KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF ARCHITECTURE AND PLANNING

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DEPARTMENT OF BUILDING TECHNOLOGY

THE PRACTICE OF LEAN THINKING AT THE PRE-CONTRACT STAGE OF BUILDING CONSTRUCTION PROJECTS BY SELECTED GHANAIAN FIRMS

by

Evans Zoya Kpamma, B.Sc. (Hons)

April, 2009

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DECLARATION AND CERTIFICATION

I hereby declare that this submission is my own work towards the MSc. Construction Management and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgment has been made in the text.

Evans Zoya Kpamma (ID: 20041295)	……	…….
(Student Name & ID)	Signature	Date

Certified by:

Dr. Theophilus Adjei-Kumi	……	…….
(Supervisor)	Signature	Date

Mr. Ayirebi Dansoh	…….	……..
(Head of Department)	Signature	Date

ABSTRACT

Construction Firms in the construction industry are faced with the challenge of aptly delivering services and products to clients at the possible minimum cost in order to remain competitive in the industry. The need to address this challenge of delivering valuable but less expensive products and services to fit clients' needs has become imperative owing to a growing desire by clients to opt for project delivery approaches that will minimise cost but ensure return of value for money.

It is, therefore, crucial for construction firms to "think lean" by exploring project delivery systems which focus on delivering value to clients and minimising waste in the project delivery process. The concept of lean thinking is a production based project delivery approach which originated from the manufacturing sector to minimise waste and maximise value in the production process.

Increased cost of production, delays in delivering construction products and services, as well as the incidence of waste associated with production are some of the common problems that confront construction firms in Ghana which the study seeks to address. The aim of the study is therefore to establish the possibility of adoption of lean production principles by construction firms in order to address the problems of delays, high cost of project delivery and waste. The objectives of the research among others included identification of the extent of practise of lean thinking and the limitations to the practice of lean construction in Ghanaian construction.

The main tools for the collection of primary data included administration of questionnaires, conduction of interviews and personal observation. Secondary data was obtained by reviewing relevant literature in textbooks, journals, reports, research papers and so on. The target population for the data collection included consultants and contractors in the construction industry. Statistical Package for Social Scientists, version 15 (SPSS Version 15) and Microsoft excel were then used to analyse the data.

Inadequate familiarity of the construction firms with the concept of lean thinking was among a number of limitations identified in the possible application of the concept Ghanaian construction industry. The possible transfer of knowledge in the application of the concept from foreign construction firms operating in Ghana was one of the opportunities identified for the practice of lean thinking in Ghanaian construction industry. It is recommended among others that consultants in Ghanaian construction industry should become abreast with the lean thinking through professional and academic training programs.

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DEDICATION

To my parents Mosobila Kpamma and Mary Kpamma

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CHAPTER ONE

INTRODUCTION

1.1 Background

The current liberal global economic order makes it challenging for Ghanaian firms in Ghanaian construction industry to remain competitive worldwide. Obtaining a good market share, maintaining a high customer loyalty, and at the same time operating at reasonable profit are very important for the Ghanaian firms to compete effectively with their foreign counterparts. Ghanaian firms in the construction industry must, therefore, strive to deliver valuable products and services at the minimum possible cost to their customers in order to remain in business. Products or services delivered to clients must also be timely and of maximum value for clients of the industry. Achieving minimum cost in construction requires that Ghanaian firms appreciate the difference between waste and value and how to eliminate the waste in construction project delivery.

The challenge of dealing with the issue of high cost of construction, while speeding up the value delivery process of construction projects has, therefore, led to the need to explore production management systems, which optimize value delivery to customers while minimizing waste. Lean production is a production management based project delivery system that emphasizes reliable and speedy delivery of value.

´´Lean production is ´lean´ because it uses less of everything compared with mass production: half the human effort in the factory, half the manufacturing space, half the investments in tools, half the engineering hours to develop a new product in half the time (Womack et al, 1991). The lean concept which originated from the manufacturing

industry places emphasis on producing to demand rather than through batch process. Products are, therefore, made only as and when required rather than in bulk to be held in store waiting to be bought (Harris and McCaffer, 2001).

The concept of lean thinking in construction project delivery seeks to maximize value delivered to customers while minimizing waste. In its basic form, the practice of lean thinking is the systematic elimination of waste (i.e. overproduction, waiting, transportation, inventory, motion, over-processing, defective units) and the implementation of the concepts of continuous flow and customer pull (Kotelnikov, 2007).

More than a passing fad, lean thinking is the culmination of a decade of development by automobile manufacturers who have, on the average, reduced labour hours per vehicle by more than half with one-third the defects. Over the last few years, other industries ranging from toys to aircraft, have successfully adapted lean production to their manufacturing operations with similar results (Caldeira, 1999).

