a certain extent. Any further effort to reduce waste will be unsustainable, as the cost of saving will outweigh the value of the resources saved. As a result, natural waste can now be used in tenders. The cost-effectiveness of the management strategies used determines the amount of natural waste created. The approaches, as well as the natural waste, are different in each scenario. For example, in a project with a sound material management policy, the cost of preventing waste will be lower than in a project without one. As a result, in the former case, the allowable level of natural waste will be lower than in the latter (Kulatunga et al., 2006; Formoso et al., 2002).

2.6.2 Direct waste

Direct waste, according to Skyoles and Skyoles (1987), is waste that can be avoided and involves the actual loss or removal and replacement of material. The cost of direct waste usually does not end up in the cost of material, but rather in the cost of removing and disposing of it. As a result, simple financial gains can be realized by preventing direct waste. Direct waste can occur at any point during the construction process, including before the delivery of materials to the job site and after the materials have been incorporated into the structure (Kulatunga et al., 2006; Formoso et al., 2002; Shen et al., 2002). Table 2.1 summarizes the many types of direct waste.

2.6.3 Indirect waste:

When materials are not physically lost and only a monetary loss results, this is referred to as indirect waste. For example, waste resulting from a concrete slab thickness that exceeds the structural design's requirements (Kulatunga et al., 2006; Formoso et al., 2002). Indirect waste is primarily caused by material substitution, waste caused by over allocation, where materials are used in greater quantities than those specified or not clearly defined in contract documents, errors, and waste caused by negligence, where materials are used in excess of the contract's requirements due to the construction contractor's own negligence (Shen et al., 2002).

2.7 Causes of Materials Waste

Many variables contribute to the development of construction trash on the job site. One or a combination of factors might result in waste. According to studies conducted in Hong Kong by Poon et al. (2001), there are numerous contributory reasons to trash formation, including both human and mechanical activity. The principal causes of materials waste in Hong Kong are summarized in Table 2.3.

There is waste at every stage of the construction process. Ordering improper materials for a project (in terms of quality, type, and size) was judged material waste by all contractors and 65 percent of consultants. This condition may emerge as a result of a lack of information flow, the deliberate use of low-quality materials to save money, or a project consultant's incorrect/inadequate specification. Two major causes of material waste, according to Bossink and Brouwers (1996) and Polat and Ballard (2004), are the selection of low-quality products and products that do not fit. Poor material handling results in material waste, according to all contractors and 61% of consultants. This can happen on the way to work, in the store, or during the application process. Poor handling can be caused by a lack of understanding about how to handle sensitive materials properly or a lack of job performance competence on the part of site workers. Poor storage methods were also cited as a source of material waste by 93% of contractors. Materials, especially fragile ones like ceramic tiles and glass, can be broken or damaged as a result of improper storage. Significant percentages of contractors and consultants believe that material waste is caused by overestimation, over-ordering, and poor site planning. Overestimation leads to material overordering, resulting in the delivery of more materials than are required for a work. Improper site layout, as a result of bad planning, disrupts the flow or sequence of activities on site, causes problems with material transportation and worker movement, and leads to poor handling and material damage. Cutting, shaping, sawing, and other construction waste can be caused by a lack of standardization of component dimensions, dimensions unrelated to material sizes, or inadequate dimensional coordination, all of which are design concerns. The majority of the causes of construction waste identified in their study have also been mentioned in prior studies (Bossink & Brouwers, 1996; Craven et al., 1994; Gavilan & Bernold, 1994; Garas et al., 2001; Polat & Ballard, 2004). Workers' mistakes cause material waste on the job site, according to 20% of contractors. In addition, 40% of consultants believe that a shortage of skilled labor leads to material waste. Garas et al. (2001) discovered that inexperienced laborers made frequent mistakes in a study of primary causes of waste generation in Egyptian construction. The majority of the causes of construction waste identified in their study have also been mentioned in prior studies (Bossink & Brouwers, 1996; Craven et al., 1994; Gavilan & Bernold, 1994; Garas et al., 2001; Polat & Ballard, 2004). Workers' mistakes cause material waste on the job site, according to 20% of contractors. In addition, 40% of consultants believe that a shortage of skilled labor leads to material waste. Garas et al. (2001) discovered that inexperienced laborers made frequent mistakes in a study of primary causes of waste generation in Egyptian construction.

The findings once again demonstrated that construction waste reduction is not only the responsibility of the construction business. In the program of needs and the design, the customer and the designer can make ecologically friendly choices. The design, procurement, material handling, operation, and residual activities have all been linked to material waste. The findings once again demonstrated that construction waste reduction is not only the responsibility of the construction business. In the program of needs and the design, the customer and the designer can make ecologically friendly choices. The design, procurement, material handling, operation, and residual activities have all been linked to material waste.

2.8 Wastage of key materials on construction sites

Many studies have been conducted to determine how much material is wasted on building sites. Steel reinforcement, concrete, formwork, blocks, cement, mortar, tiles, pipe, and aggregate are some of the materials that are thrown away on construction sites (Bossink & Brouwers 1996; Poon et al. 2004; Shen et al. 2003; Formoso et al. 2002).

2.8.1 Steel reinforcement

Steel reinforcement bars are a frequent building material (Shen et al., 2002). Controlling the usage of steel reinforcement on construction sites is difficult due to its weight and form, which makes it tough to manage (Formoso et al., 2002). Cutting, storage damage, and rusting are the three most common causes of steel waste (Shen et al., 2002).

Damage to mesh and bars, mud loss, and excessive usage of tying wire are all possible causes of steel reinforcement waste (Poon et al., 2002).

Steel reinforcement waste can be attributed to three main reasons, according to Formoso et al. (2002): When bars are chopped, short, useless portions are created.

Due to fabrication issues and encroachment, certain bars may have an unusually big diameter. Poor structural design in terms of standards and detailing, resulting in waste owing to non-optimized bar cutting.

2.8.2 Concrete

Concrete ready mixed (premixed concrete) and concrete site-mixed are the two types of mixed concrete (Formoso et al., 2002). Concrete is the most used building material, both for the substructure and the superstructure. In the case of ready mixed concrete supply, wastage is mostly caused by a mismatch between the quantity of concrete ordered and the quantity required. Because to poor planning, the contractor may not know the exact quantity, resulting in over-ordering. Concrete waste is also a result of project delays and waste treatment procedures that are unneeded (Shen et al., 2002). In a survey of 22 building sites in Hong Kong, ready mixed concrete was used for 80% of the work. 3–5% of the material was wasted on average, with the majority of it lost due to excessive material ordering, broken formwork, and redoing due to poor concrete placement quality (Poon et al., 2004). The building contractor may not know the required quantity due to poor planning, according to Bossink and Brouwers (1996). As a result, the means of transportation and formwork are overordered and overfilled. Skimming, or leveling off the concrete poured into the formwork, is required if the formwork is overfilled.

2.8.3 Timber formwork

Timber for formwork is a major contributor to building trash in Hong Kong, accounting for 30% of all garbage found on construction sites. Timber has a variety of characteristics that make it a popular building material. It's reasonably priced, lightweight, and has a good load bearing capability. It is also malleable and easily cut, allowing it to be moulded into a variety of different concrete pieces. However, because of its low durability and reusability, it is a high-waste material. The natural deterioration that occurs as a result of use and waste cutting are the two main causes of wastage. It's difficult to avoid both (Shen et al., 2002). Timber board is another common formwork material. Wastage occurs mostly as a result of usage and waste reduction, both of which are difficult to eliminate (Shen et al., 2002). According to a study conducted on Hong Kong building sites, the majority of timber waste is generated by formwork, with a smaller amount generated by cutting timber for internal finishing and fittings. After many reuses, the majority of the formwork materials shipped to site were eventually dumped as waste (100% wastage) (Poon et al., 2004).

2.8.4 Cement

Because this material is utilized as a component of mortar and cast in-place concrete in a variety of operations, such as brick work, plastering, and floor screed, analyzing cement waste is a bit of a challenge. In Brazil, on the other hand, this is a rather pricey material with a significant degree of waste (Formoso et al., 2002).

2.8.5 Sand, Lime, and Premixed Mortar

Sand and mortar are typically delivered on trucks in some parts of the world, such as Brazil, and there may be additional losses as a result of the lack of control in the delivery operation and the necessary handling it necessitates (Formoso et al., 2002). Some enterprises in Brazil have begun to employ pre-packaged, ready-to-use mortar mixes, which tends to minimize many of the issues associated with distribution, handling, and transportation. Although there is insufficient evidence, it appears that such adjustments have reduced mortar waste when compared to the previous way of making mortar on site (Formoso et al., 2002).

2.8.6 Bricks and blocks

The most frequent walling materials are bricks and blocks (Shen et al., 2002). Cutting is the primary source of brick and block trash. Because of the fragile nature of the materials, an unpacked supply may result in more wastage or broken damage. Unused bricks left on site may eventually wind up in the trash skip (Shen et al., 2002). Combinations of materials waste causes are related to the waste of bricks and blocks in the majority of underperforming sites. There are issues with material delivery at various sites, such as a lack of control over the amount of bricks or blocks actually delivered and brick damage.

2.8.7 Pipes and wires

It's a difficult chore to keep track of the sources of waste in electrical pipelines, electrical cables, and hydraulic and sewage pipes. Electrical and plumbing services are frequently subcontracted, and materials are occasionally supplied by the specialised subcontractor. Due to the fragmented nature of this work on site, such materials are frequently moved in and out. Another challenge with waste measurement is that both plumbing and electrical service designs are frequently under-detailed, and many changes in pipe routing are made during installation. The most significant sources of waste for these materials are short, unusable pieces created when pipes are cut, as well as poor material distribution design that does not encourage cutting optimization (Formoso et al., 2002).

2.9 Materials control on site

Materials control refers to the operations that ensure that materials are available in the required quantity and at the appropriate time, at the lowest possible cost, in order to meet production goals and corporate objectives. Materials control operations include calculating material requirements, requisitioning components for purchase or fabrication based on make or buy economics, record keeping, production requisitioning, and status reporting procedures (Manteau, 2010).

Control of the materials used on site begins when the contractor is given the keys to the property. All items delivered to the job site must be checked against the applicable criteria. Apart from the normal waste of materials on site, there is a great deal of damage, which is frequently the result of a lack of effective oversight. The person in charge of materials control must be the first to take responsibility. Many foremen and supervisors consider their primary role to be that of a materials supplier to the group they supervise, and hence overlook materials handling. Trades foremen will have enough time to complete their jobs properly if a materials controller is assigned to forecast material requirements and distribute supply. Materials use and handling are ultimately the responsibility of site management. Materials, on the other hand, can be stored on site for long or short periods of time until they are required (Johnston, 1981).

2.9.1 Materials storage and handling on site

Materials handling, as defined in the context of this study, entails transporting materials as efficiently as possible from one location to another. Materials handling is important, according to Badu (2008), for the following reasons: If output is to be maintained, materials flow must be maintained. The type of materials handling system used, the equipment used, and the quality of training among the operators all have a significant impact on the health and safety of many members of staff. In terms of operational costs, earnings, and overall production costs, the cost element is critical. In terms of materials handling equipment, time, and labor, managing materials is quite costly. Damage to materials can be highly costly, and it will almost certainly lower the stock life of many materials.