The core concept behind lean production, according to Caldeira (1999), is to create a flow among value adding work steps while eliminating non-value steps. This has led to changes in production processes with some recurring themes: Broad-skilled, multi-disciplined teams replacing functionally-grouped specialists; Continuous workflow which ensures steady production rates that eliminate the chaos of fragmented stop-and-go production processes; a focus on fast cycle times to eliminate non-value-adding activities.

The practice of lean thinking essentially involves top management leading, but employees being engaged. A contractor or consultant should come up with standardized processes and then figure out, over time, how to improve them. It's a continuous cycle of plan, do, check and act. The process can be applied to anything, whether it's hanging pipe, dispatching or accounting. The employees who do the actual work are the ones who can make small, incremental improvements to the processes (Mader, 2005).

Ghanaian firms can implement lean thinking in their operations by tracking productivity and their percent-of-plan-completed every day. The object is to keep design teams designing, construction crews installing, reduce inventory and cut costs. The work has to be made ready every day and anything that's impeding the work of the crew must be eliminated.

1.2 Problem Statement

The ability of Ghanaian firms in the construction industry to compete in the current open market economic system is threatened by the cost involved in the production processes they adopt for construction. A relatively high cost of their construction process is having an adverse effect on their financial performance. Maintaining and expanding their existing market share is also increasingly becoming difficult due to increased cost of their products and services which is seen by most customers as not being commensurate with the value delivered to them. A survey conducted by Nicco-Annan (2006) on the construction of some office buildings in Accra reveals cost overruns of between 60%-180%, not taking inflation into account.

Ghanaian firms have had some difficulty in delivering value to their customers on time. There have been incidents of customer dissatisfaction resulting from the inability of products and services delivered by the firms to aptly meet the needs and expectations of customers. Nicco-Annan (2006), reports that in Ghana, clients of the construction industry continue to complain about the industry's performance and its seeming inability to deliver projects on time, within budget and to expected quality standards. The production system employed by these firms fails to produce to the exact specification thus decreasing the quality of products.

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

Various forms of waste associated with the traditional project delivery system employed by Ghanaian firms are seen as contributing largely to the incidence of high cost of construction, bad financial performance and decreased value of products delivered to customers. For most of the production operations adopted by the firms, only a fraction of the total time and effort actually adds value for the end customer. A significant proportion of the time and effort is spent on waste activities. Over-production, defective

products, waiting, multiple handling, inventory and over-processing are some of the common forms of waste in the production systems employed by Ghanaian firms. These non-value adding activities – or waste – must, therefore, be targeted for removal while value adding activities are identified and maintained to be improved upon.

1.3 Purpose of Study

Ghanaian firms in the construction industry are faced with the problem of high cost of project delivery, bad financial performance and inability to deliver value to customers on time. According to Nicco-Annan (2006), for both public and private sector clients in Ghana, it has become the norm for construction work to drag on well beyond stated completion dates, overrun of budget and no delivery of the quality of work required. This has resulted from a production operation system that devotes a lot of time and effort to non value adding activities. A significant number of steps in the project delivery system of Ghanaian firms go into producing waste rather than value.

The study is intended to examine the production operations of typical Ghanaian firms in order to establish the possibility of introducing lean production principles by identifying and eliminating non-value adding steps while value-adding steps are maintained and improved upon.

1.4 Research Aim

The aim of the research is to establish the possibility of the adoption of lean production principles by Ghanaian firms in the construction industry in order to minimise waste and maximize value in their project delivery processes.

1.5 Research Objectives

The objectives of the research include:

- To identify the extent of practice of lean production principles by Ghanaian firms in the construction industry.

- To identify limitations to the practice of lean construction in Ghana.

- To identify general problems and strategies associated with the practice of lean construction.

- To establish opportunities for the smooth incorporation of lean production principles in the production operation system of Ghanaian firms.

1.6 Justification of Research Objectives

Achieving the broad aim of establishing the possibility of the introduction of lean construction principles by Ghanaian firms requires an appraisal of the current production operations of the firms to identify the extent to which the operations fall short of the lean production principles.

There is also the need to identify the threats and problems that are likely to inhibit the smooth adoption of the lean production principles by Ghanaian construction firms. With this knowledge, the possibility of introducing lean construction principles by the firms can thus be established.

Having identified the limitations to the practice of lean construction by Ghanaian firms, the best strategy for the adoption of lean production principles in their construction processes would be established.

There are some general problems and strategies associated with the practice of lean construction everywhere. These problems and strategies should be identified in order to achieve the aim of the research.