Materials handling is divided into three steps (Badu, 2008).

Table 2.9 Advantages and Disadvantages of Materials Handling Methods

The provision of proper space, protection, and control of building materials and components held on site during the construction process is known as material storage. According to Johnston (1981), insufficient oversight and irresponsible attitudes, as well as incorrect incentives, can cause inappropriate storage and handling of resources on building projects, resulting in waste. As a result, there is a need for proper material storage and handling on construction projects, as this might be a remedy to poor material storage and handling.

2.10 Waste Minimization

Waste minimization is defined by the Environmental Protection Agency (EPA) of the United States of America as "any method that decreases the volume or toxicity of a waste that requires disposal." In a practical sense, it refers to any strategy that eliminates waste. Government requirements, as well as internal cost effectiveness, demand that all wastes, particularly hazardous wastes, be produced and disposed of as little as possible. Waste reduction, according to Poon and Jaillon (2002), is any approach, process, or action that avoids, eliminates, or minimizes trash at its source, or permits waste to be reused or recycled.

Waste minimization is defined by the Environmental Protection Agency (EPA) of the United States of America as "any method that decreases the volume or toxicity of a waste that requires disposal." In a practical sense, it refers to any strategy that eliminates waste. Government requirements, as well as internal cost effectiveness, demand that all wastes, particularly hazardous wastes, be produced and disposed of as little as possible. Waste reduction, according to Poon and Jaillon (2002), is any approach, process, or action that avoids, eliminates, or minimizes trash at its source, or permits waste to be reused or recycled. Waste minimization is defined by the Environmental Protection Agency (EPA) of the United States of America as "any method that decreases the volume or toxicity of a waste that requires disposal." In a practical sense, it refers to any strategy that eliminates waste. Government requirements, as well as internal cost effectiveness, demand that all wastes, particularly hazardous wastes, be produced and disposed of as little as possible. Waste reduction, according to Poon and Jaillon (2002), is any approach, process, or action that avoids, eliminates, or minimizes trash at its source, or permits waste to be reused or recycled.

To achieve waste minimization, the company must commit to increasing the proportion of non-waste leaving activities. Waste minimization is more about common sense and a shift in mindset than it is about new technologies (Hoe, 2006). Waste minimization is the initial step in any waste management strategy. It is obvious that the optimum solution is to avoid producing any trash at all (Hoe, 2006). Minimization is examining the flow of materials into and out of a facility and determining what efforts could be taken to reduce the quality and variety of materials eliminated (Hoe, 2006). The waste minimization process, according to Begum et al. (2006), consists of two core operations: source reduction and recycling. To avoid trash formation, source reduction is preferred, while recycling is beneficial to conserve resources and prevent materials from entering the waste stream (Al-Moghany, 2006; Begum et al., 2006). Waste minimization, or waste reduction, in industry refers to methods such as: (1) product design adjustments; (2) inventory management changes; (3) operational and maintenance procedure changes; (4) material changes; (5) equipment replacement modifications; and (6) waste reuse/recycling (Hoe, 2006).

Waste reduction, a general word in the preferred waste management hierarchy, is frequently the recommended technique of managing waste to accomplish the environmental management system's broader environmental objectives (Hoe, 2006). Changes to the raw material input, the manufacturing process, and/or the end product may all be part of this system. It can be accomplished through minor procedural adjustments or big modifications that may or may not require or justify significant capital expenditure (Hoe, 2006).

2.10.1 Waste Minimization in Construction

The construction sector consumes a significant number of resources, however when the life cycle of the materials on site is closely investigated, it is widely acknowledged that a significant fraction of the materials is wasted due to poor material control on construction sites (Formoso et al., 2002; Hoe, 2006; Poon et al., 2004).

According to Coventry et al. (2001), there is a lot of potential for reducing construction and demolition waste. Practical waste minimization measures necessitate a thorough grasp of the factors that contribute to building waste (Hoe, 2006). Faniran and Caban (1998) used a survey to investigate waste minimization measures and the relative importance of construction waste sources. The researchers discovered that a significant number of businesses lacked waste-reduction programs. Furthermore, while the majority of companies with particular waste reduction policies attempted to reduce waste at the source, such as by avoiding waste generation in the first place, this effort was confined to garbage generated by site offices and facilities (Faniran & Caban, 1998). Their study concluded that by addressing the origins of all waste generated throughout the construction phase, there is potential for improving the effectiveness of waste minimization at source.

People modifying their wasteful behavior, according to Teo and Loosemore (2001), makes a substantial contribution to waste reduction in the construction business. Waste is an unavoidable by-product of construction; but, with a lack of suitable resources and incentives to support it, waste management is a low project priority (Teo & Loosemore, 2001). Their findings reflect Lingard et al. (2000) study, which found that the availability of local infrastructure and top management support are the most important factors influencing waste reduction behavior on projects. Clear communication of waste management policies, supply of appropriate waste infrastructure, and cooperation and promotion of a sense of collective responsibility among the workforce are among their ideas to help managers change operators' attitudes toward garbage. Some of the waste minimization measures identified in the literature are listed in Table 2.10.

2.10.2 The 3 "R"s of construction waste minimization

The 3 "R"s. The three concepts of building waste minimization are reduction, reuse, and recycling. Trash reduction, also known as source reduction, refers to reducing waste from being created in the first place (Begum et al., 2006). One of the fundamental principles of sustainable construction is this (Hoe, 2006). Contractors who strive for zero waste not only save natural resources and reduce the environmental implications of their extraction and processing, but they also save money (CIRIA, 1998). Designing with standard building material proportions in mind, for example, lowers purchasing, handling, and disposal expenses (Hoe, 2006; Al-Ansary et al., 2004).

Re-use is a type of waste reduction that: (1) extends resource supplies; (2) prevents high-quality resources from becoming low-quality garbage; and (3) cuts energy and pollution even more than recycling (Begum et al., 2006). Recycling garbage as useable resources, according to Ekanayake and Ofori (2000), is an important environmental management method for achieving sustainable development. Recycling waste, on the other hand, without adequately founded scientific research and development, can cause environmental problems that are far worse than the garbage itself. The successful research and development of new building materials or components using waste as raw material, is a complex and multidisciplinary task, including technical, environmental, financial, marketing, legal and social aspects (Hoe, 2006).

2.10.3 Source Reduction

Any effort that minimizes or eliminates waste generation at the source, usually within a process, is referred to as source reduction (Begum et al., 2006). It is at the top of the construction waste management hierarchy; it has the greatest environmental benefit because the activity has a direct impact (Hoe, 2006). Many designs and job site approaches, according to Al- Ansary et al. (2004), can considerably cut waste and material costs on a construction project while requiring only minor changes to typical operationsRather than ordering single lengths of supplies, contractors might employ source reduction on the job site by ordering components in variable lengths to fit building project requirements (Hoe, 2006). Waste can be reduced in the construction process by carefully coordinating material purchases (Lim & Ofori, 2004).

2.10.4 Reuse/Salvage of materials

According to Hoe (2006), the goal of reuse in a construction project is to salvage and reprocess as many resources as possible. Materials removed during demolition, scrap generated on site, and used materials or scraps from other operations all fall under this category. Many materials from demolished structures can be removed, cleaned, and restored, then reused in the same or other construction projects (CIRIA, 1998).

When reusing materials, the contractor should make sure that the material is suitable for the job, of good quality, and ready to be reused. The contractor should also take care when installing and removing materials, as well as providing warehousing so that they can be reused in the future. Excessive fasteners and adhesives might make it difficult to reuse materials. During the original construction process, provisions for changes and remodeling might be made. Controlling the use of materials by subcontractors and separating garbage for reuse would limit the quantity of waste generated (Hoe, 2006).

2.10.5 Recycling

Recycling is typically defined as the separation of recyclable materials from nonrecyclable elements and delivering them to a hauler or business to be processed into new goods (Al-Moghany, 2006; Hoe, 2006). Purchasing building materials that have recycled content aids in the development of a market for the waste material that is recycled on the job site.

2.10.6 Benefits of Construction Waste Minimization

Construction and demolition operations have distinct waste minimization difficulties (Hoe, 2006; Milward, 1995). The contractor must be flexible and innovative in identifying ways to reduce, reuse, or recycle the many sorts of wastes because each project is different and generates its own unique combination of wastes (Hoe, 2006).

Managing construction and demolition trash, according to Hoe (2006), can be a substantial cost to a company. During the construction process, some wastes necessitate cautious and possibly costly handling measures. Reducing the quantity of waste, a firm must dispose of might so benefit it in a variety of ways. Waste minimization considerations can yield benefits such as financial and environmental benefits (Al-Moghany, 2006; Poon & Jailon, 2002).

- ***Financial benefits***

Waste minimization can give financial benefits, as well as cost and time savings in some circumstances. The financial advantages can be realized over a short or extended period of time. However, by analyzing the life cycle costs, cost benefits can be enjoyed throughout the entire construction process. Reduced transportation expenses for waste products are among the financial benefits (less transportation because of less material wasted). Transportation to and from the location, as well as disposal, are all included. Costs of trash disposal are reduced. Waste minimization reduced the quantity and cost of raw resources purchased. Purchase price of new materials is reduced when reuse and recycling are taken into account (depending on materials).

Increased returns can be achieved by selling waste materials to be reused and recycled. Long term benefits through optimizing the building life concept, by avoiding expenses from demolition and construction of new buildings (Al-Moghany, 2006; Poon and Jailon, 2002). Use of recycled materials has reduced waste storage costs and minimized the dereliction of land (Al-Moghany, 2006; Lnyang, 2003). Sometimes, reuse and recycling may not always be financially viable, hence other considerations should be considered such as environmental benefits (Al-Moghany, 2006).

- ***Environmental benefits***

Waste minimization can have environmental benefits, which are vital to examine in light of the grave situation with building waste (Al-Moghany, 2006; Poon & Jailon, 2002). These environmental advantages include: The amount of garbage produced has decreased. Utilization of garbage created in a cost-effective manner. As a result of disposal, environmental problems such as noise and pollution are reduced. Transportation of rubbish to be disposed of is reduced (hence less noise, vehicle emission pollution, and energy used).

2.10.7 Lean Thinking

Lean thinking is a production philosophy and methodology that originated in Japan. It is built around various elements of the Toyota Production System (TPS) (Dao & Follestad, 2009; Tezel, 2007). These aspects will be covered further down.

2.10.8 Lean Production

The phrase "lean production" was originally used in Womack et albook .'s "The machine that changed the world" (1990). The International Motor Vehicle Program (IMVP) at Massachusetts Institute of Technology (MIT) coined this phrase to describe the Japanese method of automobile manufacturing as opposed to typical Western mass production methods. When compared to mass production, lean production utilizes less of everything. Lean provides a technique to produce more with less human effort, less equipment, less time, and less space, according to Womack and Jones (2003).

The lean production system is founded on the premise that manufacturing should only occur when a client request emerges. Lean production employs a pull method for inventory and production control in this regard. Products are manufactured Just-in-Time in Lean processes to meet the needs of customers.