1.7 Scope of Study

The study focuses on examining the operations of Ghanaian firms in the construction industry to establish how best lean construction principles can be incorporated in the production operations of these firms. The study is limited to the pre-contract phase operations in view of the fact that it is the first stage of the construction project delivery process and therefore, has immense impact on the quality and value of the final product delivered at the post-contract phase. ”Good quality construction products begin at the drawing board and the same can be said for defective construction products” (Kwakye, 2006).

Pre-contract activities of various classes of Ghanaian construction consultants and contractors would be considered under the study. The traditional procurement system will be the focus of the study due to its wide application in Ghanaian construction industry.

1.8 Research Methodology

The main tools for the collection of data included literary survey, administration of questionnaire and interviews. The research methodology was therefore assessed under each objective as follows:

Objective 1:

The objective of identifying the extent to which the pre-contract operations of Ghanaian firms fall within the principles of lean production was achieved by undertaking a careful appraisal of their operations. Data collection on this objective involved administering questionnaires to consultants while contractors and clients were interviewed

Objective 2:

Data related to the limitations that are likely to inhibit the smooth adoption of lean production principles by Ghanaian firms at the pre-contract phase of construction projects was obtained through personal observation of the pre-contract activities of various firms as well as administering questionnaires to consultants, and interviewing clients and contractors.

Objective 3:

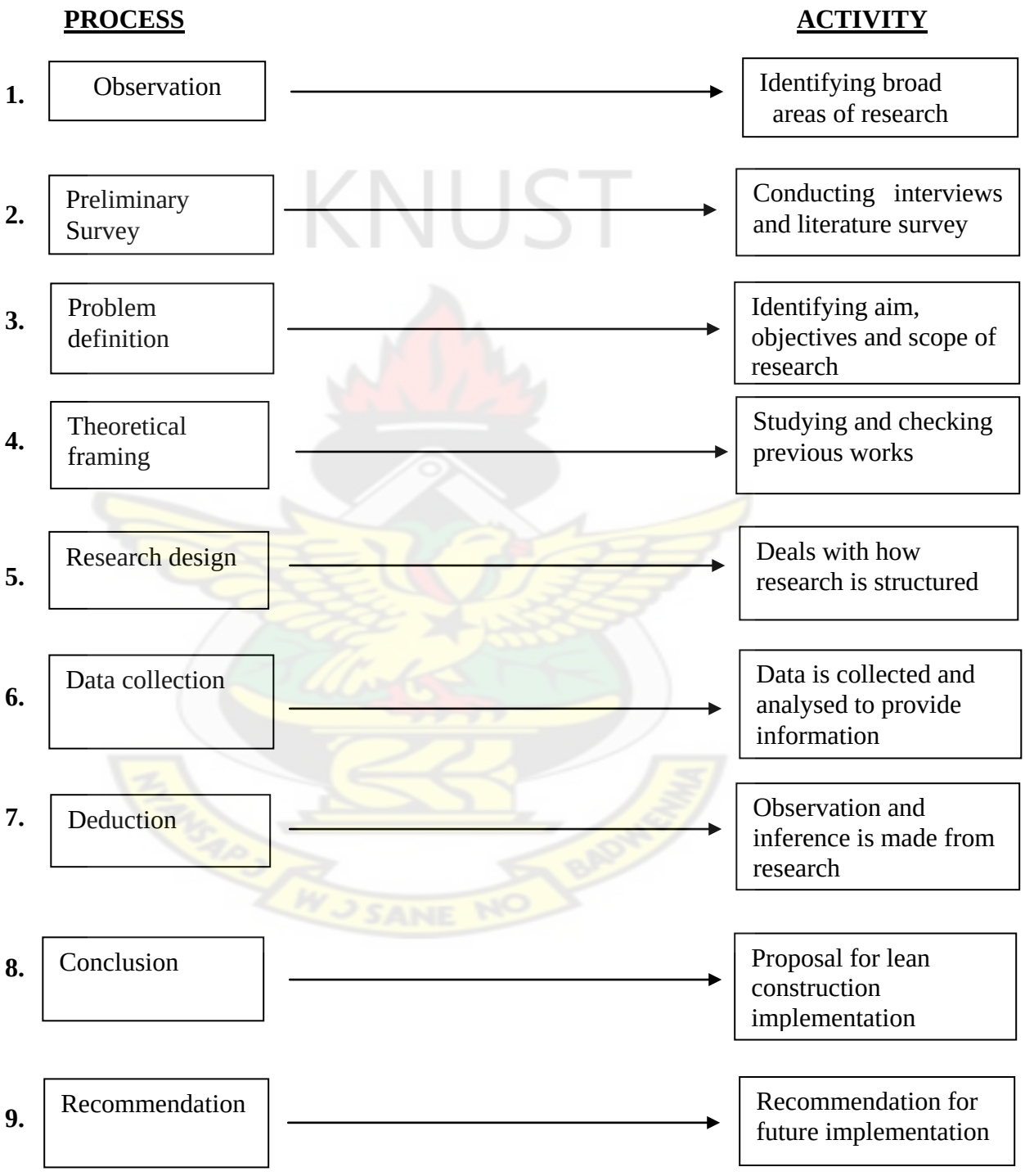
The views of consultants and contractors were sought through interviews towards establishing strategies for the smooth incorporation of lean principles in the pre-contract operations of firms in the Ghanaian construction industry.

Objective 4:

The collection of data on the general problems and strategies associated with the practice of lean production was undertaken by reading relevant literature and interviewing existing practitioners of lean thinking.

1.8.1 Research Process

The process involved in conducting the research has been structured as shown below:



1.8.2 Research Outline

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

An overview of the Ghanaian construction industry and the concept of lean thinking have been undertaken in chapter two. This chapter focuses on literature on the elements and activities in the Ghanaian construction industry environment as well as the concept of lean thinking.

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

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

Conclusions and recommendations on the research are contained in chapter five of the research. Proposals for the adoption of lean construction principles and recommendations for future implementation are discussed in this chapter.

The outline of the research is summarised as follows:

Chapter one Introduction

Chapter two	i.) Overview of the Ghanaian Construction Industry -Background -Products and services -Existing regulations and procedures -Existing procurement systems ii) The concept of Lean Thinking
Chapter three	Research Methodology
Chapter four	Data Presentation, Analysis and Discussion
Chapter five	Summary, Conclusion and Recommendations

CHAPTER TWO

THE GHANAIAN CONSTRUCTION INDUSTRY AND THE CONCEPT OF LEAN THINKING

2.1 Overview of the Ghanaian Construction Industry

According to Nicco-Annan (2006), the Ghanaian construction industry defined in its narrow sense (i.e. to include the range of activities in which construction firms specialize, but to exclude the off-site manufacture and assembly of materials and components) occupies an important place in the national economy. Nicco-Annan observed that the construction industry represents 3% of Ghana's Gross Domestic Product and employs between 25,000-30,000 people. He further argues that even though these figures appear small, they ought to be considered in the context of the high degree of casualisation in the construction industry as well as a significant informal sector whose contribution is unaccounted for in certified statistics.

The construction industry in Ghana, like in other countries, has a significant proportion of its input from other industries per unit output (e.g. cement, sand, blocks, steel, paint, quarries, timber etc.). The performance of other industries is thus linked to those of the construction industry giving rise to the believe that government uses the construction industry to regulate the national economy. The Ghanaian construction industry's output has very high import content and since there are virtually no exports by the industry, it is often argued that construction activity has immense adverse effect on Ghana's balance of trade (Nicco-Annan, 2006).

The socio-political dimension of the implications of construction activities is reflected in the fact that the availability of good housing, roads, hospitals etc. depends on construction. Furthermore constructions as a process has considerable environmental impact in the form of flooding, noise, dust, and refuse among others. In Ghana, the basis for judging the performance of the government of a political party depends on the number of rural electrification projects undertaken, health-posts commissioned, feeder roads constructed and rural water schemes realized (Nicco-Annan, 2006).

2.1.1 Products and Clients

Kwakye (2006) describes construction products as being composed of an assembly of materials or components in a fixed, confined or extended location. Construction activities in Ghana may either be of building utility or civil engineering utility. Products like commercial buildings, factories, warehouses, hospitals and schools are of building utility while roads, bridges, dams among others fall under civil engineering utility.

In Ghana, government is by far the biggest client in the construction industry, commissioning almost all infrastructural works, offices, hospitals and other non-housing work. Government as a client commissions projects either through its central authority, para-statals or as local government at various levels (Nicco-Annan, 2006).

Apart from government who fall under the category of public sector client, other types of clients in the Ghanaian construction industry include corporate clients and individual clients in the private sector. Corporate clients are companies and firms controlled other

than by a sole principal, example Social Security and National Insurance Trust (SSNIT), Shell and Ashanti Gold. Individual clients are individuals or sole proprietors usually in the construction of houses.