2.10.9 The Right Lean Wastes

Lean philosophy is a common-sense approach that aims to eliminate waste from the manufacturing process in a methodical manner. Waste, according to Womack and Jones (2003), is any human action that consumes resources but does not generate value. Ohno (1988) divides waste into seven categories, all of which may be seen in any manufacturing facility across the world: (1) overproduction; (2) waiting; (3) needless transportation; (4) unsuitable processing; (5) excessive inventory; (6) unnecessary motion; and (7) faults. Liker (2004) added an eighth waste, which is underutilized employee inventiveness.

- ***Overproduction***

This is the most serious waste since it obstructs the smooth flow of goods and services and is likely to reduce quality and productivity. Overstaffing, storage, and transportation costs are all wastes when things are produced for which there are no orders. Excessive lead and storage durations are also common outcomes of overproduction. As a result, flaws may go undetected for longer, products may deteriorate, and artificial work rate pressure may be created.

- ***Waiting***

The inefficient use of time is the subject of this waste. When items are not moving or being processed, there is a period of waiting. When workers in the manufacturing industry are waiting for equipment, plans, or directions on how to start, this waste happens. This waste has an impact on both commodities and workers, who both have to wait. For example, the optimal use of waiting time would be to train personnel.

- ***Unnecessary transport***

The third type of waste is the movement of commodities. Carrying work in progress (WIP) over long distances, inefficient transportation, or moving materials, parts, or finished goods into or out of storage or between operations are all examples of inefficient transportation. If taken to its logical conclusion, any movement in the factory could be considered waste. Furthermore, double handling and excessive movement are likely to result in material damage and deterioration.

- ***Inappropriate processing***

This waste is the result of extra processes taken to process the parts. Inappropriate processing might be shown as, for example, the use of expensive, high-tech equipment when simple tools would suffice. Overcomplexity discourages ownership and encourages staff to overproduce in order to recoup the big investment made in the complex machines.

- ***Unnecessary inventory***

This could be due to material being stored on site too much ahead of when it is required. Inventory that isn't needed adds to lead times, obsolescence, damaged goods, transportation, storage costs, and delays. The extended lead time makes it difficult to identify problems quickly and discourages communication. Inventory can be decreased by achieving flow between work stations.

- ***Unnecessary motion***

Employees must execute any unnecessary motions during the course of their task, such as stretching or bending. Walking might be considered waste if taken to its logical conclusion. Such waste is exhausting for staff and is likely to result in low productivity and, in certain cases, poor quality.

- ***Defects (Rework)***

Because flaws are direct costs, this is referred to as bottom-line waste. The production of defective parts or their rectification is usually a waste of money. Wasteful handling, time, and effort are associated with repair or rework, scrap, and inspection.

- ***Unused employee creativity***

It's about squandering time, ideas, talents, possibilities for improvement, and learning by failing to engage or listen to staff (Dimancescu et al., 1997; Hines and Rich, 1997; Liker 2004).

2.10.10 Lean Principles

"Lean" is all about delivering the right items to the right place at the right time, in the right quantity, while minimizing waste and remaining open to change (Kempton, 2006). The core principle of lean production is that by eliminating waste, quality can be enhanced, and production times and costs may be decreased (Kempton, 2006). A set of basic production principles should be applied to reduce waste (Table 2.11).

Table 2.11 Key Manufacturing Principles Employed to Reduce Waste

Lean Principle	**Explanation**
Perfect first- time quality	Achieve zero defects, revealing and solving problems at the source
Waste minimization	Eliminating all non-value-adding activities and maximizing the use of resources
Continuous improvement	Reduction of costs, increase quality and productivity
Pull processing	Products pulled from the consumer end, i.e. not pushed from the production end

Flexibility	The production of different mixes and/ or greater diversity of products, without compromising efficiency
Relationships	Building and maintaining long-term relationships with suppliers

Source: (Kempton, 2006)

Liker (2004), on the other hand, maintains that the equation may vary depending on the organization. He maintains that Lean philosophy is about designing and meticulously executing the ideas to best fit your own organization, not about duplicating the tools used by Toyota in a specific manufacturing process. The next section goes through the many tools utilized in Lean philosophy.

2.10.11 Benefits of lean construction

Liker (2004), on the other hand, maintains that the equation may vary depending on the organization. He maintains that Lean philosophy is about designing and meticulously executing the ideas to best fit your own organization, not about duplicating the tools used by Toyota in a specific manufacturing process. The next section goes through the many tools utilized in Lean philosophy. In addition, LC produces better results in projects that are complex, unpredictable, and time-sensitive (Salem et al., 2005). It is believed that its deployment in the building sectors of many emerging economies will provide the following benefits (Mossman, 2009; Lehman & Reiser, 2004).

2.10.12 Barriers to the implementation of lean construction

The traditional building system is primarily project-based, with one-of-a-kind setups (Hook & Stehn, 2008; Vrijhoef & Koskela, 2005). To modernize the construction industry and ultimately raise consumer happiness, the sector's capabilities and efficiency must be increased (Alinaitwe, 2009). Various parties in the construction industry have taken a variety of ways to assist in the development of methods that are thought to be able to improve and, as a result, raise the sector's efficiency and effectiveness (Alinaitwe, 2009; Mastroianni & Adelhamid, 2003).

Many of the specialist areas and disciplines in the construction business are based on cyclic processes. Proponents of lean construction say that by identifying unproductive activities in processes and making adjustments for them, improved understanding and overall performance may be achieved (Alinaitwe, 2009; Dunlop and Smith, 2004).

A set of flow and conversion operations make up LC (Alinaitwe, 2009). Conversion activities are actions that add value to a material or change information into a product, while flow represents chores such as inspections, waiting, transferring, and storage (Alinaitwe, 2009). Harris et al. (2005) defines lean construction as a concept that includes Total Quality Management (TQM), Last Planner System (LPS), Business Process Re-engineering (BPR), Concurrent Engineering (CE), Product Circles (PCs), and Team and Value Based Management from the construction management industry. In the opinion of Alinaitwe (2009), most of these concepts (Figure 2.4) are interrelated and all aim to improve performance while minimizing waste.

As with implementation of other methods or approaches aimed at increasing the performance of the construction sector, the application process of lean principles is sure to encounter various obstacles. Research findings of the Production Management Center (GEPUC) of the Catholic University of Chile, has shown that the application of the LC concept in the industry has faced problems pertaining to time, training, organizational aspects and lack of self-criticism (Alarcon et al., 2008). Furthermore, attitudes, internal connections, and cooperation are all key issues with the use of the lean construction idea. Obstacles in these areas include a lack of organizational culture that supports teamwork, a lack of group culture, a lack of shared vision and consensus, and a lack of knowledge and skills, among others (Castka et al., 2004; Cua et al., 2001; Conte and Gransberg, 2001).

Several studies have been undertaken in various countries to look into aspects that could influence the success of lean construction adoption. Based on a thorough and critical evaluation of worldwide literature relevant to the adoption of lean practices, Bashir et al. (2010) divided these hurdles into six categories. Among the steps taken to overcome potential roadblocks to lean deployment are the following:

Construction identified from literature are:

Table 2.15 Barriers to Implementation of Lean Construction

No.	BARRIERS
1	Lack of interest from clients
2	Waste accepted as inevitable
3	Poorly defined individual responsibilities
4	Lack of training
5	Less involvement of contractors and specialists in design process
6	Delays in decision making
7	Lack of top management support and commitment
8	Poor project definition
9	Delay in materials delivery
10	Lack of equipment
11	Materials scarcity
12	Unsuitable organizational structure
13	Lack of supply chain integration

14	Poor communication
15	Long implementation period
16	Inadequate pre-planning
17	Lack of client and supplier involvement
18	Corruption
19	Poor professional wages
20	Lack of standardization
21	Lack of technical skills
22	High level of illiteracy
23	Lack of awareness programs
24	Difficulty in understanding concepts
25	Inconsistency in government policies
26	Lack of buildable designs
27	Incomplete designs
28	Lack of agreed implementation methodology
29	High dependency of design specifications on in-situ materials and components rather than standardized and industrialized prefabricated components
30	Extensive use of subcontractors
31	Lack of long-term commitment to change and innovation
32	Lack of long-term relationship with suppliers
33	The fragmented nature of the construction industry
34	Lack of holistic implementation
35	Inadequate exposure to requirements for lean implementation
36	Lack of information sharing

37	Lack of social amenities and infrastructure
38	Unsteady price commodities
39	Inflation
40	Uncertainty in supply chain

Source: (Bashir et al., 2010)

2.10.13. Summary

Construction activities generate waste that is both avoidable and unavoidable. Identifying and categorizing the different types and sources of avoidable waste might help reduce it. This chapter examined literature on the global and Ghanaian construction industries, material waste, sources and causes of material waste, and waste mitigation strategies. It goes on to explain lean thinking, lean production, and lean production concepts, as well as the introduction of lean construction in the construction sector and the challenges that it faces.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the research method adopted in this study. It discusses the design of the survey questionnaire and the selection of sample respondents for the questionnaire survey. The statistical tools for the data analysis are also discussed.

3.2 Research design

Research design is the overall plan for obtaining answers to the questions being studied and for handling some of the difficulties encountered during the research process (AlMoghany, 2006; Polit & Hungler, 1999). Research design is an action plan for getting from „here" to „there" where „here" may be defined as the initial set of questions to be answered, and „there" is some set of conclusions (answers) about these questions. Between „here" and „there" there are a number of major steps, including the collection and analysis of relevant data (Al-Moghany, 2006; Naoum, 1998). According to Al-Moghany (2006), researchers cannot assume that people think in certain ways without asking them what they think. The design normally specifies which of the various types of research approach will be adopted and how the researcher plans to implement scientific controls to enhance the interpretability of the results (Polit and Hungler, 1999). There are a variety of survey designs that can be used to accommodate different substantive needs and problems if those problems are anticipated in the planning of the survey (Al-Moghany, 2006; Weisberg & Bowen, 1977). The structured questionnaire is probably the most widely used data collection technique for conducting surveys to find out facts, opinions and views (Naoum, 1998). Interviews can be classified according to the degree to which they are structured. In an unstructured or nondirective type of interview the interviewer asks questions as they come to mind. On the other hand, in the structured or directive interview the questions are specified in advance (Dessler, 2000). In a quantitative study, the steps involved in investigating are fairly standard (Al-Moghany, 2006).

This study adopted the development and administration of structured questionnaires. The questionnaire survey was adapted to get feedback on opinions of respondents‟ about wastage of building materials and the implementation of lean principles in the Ghanaian construction industry. The site visits involved observations where the researcher sought to find out how materials were stored and handled and also to provide a compendium on high waste generating building materials used in the construction industry.

3.3 Target Population

This study sought to examine the understanding of how to reduce waste on building construction sites using lean concepts. The target population of the study comprised construction site managers and supervisors employed by D1K1 and D2K2 construction companies within the Navorogo Municipality of the Upper East region of Ghana. Thus, target population comprised; the project managers, project engineers, site engineers/managers, Works superintendents, and site supervisors employed by D1K1 and D2K2 contractors. The municipality was chosen based on convenience and the ease with which the researcher could obtain data. The classification of companies according to the Ministry of Water Resources Works and Housing indicates that these companies represent the highest class with the D1K1 having no limit to the size of the project they can undertake. The decision to use D1K1 and D2K2 companies was based on the fact that they are relatively well organized in terms of human capital and other related resources. Again, these companies characteristically have some permanent professional team members at all times and to some extent have comparatively good administrative structures to ensure quality management practices. Available data at the Ministry of Water Resources, Works, and Housing indicate that D1K1 and D2K2 construction firms that are in good standing operating nationwide as of April 2019 were 102. A sampling frame was compiled for the construction professionals working in the D1K1 and D2K2 operating in the Upper East region.

3.4 Sampling technique and sample size

The concept of sample arises as a result of the inability of the researcher to test all individuals in a given population and must be representative of the population from which it is drawn. The study adopted a census approach in the first stage in which the population of D1K1 and D2K2 contractors operating in the two selected regions was used. In the second stage systematic random sampling was adopted to select the construction site managers and supervisors using the sampling frame compiled. The sample size must be adequate so that generalizations can be drawn from the statistical analysis for a specific conclusion (Oskar, 2012). Out of the total construction site managers and supervisors (205) in the regions, a sample size of 136 was determined based on (Krejcie and Morgan 1970) Table for sample size determination in Table 3.1 below.

Table for determination of sample size (Source Krejcie and Morgan 1970)

N	*S*	*N*	*S*	*N*	*S*
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	1000000	384

Note. *N* is population size.
S is sample size.

Krejcie, R.V. and Morgan, D.W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement*,Vol. 30, 607-610.

3.5 Data Collection

The study depended on both primary and secondary data. Primary data was made up of first-hand data collected by the candidate through the use of questionnaires, interviews and site visits (observation). The secondary sources of data were obtained using relevant books, journals, magazines and research papers.

3.5.1 Research Instrument

The research data was collected mainly through interviews and questionnaires. Field observations through site visits were also employed to gather data on high waste generating building materials.

3.5.2 Questionnaire Design

The questionnaire, which consisted of 3 major sets of closed-ended questions was designed to obtain data on the sources and causes of materials waste and waste minimization measures, the questionnaire further sought to obtain information on the level of knowledge of construction professionals on the concept and benefits of lean construction and barriers to the implementation of lean construction in the Ghanaian building industry. Interviews were also used to obtain more specific information about material waste and lean construction.

3.5.3 Structure of questionnaire

The questions were constructed using the Likert scale. The respondents were asked to rank on a scale of 1-5 factors that cause materials waste on construction sites where 1= „Highly unimportant", 2= „Unimportant", 3= „Neutral", 4= „Important" and 5= „Highly important". For each waste minimization measure, the respondents were asked to score the level of contribution to waste minimization on the Likert scale of 1 to 5 where 1= „very low", 2= „low", 3= "Medium", 4= „High" and 5= „Very high". The respondents were further asked to score each measure according to the level of practice in their organization on a scale of 1 to 5 where 1= „Not practiced at all", 2= „Not practiced", 3= „Practiced", 4= „Frequently practiced" and 5= „Most frequently practiced".

Concerning the principles of lean construction, the respondents were asked to indicate their level of agreement to the application of the principles to project delivery in the construction industry on a five- point Likert scale (from 1= „highly disagree" to 5 = „highly agree"). For the achievability of customer values, respondents were asked to rank from 1 = „highly unachievable" to 5= „highly achievable". For the benefits of lean construction, the respondents were asked to rank from 1 = „highly unbeneficial" to 5 „highly beneficial" and for measures to bridge the knowledge gap, respondents were asked to rank from 1 „highly unimportant" to 5 „highly important".

On the issues of barriers to the implementation of lean construction, the respondents were asked to score the severity of the 33 potential barriers out of the forty which were pretested to the implementation of lean construction on the Likert scale of 1-5 where 1= „Not very severe" and 5= „Very severe". The 17 measures to overcome potential barriers to implementation of LC were also scored on a scale of 1-5, where 1= „Highly Unimportant", 2= „Unimportant", 3= „Neutral", 4= „Important" and 5= „highly important.

3.5.4 Procedure for data collection

A sample of 83 construction professionals from D1K1 construction organizations in the Ashanti region were considered for the administration of the questionnaires. The questionnaires were administered through google form.

3.6 Data analysis

The completed questionnaires were edited to ensure completeness, consistency and readability. Once the data had been checked, they were arranged in a format that enabled easy analysis. Quantifiable data from the questionnaires was coded into the software for analysis. Statistical Package for Social Sciences (SPSS 16.0) was selected because it was considered to be user-friendly. Descriptive statistical analysis techniques were used as well as relative importance index and inferential statistics.

3.7 Summary of the chapter

The research methodology used in this study was discussed as above. A description of how the questionnaire was administered and the various sections in the questionnaire were highlighted. Subsequently, the statistical tools for data analysis were discussed. With this background, statistical results obtained from the data are discussed in chapter four.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

The results of the survey are reported and discussed in this chapter. Following the completion of the questionnaire survey, the responses were statistically analysed.

4.2 Response Rate

A total of 136 questionnaires were distributed to the respondents and 65 were completed and returned. The response rate achieved was therefore 48%. This response rate is considered adequate (Kheni & Ackon 2013).

4.3 Demographic Characteristics of the Respondents

The first section delves into the respondents' demographics and how these characteristics influence consultants' attitudes on on-site waste. The demographic features of the respondents are shown in Table 4.1.

Table 4.1 Category of Respondents

Variable	Frequency	Percent	Valid Percent	Cumulative Percent
Gender				
Male	77	84.6	84.6	84.6
female	14	15.4	15.4	100
Total	**91**	**100**	**100**	
Educational qualification				
PhD	1	1.5	1.5	1.5
Master's degree	18	27.7	27.7	29.2
Frist degree	32	49.3	49.3	78.5
Diploma	14	21.5	21.5	100
Total	**65**	**100**	**100**	
Work experience				
Below 5years	5	7.8	7.8	7.8
5-10years	11	16.9	16.9	24.7
11-15years	8	12.3	12.3	37.0
16-20years	27	41.5	41.5	78.5
Above 20years	14	21.5	21.5	100
Total	**65**	**100.00**	**100.00**	
Category of Professionals				
Architect	28	43.1	43.1	43.1
Quantity Surveyor	16	24.6	24.6	67.7
Civil Engineer	9	13.8	13.8	81.5
Building Manager	12	18.5	18.5	100.0
Total	**65**	**100.0**	**100.0**	

4.3.1 Gender of Respondents

Figure 4.1 depicts the gender of the respondents. According to the questionnaire results, 62 of the respondents were males, accounting for 95% of the total, while 3 were females, accounting for 5% of the total. This suggests that men account for a greater proportion of the professionals in Ghana's construction industry.

4.3.2 Area of specialization of Respondents

Figure 4.1 illustrates the respondents' professional standing in each area. Architects received 43.1 % of valid responses in this study, whereas quantity surveyors, civil engineers, and building managers received 24.6 %, 13.8 %, and 18.5 %, respectively. Architects made up the majority of the responders.

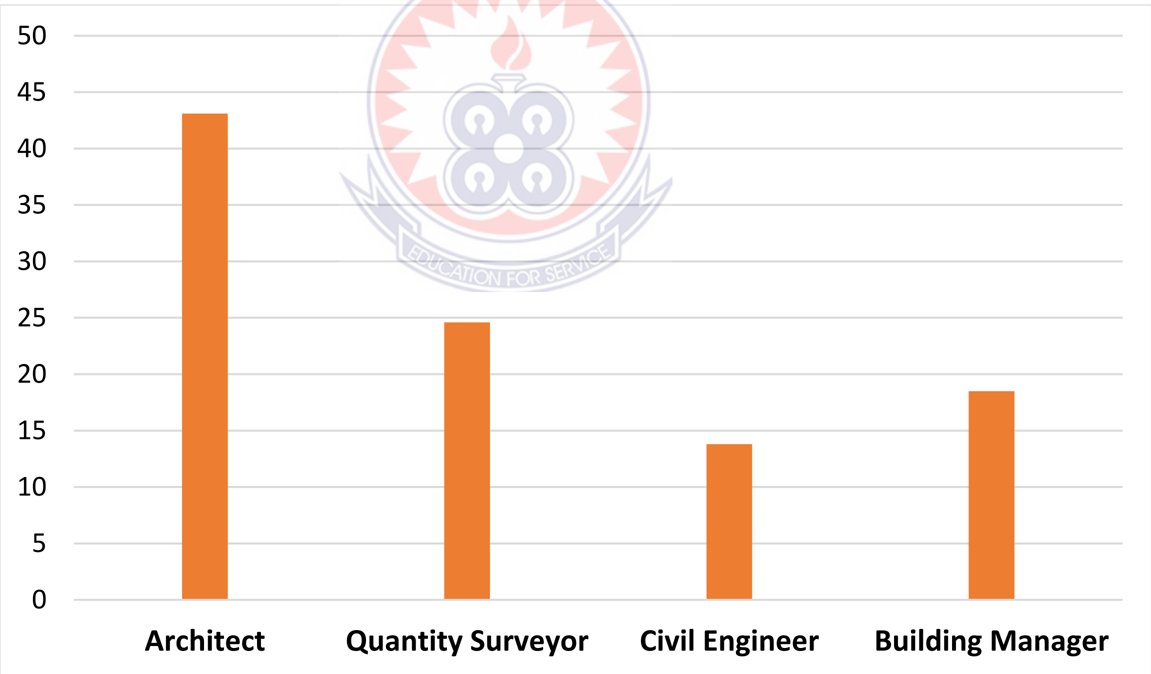

Figure 4.1 Areas of specialization of Respondents

4.3.3 Respondents Work Experience

Figure 4.3 shows the number of years respondents had worked in the construction industry. According to the report, 7.8% of respondents have worked in the construction business for fewer than 5 years. Respondents with 5 to 10 years of work experience received 16.9%, 11 to 15 years received 12.3%, 16 to 20 years received 41.5 %, and those with more than 20 years received 21.5 %.

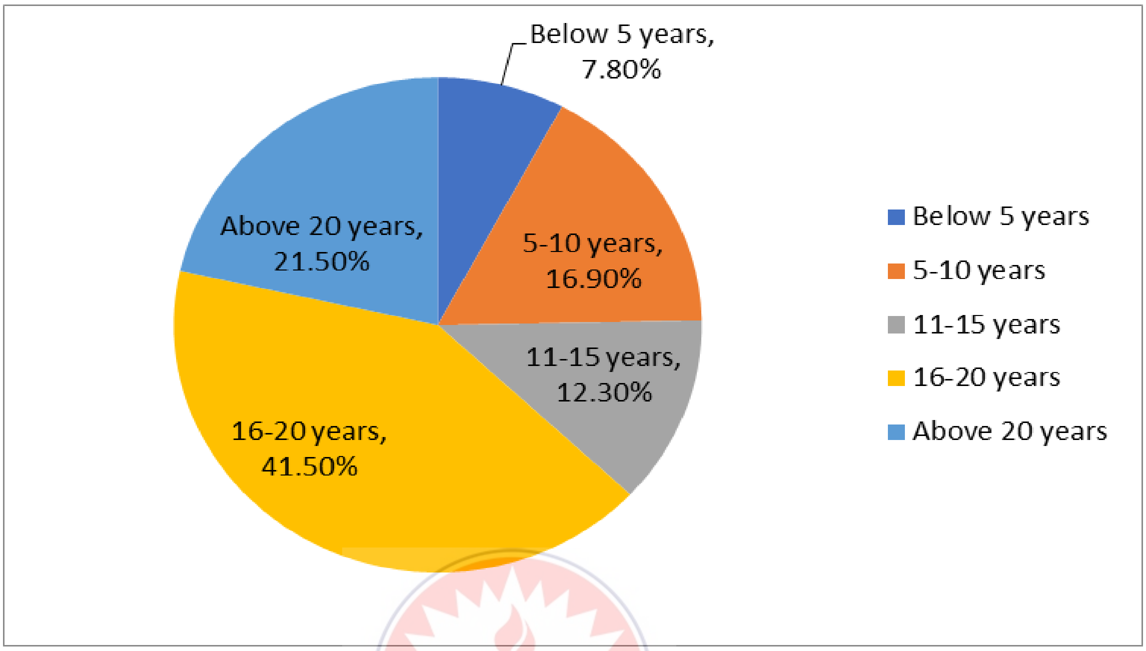

Figure 4.2 Respondent's years of experience in the Construction Industry

4.4 Educational Qualification of Respondents

Figure 4.1 shows that 1.5 % had a PhD, 27.7% had a master's degree, and 49.3 % had a bachelor's degree. A diploma was held by the remaining 21.5 %. This shows that the respondents used in the study were qualified and hence provided the data required for the studies.