2.1.2 Project Procurement Systems

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

Procurement systems, according to Walker (1996) may be classified with respect to the level of integration of design and construction process as:

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

a. Conventional/Traditional Procurement System:

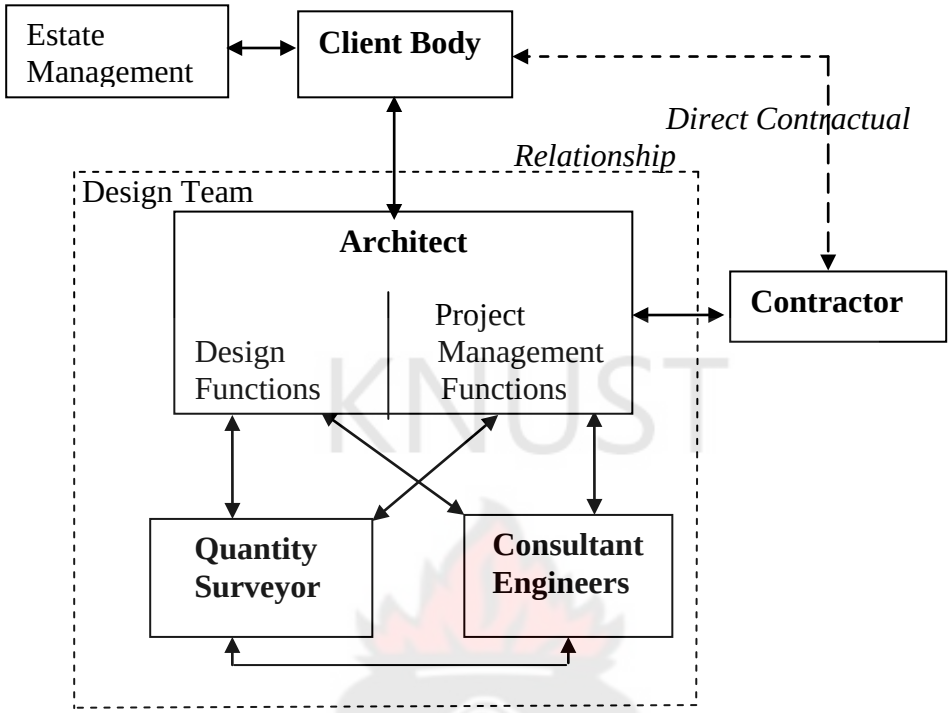


Figure 2.1: Structure of Traditional Procurement System (Walker 1996)

The tasks of design and construction in this system, as shown above, are separated because the distinct responsibilities of design consultants and contractors respectively. Design and construction under this system are managed separately as different stages of the project execution process. Most projects within the domain of the public sector in Ghana are executed under this procurement system.

This approach to procuring, Walker (1996) states, involves discrete design development, tender, and construction delivery phases. The separation of design and production function, it is argued, will lead to design without concern for buildability or production economies, lack of feedback to the design team, and perpetuation of mistakes from project to project.

The traditional procurement system is absolutely hostile to the tenets of lean thinking as the concept of lean thinking strives to achieve more integration between the design and construction phases of the project delivery process. Lean thinking seeks to minimize waste and maximize value to clients by ensuring a high concern for buildability and production economies, continuous feedback to design team, and the elimination of mistakes throughout the entire project delivery process.

b. Integrated Procurement System:

Design and construction, under this system, becomes the responsibility of one organization usually a contractor and the client has only one organization to deal with. As projects increase in size and complexity without a corresponding increase in design time, it becomes difficult to allow all alternatives to be fully studied and considered, thus increasing uncertainties. A more integrated approach to design and construction is therefore appropriate under these circumstances of large size and complex projects.

The integrated system is the generic term for many systems which seek to integrate design and construction processes. With a thin line between them, examples of the Integrated System include Design and Build, Package Deal or Turnkey. This system draws the project delivery process closer to the principles of lean thinking because it recognizes that design, manufacture and assembly processes must not be separated but integrated to deliver quality, value for money, speed and high productivity to the client.