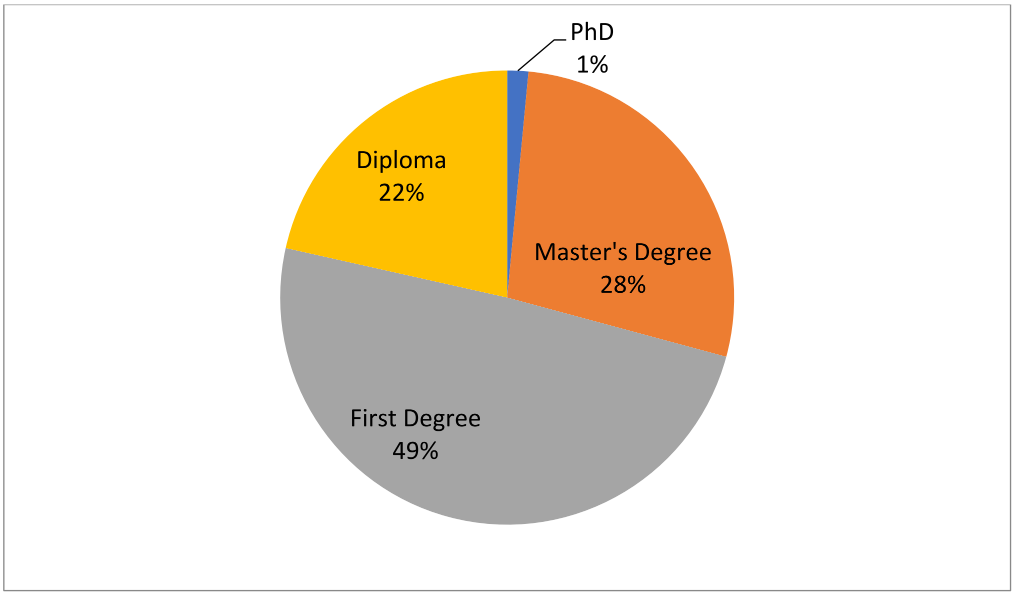

Figure 4.3 Respondent's educational qualification

4.5 Waste Minimization Methods

Using weighted average and coefficient of variation criteria, a structured questionnaire survey was conducted to identify measures that were considered best in minimising materials wastage and to provide empirical evidence on levels of significant contribution of waste minimization measures to waste reduction and levels of practice of same measures.

4.5.1 Ranking of waste minimization measures by respondents

Table 4.2 shows that the mean scores of all the waste minimization measures evaluated are greater than the neutral value of 3.0 for the respondents. All measures were considered as important for minimizing wastage of materials on site. The results further show that purchasing raw materials that are just sufficient, using materials before expiry dates, good coordination between store and construction personnel to avoid over ordering, use of more efficient construction equipment and adoption of proper site management techniques are the most important measures which can minimize the wastage of materials on construction sites. Other equally important measures are shown in Table 4.9. The least but important measures identified by the respondents include encouraging re-use of waste materials in projects, use of low waste technology and recycling of some waste materials on site.

Table 4.2 Ranking of Waste Minimization Measures

Waste minimization measures	Mean scores	Standard	Ranking
Purchasing raw materials that are just sufficient	4.75	0.286	1
Using materials before expiry dates	4.66	0.461	2
Good coordination between store and construction personnel to avoid over ordering	4.44	0.689	3
Use of more efficient construction equipment	4.41	0.605	4
Adoption of proper site management techniques	4.36	0.727	5
Training of construction personnel	4.35	0.797	6
Proper storage of materials on site	4.34	0.82	7
Checking materials supplied for right quantities and volumes	4.32	0.817	8
Good construction management practices	4.24	1.098	9
Employment of skilled workmen	4.22	0.813	10
Mixing, transporting and placing concrete at the appropriate time	4.21	0.978	11
Adherence to standardized dimensions	4.18	1.103	12
Accurate and good specifications of materials to avoid wrong ordering	4.17	0.765	13
Accurate measurement of materials during batching	4.16	0.942	14
Minimizing design changes	4.15	0.876	15
Vigilance of supervisors	4.13	0.982	16
Change of attitude of workers towards the handling of materials	4.12	0.893	17

Weekly programming of works	4.10	0.896	18
Access to latest information about types of materials on the market	4.07	0.948	19
Careful handling of tools and equipment on site	4.07	1.032	20
Waste management officer or personnel employed to handle waste issues	4.01	1.068	21
Early and prompt scheduling of deliveries	4.01	1.203	22
Just in time operations	3.99	1.187	23
Encourage re-use of waste materials in projects	3.76	1.197	24
Use of low waste technology	3.73	1.339	25
Recycling of some waste materials on site	2.65	1.524	26

The findings support previous research that suggests that purchasing just enough raw materials, using materials before they expire, training construction personnel, and using more efficient construction equipment, among other things, are all effective ways to reduce material waste on construction sites (Begum et al., 2006; Faniran & Caban, 1998; Ho, 2001; Poon et al., 2001; Shen et al., 2002; Shen & Tam, 2002; Sherman, 1996).

4.6 The levels of contribution of the waste minimization measures

Table 4.2 shows a summary of average significant scores, minimization index values, and rankings of the levels of significance contribution of the minimization measures on the basis of MIV. The waste minimization measure (Purchasing raw materials that are just sufficient) was ranked the first measure that most significantly contributes to waste minimization, indicating that, purchasing raw materials that are just sufficient for a project, very highly contributes to waste minimization. Recycling of some waste materials on site was ranked the 26th, indicating that, recycling of some waste materials on site has the least significant contribution to waste minimization. The other measures evaluated have average significant scores ranging between 4.75 and 3.73. Thus, apart from recycling of some waste materials on site, using of low waste technology and encouraging re-use of waste materials in projects, all the other measures evaluated by the construction professionals have medium to high contribution to waste minimization in Ghana.

This supports Teo and Loosemore (2001) and Lingard et al. (2000) findings on trash minimization in Australia. Waste control was reported to be a low project priority among construction workers in Australia. Even though waste sorting and recycling were widely discussed in Australia, most locations did not use them at the time. Confirming the findings of Begum et al. (2006) and Shen and Tam, adopting environmentally friendly technology on site and using low-waste technology are deemed less desirable environmental management measures to construction enterprises in Ghana (2002). Such efforts were considered as increasing their manufacturing costs, thereby undermining their perceptions of waste minimization as a cost-cutting strategy.

4.7 Extent of practice of lean thinking in the Ghanaian construction industry

The results shown in Tables 4.3 indicates that mean scores of all the 10 principles evaluated are greater than the mean value of 3.0 according to the study. This indicates that the respondents agree with all the ten basic principles of lean construction, and that the principles should be considered during project execution. The results further showed that the respondents consider establishing continuous improvement, delivering what the client wants, constantly seeking better ways to do things, and minimizing waste as the first four important lean principles to be considered in project execution.

Other important principles include; building and maintaining long term relationships with suppliers, and avoiding defects in the works done.

The responses agreed with results from the literature, which describe core principles of lean construction as delivering what the client wants, establishing continuous improvement, and doing things correctly the first time (Dulaimi & Tanamas, 2001; Kempton, 2006; Mathew Hunter Associates, 2005; Salem & Zimmer, 2005).

Table 4.3 Principles Applied in Carrying Out Projects – Opinions of Consultants

Principle	**Mean Score**	**Standard Deviation**	**Ranking**
Establishing continuous improvement	4.46	0.703	1
Delivering what the client wants	4.44	0.615	2
Constantly seeking better ways to do things	4.35	0.735	3
Waste minimization	4.25	0.717	4
Building and maintaining long term relationships with suppliers	4.21	0.768	5
Avoiding defects in the works done	4.15	0.985	6
Doing the right things at the first time	4.14	0.679	7
Involving the whole project team from the design right through	4.10	1.039	8
Increasing output value through systematic consideration of	3.91	0.786	9
Increasing output flexibility	3.58	1.045	10

4.8 Barriers to implementation of Lean Construction in Materials Waste Minimization

The mean scores and standard deviations of the hurdles to Lean Construction implementation discovered in the literature and confirmed by industry practitioners were graded. The results in Table 4.4 demonstrate that the following are the top five hurdles to LC implementation in Ghana: fragmented nature of the industry, extensive use of subcontractors, lack of long-term relationship with suppliers, delays in decision making, and waste accepted as inevitable, in that order. The weakest barriers include; inefficient use of quality standards lack of supply chain integration and poor project definition among others.

The impact of the construction industry's fragmentation on lean construction implementation has been thoroughly studied in the literature (Abdullah et al., 2009; Bashir et al., 2010; Bender & Septelka, 2002; Frodel & Josephson, 2009; Mossman, 2009). The traditional construction process is typified by its fragmented nature, with loosely tied actors participating in only a few phases (Johansen et al., 2002). The success of lean construction is heavily reliant on a well-coordinated team working toward common goals and objectives (Abdullah et al., 2009).

The extensive use of subcontractors in Ghana as a barrier to LC implementation reflects literature findings (Abdullah et al., 2009; Bashir et al., 2010; Forbes & Ahmed, 2004). Subcontractors are primarily responsible for specialised work, and contractors frequently use subcontractors who do not have direct client contracts. Most subcontractors work with little resources and lack competence, putting quality at risk (Forbes & Ahmed, 2004). Poor subcontractor supervision may result in the failure to solve crucial LC problems. The widespread employment of subcontractors, many of whom lack technical understanding, is a significant impediment to lean construction.

Table 4.4 Ranking of Barriers to Implementation of Lean Construction in minimizing materials waste

Barriers	Mean	Standard	Rank
Fragmented nature of the industry	4.650	0.741	1
Extensive use of subcontractors	4.580	0.670	2
Lack of long-term relationship with suppliers	4.550	0.729	3
Delays in decision making	4.540	0.707	4
Waste accepted as inevitable	4.430	0.786	5
Inconsistency in government policies	4.370	0.835	6
Materials scarcity	4.300	0.817	7
Lack of long-term commitment to change and	4.290	0.837	8
Delays in materials delivery	4.240	0.805	9
Long implementation period	4.220	0.794	10
Less involvement of contractors and specialists in	4.220	0.836	11
Lack of technical skills	4.080	0.867	12
corruption	4.060	0.964	13
Lack of client and supplier involvement	4.050	0.784	14
Poor communication	4.040	0.791	15
Lack of management support and commitment	4.040	0.855	16
Inadequate pre-planning	4.000	0.866	17
Incomplete designs	3.990	0.833	18
Lack of agreed implementation methodology	3.980	0.754	19
High dependency of design specifications on in-situ	3.970	0.825	20
Lack of buildable designs	3.970	0.837	21
Difficulty in understanding lean concepts	3.970	1.025	22
Unsuitable organizational structure	3.960	0.783	23
Poor professional wages	3.950	0.893	24
Poorly defined individual responsibilities	3.930	0.797	25
Lack of standardization	3.930	0.883	26
Lack of technical skills	3.910	0.872	27
Lack of training	3.910	0.934	28
Lack of equipment	3.900	0.849	29
Lack of interests from clients	3.890	0.878	30
Poor project definition	3.880	0.734	31
Lack of supply chain integration	3.880	0. 907	32
Inefficient use of quality standards	3.800	0.826	33

The lack of a long-term relationship with suppliers has a variety of ramifications for lean construction deployment (Abdullah et al., 2009; Bashir et al., 2010; Bender & Septelka, 2002; Frodel & Josephson, 2009; Mossman, 2009). Contractors who spend 70% to 80% of their revenue on materials and services should understand that their suppliers are involved in the delivery process (Frodel & Josephson, 2009). They should prioritise the value given by suppliers in order to improve their competitiveness. The construction industry's fragmentation has also been blamed for the lack of long-term ties between contractors and their suppliers (Frodel & Josephson, 2009).

Delays are common in the construction industry. Delay is a term used to describe the process of slowing down but not entirely stopping work. Work is disturbed, productivity is lost, and projects are completed late, which can result in the contractor quitting the project or the client cancelling the contract. Management must keep track of the project's progress in order to avoid any potential delays.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This section deals with the summary of the major findings, the general conclusions drawn on the bases of the findings, and recommendations which are deemed to be useful.

5.2 Summary of Key Findings

In this part, a summary of the findings derived from the data analysis was been linked to the study's objectives.

5.2.1 Level of contribution of the waste minimization measures

All 26 measures were deemed relevant by the respondents for reducing material waste on the job site. The findings also revealed that purchasing just enough raw materials, using materials before they expire, good coordination between store and construction personnel to avoid overordering, using more efficient construction equipment, and using proper site management techniques are the five most important measures that can reduce material waste on construction sites. Encourage re-use of waste materials in projects, adoption of low-waste technology, and on-site recycling of some waste materials are among the least expensive but most significant strategies identified by respondents.

In the Ghanaian construction industry, the study offered empirical evidence on the levels of contribution and practice of waste minimization techniques. It has been discovered that purchasing just enough raw materials, using materials before they expire, and using more efficient construction equipment are perceived as the three measures that most significantly contribute to waste minimization and are also the most widely implemented waste minimization measures. Encouragement of waste re-use in projects, use of low-waste technology, and recycling of some waste materials on-site are, however, seen as the least important factors that contribute to waste minimization and the least practiced measures simply because such measures are seen as increasing rather than decreasing production costs.

5.2.2 Perspectives for the implementation of lean construction

The study found that there is some level of understanding of the idea of lean construction among experts in the Ghanaian construction industry. Construction organisations' actions, such as delivering what the client wants, developing continuous improvement, "constantly finding better ways to do things, waste minimization, and minimising errors in completed work, are reported to be usually aligned with lean construction practices. The majority of construction professionals polled are open to lean principles being implemented in the industry, and believe that doing so would bring numerous benefits, including improved project delivery methods and delivery of products or services that enable clients to better accomplish their goals.

Barriers to successful implementation of lean construction

Factor analysis allowed 26 of the factors identified by professionals in the Ghanaian construction industry as potential barriers to the implementation of LC to be grouped into six categories: lack of proper planning and control, which includes delays in materials delivery, inefficient use of quality standards, a long implementation period, waste accepted as inevitable, inconsistency in government policies, and a high reliance on in-situ.

The fragmented character of the sector, a lack of interest from clients, poorly defined individual roles, and reduced engagement of contractors and specialists in the design process all contribute to a lack of collaboration. Poor project management, which includes a lack of project description, equipment, agreed-upon implementation methods, and ineffective organisational structures; Technical limitations, such as a lack of buildable designs, incomplete designs, and a lack of standardisation; Poor professional pay and corruption contribute to a lack of professional motivation. Parties' bad communication includes a lack of grasp of lean ideas as well as poor communication.

5.3 Conclusion

The study concluded that the five most important measures for reducing material waste on construction sites are purchasing just enough raw materials, using materials before they expire, good coordination between store and construction personnel to avoid overordering, using more efficient construction equipment, and using proper site management techniques. Reusing waste materials in projects, adopting low-waste technology, and on-site recycling of some waste materials are among the least expensive but most important solutions, according to the report.

The lean principles being adopted in the industry, and think that doing so will provide several benefits, including enhanced project delivery techniques and delivery of products or services that will help clients achieve their objectives more effectively.

Lack of interest from customers, poorly defined individual tasks, and diminished engagement of contractors and specialists in the design process are all factors that contribute to a lack of collaboration, according to the study. Lack of project description, equipment, agreed-upon implementation methods, and ineffective organisational structures are all examples of poor project management.

5.4 Recommendations

The following recommendations were made to improve the application of lean concepts on building sites in Ghana in order to reduce material waste.

In the drive to reduce materials waste in construction, proper site and waste management practices, as well as the creation of precise material specifications, are advised actions to take. It is advised that the government pass legislation and establish regulations that encourage good attitudes toward waste minimization at all levels of a construction project in order to aid the construction industry in reducing material waste. In addition, Ghana's construction sector should work with relevant government organisations to set adequate criteria for preparing waste management strategies for the industry.

Construction firms should modify organisational cultures that do not favour lean construction and promote the concept of lean construction through workshops and conferences, among other things, to bridge the knowledge gap on the use of LC.

Construction managers should be devoted to change, understand client needs and expectations, and continue continuous improvement (i.e., cost reduction, quality improvement, and productivity improvement). Government agencies, for their part, should develop policies that might help make lean approaches a reality. The identified impediments to LC implementation, as well as strategies to remove them, should create an enabling environment for construction practitioners to successfully apply lean construction and increase construction quality and efficiency for the client's benefit.

5.6 Recommendation for future studies

Future studies should be conducted on Culture and Waste Management in the Ghanaian Construction Industry. Other researchers can also work on Sustainability, Resource Efficiency and Waste Elimination in the Ghanaian Construction Industry.

REFERENCES

Abdelhamid, T.S. (2004). The self-destruction and renewal of lean construction theory: A prediction from Boyd‟s Theory. In Proceedings of the 12th Annual Conference of the International Group of Lean Construction, Helsinga, Denmark.

Abdullah S., Abdul-Razak A., Abubakar A. and Mohammad I. S. (2009). Towards Producing Best Practice in the Malaysian Construction Industry: The Barriers in Implementing the Lean Construction Approach. In Proceedings of the International Conference on Construction Industry, Padang, Indonesia.

Agopyan, V., Souza, U.E.L., Paliari, J.C., Andrade, A.C. (1998). Alternatives for reducing waste of building materials on construction sites: final report. EPUSP/FINEP/ITQC, Sao Paulo, Portugal.

Akintoye, A.(1995). Just in Time Application and Implementation for Building Material Management. Construction Management and Economics 13, 105-113.

Alarcon, L. F., Diethelm, S. and Rojo, O. (2002). Collaborative Implementation of Lean Planning Systems in Chilean Construction Companies, Proceedings of the 10th Annual Conference of the International Group for Lean Construction. Gramado, Brazil, 6 - 8 August 2002.

Al-Moghany, S.S. (2006). Managing and Minimizing Construction Waste in Gaza Strip. A thesis submitted to the Islamic University of Gaza- Palestine.

Alwi, S., Hampson, K. and Mohamed, S. (2002). Waste in the Indonesian construction projects, In Proceedings of the 1st International Conference on Creating a Sustainable Construction Industry in Developing Countries, November 11-13, Stellenbosch, pp. 305-15.

Arditi, D., Akan, G. T., and Gurdamar, S. (1985). Reasons for Delays in Public Projects in Turkey. Construction Management and Economics, Volume 3.

Assibey-Mensah, G.O. (2008). Ghana"s Construction Industry and Global Competition: A research Note, Journal of Black Studies, Sage Publication

Ayarkwa, J. and Adinyira, E. (n.d). Construction material waste in Ghana: Sources, causes and minimization. Submitted for publication in the Journal of Construction: South Africa ISSN 1994-7402.

Badu, E. (2008). Project Resource Management. A Course Material Submitted to the Institute of Distance Learning, Kwame Nkrumah University of Science and Technology, Ghana.

Baldwin, A., Poon, C., Shen, L., Austin, A., and Wong, I. (2006). Designing out waste in high-rise residential buildings: analysis of precasting and prefabrication methods and traditional construction. In: Runming, Y., Baizhan, L., Stammers, K. (Eds.), International Conference on Asia-European Sustainable Urban Development, Chongqing, China, 5–6 April 2006, Centre for Sino-European Sustainable Building Design and Construction, Beijing (ISBN 0-903248-03-04).

Ballard, G. and Howell G. (2004). Competing Construction Management Paradigms. Lean Construction Journal, **1**, 38-45.

Ballard, G. and Howell, G. (2003). An update on Last Planner. In J. C. Martinez, Formoso, C.T. (eds) 11th IGLC Conference, Virginia Tech, Blacksburg, VA.

Ballard, G. (2000a). "Lean Project Delivery System", L. C. I. White Paper, No. 8, Lean Construction Institute, Las Vegas, Nevada, www.leanconstruction.org/pdf/WP8-LPDS.pdf, Last Accessed Date: May, 2007.

Bashir, A.M., Suresh, S., Proverbs, D.G. and Gameson, R. (2010). Barriers towards sustainable implementation of Lean Construction in the United Kingdom Construction Organizations. Paper presented at the ARCOM Doctoral Workshop, Wolverhampton.

Begum, R.A., Siwar, C., Pereira, J.J. and Jaafar, A.H. (2006). Implementation of waste Management and minimization in the Malaysian construction industry. Conservation and Recycling, 51, 190-202.

Bender, W.J. and Septelka, D.S. (2002). Teambuilding in the Construction Industry. In Proceedings of the 46th Annual Meeting of AACE International, Portland.

Bertelsen, S. (2003). Construction as a Complex System, In Proceedings of the 11th Annual Conference of the International Group for Lean Construction, 2003, Blacksburg, Virginia, U.S.A.

Bertelsen, S. (2002). Bridging the Gap- Towards a comprehensive understanding of Lean Construction. IGLC-10, Gramado, Brazil, 2002.