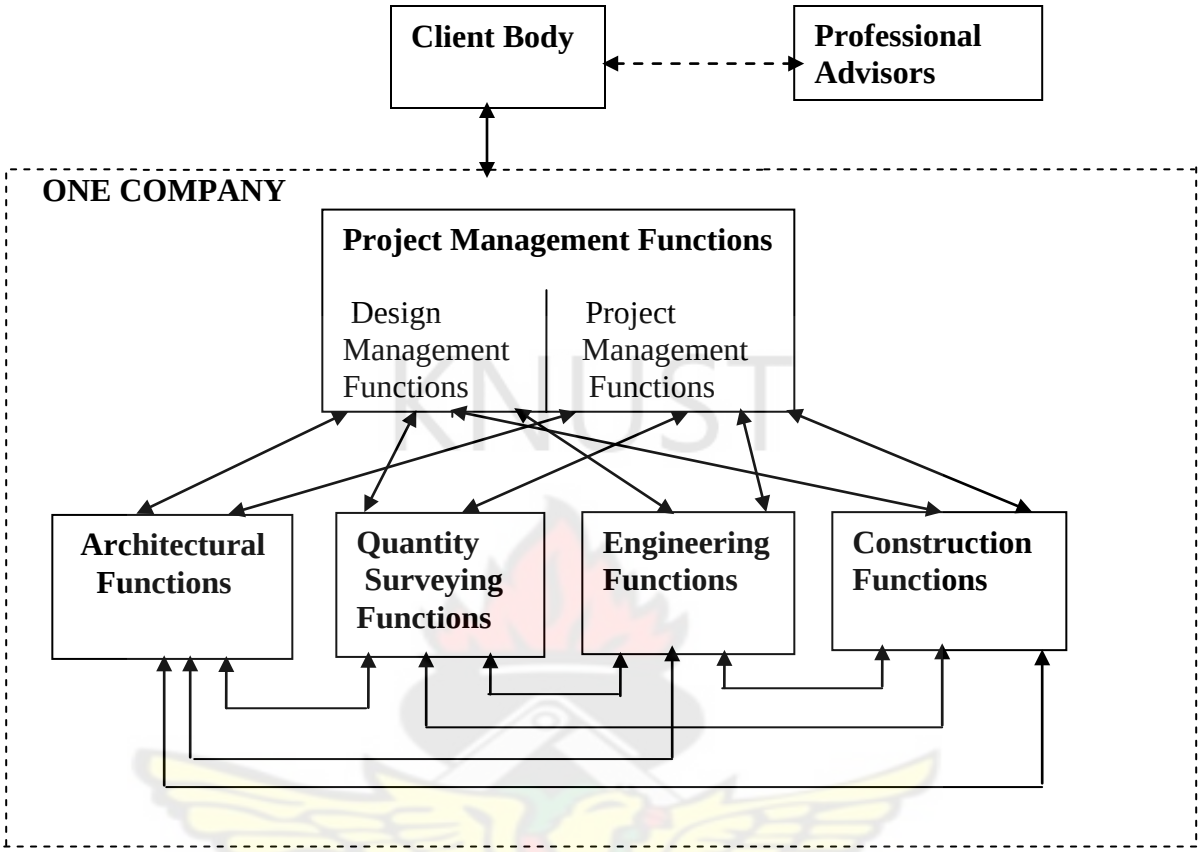


Figure 2.2: Structure of Design and Build System (Walker 1996)

c. ***Management -oriented Procurement System:***

This is a management based integrated approach to procurement that has been adopted to address the uncertainties and failures associated with the traditional system and to respond effectively to the needs of the modern construction client. The management oriented system recognizes the role the modern contractor can play in the design, production and management processes (Walker, 2006). In Ghana this system is increasingly being employed by multinational organizations like the World Bank.

Management-oriented procurement system is implemented either as management contracting or construction management. The focus of this system to

achieve better integration in the design and construction processes in order to reduce waste and deliver value to clients in a speedy fashion, brings it closer to the lean project delivery system.

Howell and Ballard (1999) however argue that lean production unlike the management-oriented systems provides the basis for an operations based project delivery system. In other words whereas lean thinking focuses on both product and process design from the onset, the management oriented approaches place less emphasis on process design at the beginning of the project delivery process.

2.1.3. Regulatory Framework

Design and production phases in the Ghanaian construction industry are subject to monitoring, checking and approval by regulatory authorities. The intervention by regulatory authorities is a constraint to continuous flow because the need for approval and permits in the design and construction processes can cause delays and uncertainties. According to Koskela (1992), codes may be obstacles to innovation if they strictly require compliance to procedure rather than ensuring performance.

Some of the regulations which are required to be adhered to in the design and construction processes include the National Building Regulations, the Environmental Assessment Regulations and the Fire Precautions (premises) Regulations. Though these regulations are expected to ensure quality of construction products and safety to the environment, their enforcement involve a lot of bureaucratic and non-value adding steps

to obtain permits and certification thus compromising on the principles of lean project delivery process.

National Building Regulations:

The National Building Regulations of 1996 (L.I. 1630), are required to be applied to the erection, alteration or extension of a building. Application for a permit is required to be made, under these regulations, to the District Planning Authority when one intends to erect any building, or make any structural alteration to any building, or execute any works or install any fittings in connection with a building. One of the sources of problems arising from the implementation of the regulations in the practice of lean construction is that most of the applications for building permits are required to be done with the submission of completed detailed drawings.