Bertelsen, S., and Koskela, L. (2002). Managing the Three Aspects of Production in Construction, In Proceedings of the 10th Annual Conference of the International Group for Lean Construction, 2002, Gramado, Brazil.

Bossink, B. A. G. and Brouwers, H. J. H. (1996). Construction waste: quantification and source evaluation. Journal of Construction Engineering and Management, **122**(1), 55–60.

Byrne, Z.S. and Lernay, E. (2006). Different media for organizational communication: perceptions of quality and satisfaction. Journal of Business and Psychology, 21 (2), 149-175.

Castka, P., Bamber, C. and Sharp, J. (2004). Benchmarking Intangible Assets: Enhancing Teamwork Performance using Self Assessment. Benchmarking, 11, 571–583.

Chen, Z., Li, H., Wong, C.T.C. (2002). An application of bar-code system for reducing construction wastes. Automation in Construction 11 (5), 521–533.

Common, G., Johansen, E. and Greenwood, D. (2000). A survey of the take-up of lean concepts among UK construction Companies. In Proceedings of the 8th International Group for Lean Construction Annual Conference. Brighton, United Kingdom.

Conte, A.S and Gransberg, D. (2001). Lean construction: From theory to practice. AACE International Transactions. CSC 10.1–CSC10.5.

Conway, H., Crandall, M., Ryan, K. and Khalil, G. (2005). Construction: A Report on the Industry submitted to Industrial College of the Armed Forces National Defence University, pp 6-7

Construction Industry Board (1998). Fact Sheet on Partnering: Thomas Telford Publishing Coventry, S., Shorter, B., Kingsley, M. (2001). Demonstrating Waste Minimisation Benefits in Construction. In: CIRIA C536. Construction Industry Research and Information Association (CIRIA), London, United Kingdom.

Craven, D. J., Okraglik, H. M. and Eilenberg, I. M. (1994). Construction waste and a new design methodology. In Kibert, C. J. (ed.), Sustainable Construction, Center for Construction and Environment, Gainesville, FL, pp. 89–98.

Cua, K.O., McKone, K.E., and Schroeder, R.G. (2001). Relationships Between Implementation of TQM, JIT and TPM and Manufacturing Performance. Journal of Operations Management, 19, 675–694.

Dainty, A.R.J., Bryman, A. and Price, A.D.F. (2002). Empowerment within theUK Construction sector. Leadership and Organization Development Journal, 23(6), 333-342

Dansoh, A (2005). Strategic Planning for Construction Firms in Ghana, Construction Management and Economics, Vol. 23, No.2, PP. 163-168.

Dao, D. and Follestad, B.H. (2009). Efficient Materials Delivery and Site Management: A Lean Construction Perspective. Case Study at Statsbygg. A master‟s degree thesis submitted to the Molde University College.

Datta, M. (2000). Challenges Facing the Construction Industry in Developing Countries. Proceeding of 2nd International Conference on Construction in Developing Countries, 15-17 November, Gabarone, Botswana.

Dessler, G. (2000). Human Resource Management (8th Edition). New Jersey: Prentice-Hall.

Dulaimi, M.D. and Tanamas, C. (2001). The principles and applications of lean construction in Singapore, In Proceedings of the IGLC 9, Singapore.

Dunlop, P. and Smith, S.D. (2004). Planning, estimation and productivity in lean concrete pour. Engineering, Construction and Architectural Management, 11, 55–64.

Ekanayake L.L. and Ofori, G. (2000). Construction material waste source evaluation. In: Proceedings of the Second Southern African Conference on Sustainable Development in the Built Environment, Pretoria, 23–25 August 2000. p. 35-1–6.

Enshassi, A. (1996) Materials control and waste on building sites. Building Research and Information, 24(1), 31–4.

EPD (2000), Environment Hong Kong (2002), Environment Protection Department, Hong Kong Government.

Eyiah, A K and Cook, P (2003). Financing small and medium-scale contractors in developing countries: a Ghana case study, Construction Management and Economics, 21(4), 357-367.

Fatta, D., Papadopoulos, A., Avramikos, E., Sgourou, E., Moustakas, K., Kourmoussis, F., Mentzis, A. and Loizidou, M. (2003). Generation and Management of Construction and Demolition Waste in Greece - an Existing Challenge. Elsevier Science. Resources, Conservation and Recycling 40. pp81–91.

Faniran, O. O. and Caban, G. (1998). Minimizing waste on construction project sites. Engineering, Construction and Architectural Management, **5**(2), 182–8.

Ferguson, J., Kermode, N., Nash, C. L., Sketch, W. A. J. and Huxford, R. P. (1995). Managing and Minimising Construction Waste: A Practical Guide, Institution of Civil Engineers, London.

Forbes, L. and Ahmed, S. (2004). Adapting lean construction methods for developing nations. Second LACCEI International Latin America and Carribean Conference for Engineering and Technology (LACCEI"2004) "Challenges and Opportunities for Engineering Education, Research and Development" 2-4 June 2004, Miami, Florida, USA.

Formoso, C.T., Lucio Soibelman, M., De Cesare, C. and Isatto, E.L. (2002). Materials Waste in Building Industry: Main causes and prevention. Journal of Construction Engineering and Management, Vol 128(4), pp. 316-325.

Formoso, T.C., Hirota, E.H. and Isatto, E.L. (1999). "Method for waste control in the building industry", available at: http://construction.berkeley.edu.

Formoso, C. T., Franchi, C. C. and Soibelman, L. (1993). Developing a method for controlling material waste on building sites. In Economic Evaluation and the Built Environment, CIB, Lisbon, Portugal, pp. 67–78.

Forsythe, P. and Marsden, P.K. (1999). Modelling construction waste performance- an arising procurement issue. S.O. Ogunlana ed., profitable partnering in construction procurement, CIB W92 (Procurement systems) and CIB TG23 (Culture in construction) joint symposium, Spon, London, 679-688.

Frodel, M. and Josephson, P.E. (2009). Perceived Constraints when Establishing and Maintaining Contractor-Supplier Relations in Construction. Construction Management, Chalmers University of Technology.

Ganesan, S. (2000). Employment, Technology and Construction Development, Ashgate Publishing Company, Aldershot.

Garas, G.L., Anis, A.R and El Gammal, A. (2001). Materials waste in the Egyptian Construction Industry. In Proceedings of IGLC-9, Singapore.

Gary, J.T. (2004). World Construction Spending Nears 4Trillion Dollars for 2004. Engineering News-Record (E.N.R.). McGraw Hill Construction, Vol 254, No. 1, pp 12-13.

Gavilan, R. M. and Bernold, L. E. (1994). Source evaluation of solid waste in building construction. Journal of Construction Engineering and Management, 120(3), 536– 55.

Gigado, K.I. (1996). Project Complexity: The focal point of construction project planning. Construction Management and Economics, 14(3), 213-225.

Gil, N, Tommelein, D, Kirkendall, B. and Ballard, G. (2000). Lean product development process to support contract involvement during design. In proceedings of 8th International Conference on Computing in Civil and Building Engineering. R. Fruchter (ed), Stanford, California: American Society of Civil Engineers (ASCE), 14-17.

Griffin, M.A., Pattersoa, M.G. and West, M.A. (2001). Job satisfaction and teamwork: the role of supervisor support. Journal of Organizational Behaviour, 22, 537-550.

Groak, S. (1992). The idea of building: thought and action in the design and production of buildings. 1st ed. London, New York: E and F.N. Spon.

Gyadu-Asiedu, W. (2009). Assessing construction project performance in Ghana. Modelling practitioners‟ and clients‟ perspectives. A Thesis Submitted to the Technology University of Eindhoven, Faculty of Architecture, Planning and Building, Eindohoven, Netherlands.

Ho, O.S.T. (2001). Construction waste management - a contractor‟s perspective. The Hong Kong Institute of Builders. Hong Kong.

Hoe, L.K. (2006). Causal model for management of subcontractors in waste minimization. A thesis submitted for the degree of doctor of philosophy. Department of Building, National University of Singapore.

Holm, F.H. (1998). Ad Hoc Committee on Sustainable Building, Norwegian Building Research Institute, Blinderm.

Hudson, M. (2007) Managing Without Profit : The Art of Managing Third-sector Organizations. 2nd ed. London: Directory of Social Change.

Ibn-Homaid, N. T., (2002). A Comparative Evaluation of Construction and Manufacturing Materials Management. International Journal of Project Management 20,263-270.

International Investment and Services Directorate Industry (1999). The Canadian Construction Industry; A Consultation Paper in Preparation for World Trade Organization (WTO) General Agreement on Trade in Services (GATS) Negotiations, pp 10-12.

Jin, V.L.A. (2007). Lean construction. Knowledge and barriers to its implementation in the Malaysian construction industry. An unpublished Thesis at the Universiti Teknologi, Malaysia.

Johansen, E. and Walter, L. (2007). Lean Construction: Prospects for the German Construction Industry.

Johnston, J.E. (1981). Site Control of Materials. Butterworths, London.

Jones, P. and Greenwood, R. (2003). Construction Waste Minimization in Housing. Center of Research in the Built Environment, Cardiff University, Wales, UK.

Jorgensen, B. and Emitt, S. (2008). Lost in Transition: The Transfer of Lean Manufacturing to Construction. Engineering, Construction and Architectural Management, 15, 365-398.

Kamara, J. (2003). Enablers for concurrent engineering in construction. In proceedings of 11th Conference of International Group for Lean Construction, Blacksburg, V.A., 170-182.

Kempton, J. (2006). Can lean thinking apply to the repair and refurbishment of properties in the registered social landlord sector? Structural Survey, 24(3), 201-211.

Kim, D. (2002). Exploratory study of Lean Construction: Assessment of lean implementation. The University of Texas.

Koskela, L. and Howell, G. (2002). The Underlying Theory of Project Management is obsolete. Proceedings of the PMI Research Conference, 2002, 293-302.

Koskela, L. (2000). An Exploration towards a Production Theory and its Application to Construction, PhD. Dissertation, VTT BuildingTechnology, Espoo, Finland.

Koskela, L. (1999). Management of Production in Construction: a theoretical view. In Proceedings of the 7th Annual Conference of Internanational Group for Lean Construction-IGLC. Berkeley, C.A.

Koskela, L. (1992). Application of the New Production Philosophy to Construction. Technical Report No. 72, CIFE, Stanford University, pp. 4-50.

Koskela, L. Howell, G. Ballard, G. and Tommelein, I. (2004). The foundation of Lean Construction. Design and Construction: Building in value, R. Best, and G. De Valence editions, Butterworth-Heinemann, Elsevier, Oxford, UK.

Lee, S., Diekmann, 1 E., Songer, A. D., and Brown, H. (1999). Identifying Waste: Applications of Construction Process Analysis. Proceedings IGLC-7, University of California, Berkeley, CA, USA.

Lehman, T. and Reiser, P. (2004). Maximizing value and minimizing waste: Value engineering and lean construction. In SAVE International 44th Annual Conference Proceedings.

Liker, J.K. (2004). The Toyota Way: 14 management principles from the world‟s greatest manufacturer. New York; London, McGraw-Hill.

Lingard, H., Graham, P. and Smithers, G. (2000). Employee perceptions of the solid waste management system operating in a large Australian contracting organisation: implications for company policy implementation. Construction Management and Economics, 18:4, 383–93.