There is therefore less integration among the steps in the project delivery process, as the design stage is completely separated from the application for permit stage. Another problem is that consideration and subsequent approval of applications for permit could take as long as one year or more, thus causing delays in the execution of projects. Besides Requirement for strict adherence to some design and construction codes under the regulations is a likely barrier to innovation to ensure customer satisfaction in the practice of lean construction.

Environmental Assessment Regulations:

The Environmental Assessment Regulations of 1999, (L.I. 1652) provides for an integrated approach to environmental assessment. Environmental assessment

under this regulation being defined as the process for the orderly and systematic identification, prediction and evaluation of the likely environmental, socio-economic, and cultural and health effects of an undertaking and the mitigation and management of those effects.

The process of registration and obtaining an environmental permit depends on the nature and scope of the construction process. Under the regulations some undertakings, categorised as schedule 1, requires registration and issuance of an environmental permit before their commencement. Examples of construction activities that fall under this category include road construction, waterworks and sewage systems, and hydroelectric power plants. The second category of undertakings, referred to as schedule 2, is granted permit only when the responsible person or agency submits an environmental impact assessment to the Environmental Protection Agency.

The implementation of these regulations, like the National Building Regulations, involves a number of non-value adding steps which cause delay in the project delivery process. Construction undertakings, especially under schedule 2 could see several months being lost to the process of obtaining environmental permits. This tends adversely affects speedy delivery of value required under the lean project delivery system.

Fire Precaution (premises) Regulations:

The Fire Precautions (Premises) Regulations 2003 L.I. 1724, was passed to give backing to the Ghana National Fire Service to insist on or evaluate Fire Safety Precautionary measures in premises, to occupants or any person staying in that premises by ensuring that they can escape from fire safely and quickly. This has lead to the need for the acquisition of a fire certificate certifying the adequacy of precaution measures in a particular premise.

Premises which are eligible for the fire certificate, under the regulations, are basically those whose purpose involves access to the premises by members of the public whether on payment or not. Examples are public residential areas (like hotels, guesthouse, restaurants etc.), Places of work (like offices), entertainment centres etc. Obtaining the certificate involves the submission of an application form and a letter with attachments like fire engineering drawings and fire installation protection or conceptual report on the project. Though the acquisition of fire certificate ensures fire safety in the operation of construction products, the procedure does not allow for continuous flow in the project delivery process.

2.2 The Concept Of Lean Thinking

According to Kotelnikov (2007), 'Lean' is doing more with less: less time, less inventory, less space, less labour, and less money. Referring to "Lean manufacturing" as the "Toyota production system", Kotelnikov (2007) further describes "Lean

manufacturing" as a shorthand for a commitment to eliminating waste, simplifying procedures and speeding up production.

Unlike current approaches to managing construction (including design-build) and programmatic improvement efforts (partnering and TQM), lean construction provides the foundation for an operations based project delivery system. From roots in the Toyota Production System, this new way of designing and making capital facilities makes it possible for significant improvements on complex, uncertain and quick projects (Howell and Ballard, 1999).

2.2.1 Historical Evolution of Lean Thinking

Lean production (or the Toyota Production System) was developed after the Second World War by Toyota. Engineer Ohno, a smart person dedicated to eliminating waste led the Toyota team. The term "lean" was coined by the research team working on an international auto production to reflect the waste reduction nature of the Toyota production system and to contrast it with craft and mass forms of production (Womack et al, 1991).

Faced with the challenge of producing a variety of cars with Toyota's small capital base for a small market, Ohno shifted attention to the entire production system from the narrow focus of craft production on worker productivity and mass production on machine. He followed the work of Henry Ford and continued the development of flow based production management. However unlike Ford who had an almost unlimited desire for a standard product, Ohno wanted to build cars to meet customers´ peculiar

demand. Having been influenced by Total Quality Management (TQM) and as a result of efforts to reduce machine set up time Engineer Ohno developed a simple set of objectives for the design of the production system: Produce a car to the requirements of a specific customer, deliver it instantly, and maintain no inventories or intermediate stores (Howell, 1999).

The desire of Toyota to achieve zero waste and perfection, according to Howell and Ballard (1999), shifted the improvement focus from the activity to the delivery system. Ohno and other Japanese engineers got exposed to the mass production of cars from their plant visits in the United States and where US managers saw efficiency, Ohno saw waste at every turn. He realised that the pressure to keep each machine running at maximum production led to a lot of intermediate inventories he called “the waste of over production.”