Lnyang, H. I., (2003). Framework for Recycling of Wastes in Construction. Journal of Environmental Engineering, Vol. 129, No. 10, pp 887 – 898.

Macomber, H. and Howell, G. (2004). Two Great Wastes in Organizations. Proceedings of the 12th Annual Conference of the International Group for Lean Construction IGLC-12, August, Denmark.

Manteau, K.A. (2010). Materials Management. A Course Material Submitted to the Department of Building Technology, Kwame Nkrumah University of Science and Technology, Ghana.

Marija, J.N. (2003). SPSS 12.0 Statistical Procedures Comparison. Prentice Hall, Upper Saddle River, New Jersey.

Mastroianni, R. and Abdelhamid, T. (2003). The challenges: The impetus for change to lean project delivery. In proceedings of 11th Conference of International Group for Lean Construction, Blacksburg, V.A., 170-182. Mathew Hunter Associates, 2005, Lean Thinking Works in Construction Too. Available at http://www.contractormag.com/articles/newsarticles.

McDonald, B., Smithers, M. (1998). Implementing a waste management plan during the construction phase of project: a case study. Journal of Construction Management and Economics 16 (1), 71–78.

Moser, L and Dos -Santos, A. (2003). Exploring the role of visual controls on mobile cell manufacturing: A case study on drywall technology. In Proceedings of 11th Conference of International Group for Lean Construction, Blacksburg, V.A.

Mossman, A. (2009). Why isn"t the UK Construction Industry going lean with gusto? Lean Construction Journal, **5** (1), 24-36.

Naoum, S.G. (1998). Dissertation Research and Writing for Construction Students. Boston: Butterworth-Herinemann.

Ohno, T. (1994). Toyota Production System: beyond Large-Scale Production. Productivity Press: Cambridge, Mass. 142pp.

Olatunji J. (2008). Lean-in-Nigerian Construction: State, Barriers, Strategies and "Goto-gemba" Approach. Proceedings 16th Annual Conference of the International Group for Lean construction, Manchester, United Kingdom.

Osmani, M., Glass, J. and Price, A.D.F. (2008). Architects Perspectives on Construction Waste Reduction by Design. Waste Management, Vol 28, No. 7 pp. 1147-1158.

Pinto, T.P. (1989). Materials waste in traditional construction processes. Research Rep., Federal University of Sao Carlos, Sao Carlos, Portugal.

Polat, G. and Ballard, G. (2004). Waste in Turkish Construction- Need for Lean Construction Techniques. In Proceedings of the 12th Annual Conference of the International Group for Lean Construction IGLC-12, August, Denmark, 488-501.

Poon, C.S. and Jaillon, L. (2002). A Guide for Minimizing Construction and Demolition Waste at the Design Stage. The Hong Kong polytechnic University.

Poon, C.S., Yu, A.T.W., Jaillon, L. (2004). Reducing building waste at construction sites in Hong Kong. Construction Management and Economics 22 (June), 461–470.

Poon, C.S., Yu, T.W. and Ng, L.H. (2001). A Guide for Managing and Minimizing Building and Demolition Waste. The Hong Kong polytechnic University.

Radosavljevic, M., Horner, R. and Malcolm, W. (2002). The evidence of complex variability in construction labour productivity. Construction Management and Economics, 20, 3-12.

Rameezden, R. and Kulatunga, U. (2004). Materials wastage on construction sites: identification of major causes. Journal of Built Environment, Sri Lanka, vol (4), pp 35-41.

Pinto, T.P. (1989). Materials waste in traditional construction processes. Research Rep., Federal University of Sao Carlos, Sao Carlos- Portugal.

Pongrácz E. and Pohjola V.J. (1997). The Conceptual Model of Waste Management Proc. ENTREE.97, November 12.14 1997, Sophia Antipolis, France. pp. 65.77.

Salem, O., Solomon, J., Genaidy, A. and Minkarah, I. (2005). Lean construction: From theory to implementation. Journal of Management in Engineering, **4**, 168-175.

Salem, O. and Zimmer, E. (2005). Application of Lean Manufacturing Principles to Construction. Lean Construction Journal, ***2(****2), 51-54.* Available at www. Leanconstructionjournal.org

Santos, A., Formoso, C.T. and Tookey, J.E. (2002). Expanding the meaning of standardization within construction process. The TQM Magazine, 14(1), pp.25-33.

Shen, L.Y., Tam, V.W.Y. (2000). Material wastage in construction activities- a Hong Kong survey. In: Proceedings of the first CIB-W107 International Conference: creating sustainable construction industry in developing countries, pp125-131.

Shen, L. Y., Tam, W. Y. V., Chan, C. W. S. and Kong, S. Y. J. (2002). An examination on the waste Management practice in the local construction site, Hong Kong Surveyor **13**(1), 39-48.

Sherman,R.L. (1996). Managing Construction and Demolition Debris: A Guide for Builders, Developers and Contractors. Published by: North Carolina Cooperative Extension Service. Publication Number: AG-473-19.

Skyoles, E. R. and Skyoles, J. R. (1987). Waste Prevention on Site, Mitchell, London.

Smallwood, J.J. (2000). Construction and the environment-general contractor (GC) perceptions and practices. In: Proceedings of the first CIB-W107 International Conference: creating sustainable construction industry in developing countries, pp 155-164.

Spivey, D. A. (1974). Construction solid waste. J. Constr. Div., Am. Soc. Civ. Eng., 100(4), 501–506

Sriprasert, E. and Dawood, N. (2002). Next generation of construction planning and control system: The Lewis approach. In proceedings of the 10th IGLC, Gramado, Brazil.

Teo, M.M.M. and Loosemore, M. (2001). A theory of waste behavior. Construction Management and Economics, Vol (19), 7: 741-751

Vulink, M. (2004). Technology Transfer in the Construction Industry of Ghana: Human Resource Development through International Collaboration between Foreign and Local Contractors in the Greater Accra Region.

Wang, J.Y., Kang, X.P. and Tam, V.W.Y. (2008). An investigation of Construction Wastes: an empirical study in Shenzhen. Journal of Engineering, Design and Technology, Vol. 6 No. 3, pp. 227-236.

Weick, E.K. and Browning, L.D. (1986). Argument and narration in organizational communication. Journal of Management, 12(2), 243-259.

Weisberg, H.F. and Bowen, B.D. (1977). An Introduction to Survey Research and Data Analysis. San Francisco: W.H. Freman and Company, pp. 46-71.

Womack, J.P.(1999). Manufacturing Has Moved to Lean - It's Time Construction Does Too. Proceedings 10th Winter Conference in Archistruction, Neenan, Denver, Colorado, USA.

Womack, J. P., and Jones, D. T. (1996). Lean Thinking: Banish Waste and Create Wealth in Your Corporation. Simon and Schuster, New York, N.Y., USA.

Yahya, K. and Boussabaine, A.H. (2006). Eco-costing of construction waste. Management of Environmental Quality: An International Journal, vol 17, No. 1, pp 6-19.

QUESTIONNAIRE FOR CONSTRUCTION PROFESSIONALS

1. Gender

   Male [ ]

   Female [ ]

2. Profession

   Architect [ ]

   Building Contractor [ ]

   Project manager [ ]

   Quantity Surveyor [ ]

   Site supervisor [ ]

   Other, please specify…………………………………

3. Level of education

   HND [ ] Bachelors Degree [ ] Masters Degree [ ]

   Doctorate degree [ ] other, please specify………………..

4. Level of experience in years

   Below 5years [ ] 5-10 years [ ] 10-15 years [ ] 15-20 [ ] above 20 years [ ]

   Others, pleasespecify…………………………………………………………..

1. WASTE MINIMIZATION MEASURES

Below are possible measures that contribute to the minimization of materials waste. Rank on a scale of 1-5

1	2	3	4	5
Very low contribution	Low contribution	Medium contribution	High contribution	Very high contribution

MEASURES	**1**	**2**	**3**	**4**	**5**
Recycling of some waste materials on site					
Good construction management practices					
Training of construction personnel					
Good coordination between store and construction personnel to avoid over-ordering					
Use of more efficient construction equipment					
Vigilance of supervisors					
Proper storage of materials on site					
Just in time operations					
Early and prompt scheduling of deliveries					
Adherence to standardized dimensions					
Change of attitude of workers towards the handling of materials					
Regular education and training of personnel on how to handle					
Checking materials supplied for right qualities and volumes					

Employment of skilled workmen					
Accurate measurement of materials during batching					
Accurate and good specifications of materials to avoid wrong ordering					
Encourage re-use of waste materials in projects					
Careful handling of tools and equipment on site					
Weekly programming of works					
Mixing, transporting and placing concrete at the appropriate time					
Waste management officer or personnel employed to handle waste issues					
Adoption of proper site management techniques					
Access to latest information about types of materials on the market					
Minimizing design changes					
Purchasing raw materials that are just sufficient					
Using materials before expiry dates					

2. KNOWLEDGE ON LEAN CONCEPTS

Below are lists of principles applied in carrying out projects. Rank on a Likert scale of 1-5 your level of agreement to the application of these principles to the design and construction stages of your activities.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	2	3	4	5

PRINCIPLE	1	2	3	4	5
Delivering what the client wants					
Establishing continuous improvement: thus, reduction of costs, increase in quality and productivity					
Doing the right things at the first time: thus achieve zero defects, revealing and solving problems at the source					
Avoiding defects in the works done that can result in for example, waste, unnecessary rework, loss of customers and corporate reputation					
Involving the whole project team through the design to construction					
Constantly seeking better ways to do things					
Increasing output value through systematic consideration of customer requirements					
Increasing output flexibility: thus, the production of different mixes and/ or greater diversity of products, without compromising efficiency					
Waste minimization: thus, eliminating all non-value adding activities and maximizing the use of all resources					
Building and maintaining long-term relationships with suppliers					

3. BARRIERS TO THE IMPLEMENTATION OF LEAN CONSTRUCTION CONCEPTS

Below are lists of factors acting as barriers to the implementation of lean construction concepts. Rank them on a scale of 1-5 according to their level of severity.

1	2	3	4	5
Not influential	Less influential	Quite influential	Influential	Very influential

BARRIERS	1	2	3	4	5
Lack of interest from clients					
Waste accepted as inevitable					
Poorly defined individual responsibilities					
Lack of training					
Less involvement of contractors and specialists in design process					
Delays in decision making					
Lack of top management support and commitment					
Poor project definition					
Delay in materials delivery					
Lack of equipment					
Materials scarcity					
Unsuitable organizational structure					
Lack of supply chain integration					
Poor communication					

Long implementation period					
Inadequate pre-planning					
Lack of client and supplier involvement					
Corruption					
Poor professional wages					
Lack of standardization					
Lack of technical skills					
High level of illiteracy					
Lack of awareness programs					
Difficulty in understanding concepts					
Inconsistency in government policies					
Lack of buildable designs					
Incomplete designs					
Lack of agreed implementation methodology					
High dependency of design specifications on in-situ materials and components rather than standardized and industrialized prefabricated components					
Extensive use of subcontractors					
Lack of long-term commitment to change and innovation					
Lack of long-term relationship with suppliers					
The fragmented nature of the construction industry					