Ohno also observed defects built into cars because of the pressure to keep the assembly line moving. Production at all costs implied that defects were left in cars as they moved down the line. "These defects disrupted down stream work and left completed cars riddled with embedded defects. Where the US approach aimed to keep the machines running and the line moving to minimize the cost of each part and car, Ohno’s system design criteria set a multi-dimensioned standard of perfection that prevented sub-optimization and promoted continuous improvement" (Howell and Ballard, 1999).

According to Howell, zero time delivery of a car that meets customer needs with nothing in inventory called for stiff coordination between the progress of each car down

the line and the arrival of parts from supply chains. The incidence of rework arising from errors could not be tolerated as it reduced throughput (that is the time to make a car from beginning to end) and caused unreliable workflow.

Engineer Ohno, reports Howell (1999), in trying to eliminate the incidence of rework arising from errors went as far as calling for workers to stop the line on receipt of a defective part or product from upstream unlike in US plants where only the plant manager could stop the line. Requiring workers to stop the line led to the decentralization of decision making. The decentralization process was carried further when he replaced centralized control of inventory with a simple system of cards or bins which signalled the upstream station of downstream demand. "In effect, an inventory control strategy was developed which replaced central push with distributed pull". Howell (1999) also observed Ohno´s decentralization of shop floor management by making visible production system information to everyone involved with production. “Transparency” allowed people to make decisions in support of production system objectives and reduced the need for more senior and central management.

The Toyota production team after understanding the demands of low waste production in manufacturing, moved back into the design process and out along supply chains. In an effort to cut down the time to design and deliver a new model, the design of the production process was carefully considered along with the design of the car. The responsibility of ensuring that engineering components meet design and production criteria was then shifted to the suppliers (Howell, 1999).

Lean production, according to Howell (1999), is evolving but the basic outline has become clear: Design a production system that will deliver a custom product instantly on order but maintain no intermediate inventories. The concepts include:

- Identify and deliver value to the customer: eliminate anything that does not add value.
- Organize production as a continuous flow.
- Perfect the product and create reliable flow through stopping the line, pulling inventory, and distributing information and decision making.
- Pursue perfection: Deliver on order a product meeting customer requirements with nothing in inventory.

"Lean production can now be understood as a new way to design and make things differentiated from mass and craft forms of production by the objectives and techniques applied on the shop floor, in design and along supply chains. Lean production aims to optimize performance of the production system against a standard of perfection to meet unique customer requirements" (Howell, 1999).

2.2.2 Related Concepts to Lean Thinking

The strategic process of continuous improvement that evolved in the manufacturing industry to achieve 'best in class' or 'world class' standards depends on such related concepts to lean production as Total Quality Management, Benchmarking, Just In Time, Concurrent Engineering, Re-engineering, Value Management, Modular Building, Last Planner System and Employee Participation.

Total Quality Management (TQM):

Total Quality Management is a management lead philosophy of providing complete customer satisfaction. All levels of activity must participate in quality procedures and standards from the individual, working crew, contract site, head office department to the entire corporation itself including subcontractors and other outside suppliers, all aimed at ensuring that customers obtain products and services at the standard expected or negotiated (Harris and McCaffer, 2001).

The term 'total', according to Shingo (1988), refers to three extensions:

(i) Expanding quality management from production to all departments,

(ii) Expanding quality management from workers to management, and

(iii) Expanding the notion of quality to cover all operations in the company.

Benchmarking:

Benchmarking refers to comparing one's current performance against the world leader in any particular area (Compton, 1992). The comparison, according to Harris and McCaffer (2001), may be with similar internal units in the same organization or with external competitors operating in a different industry.

The primary objective of benchmarking is to achieve 'best practice' principally by measuring effectiveness against quality of end product or service to the customer, productivity, cost level, safety and delivery time criteria (Harris and McCaffer, 2001).

Just in Time:

The driving idea in the Just in Time approach is reduction or elimination of inventories (work in progress). This, in turn, leads to other techniques that are forced responses to coping with fewer inventories: lot size reduction, layout reconfiguration, supplier co-operation, and set-up time reduction. It is a pull type production control method, where production is initiated by actual demand rather than by plans based on forecasts (Koskela, 1992).

Elimination of waste is identified as a cornerstone in the implementation of just in time. waste was recognized by Shingo (1984) as being made up of overproduction, waiting, transporting, too much machining (over processing), inventories, moving, making defective parts and products.

Concurrent Engineering:

Concurrent engineering occurs primarily at the product design phase. According to Harris and McCaffer (2001), it is the integration of the design and construction phases. Koskela (1992) in referring to concurrent engineering as simultaneous engineering describes it an improved design process characterized by rigorous upfront requirements analysis, incorporating the constraints of subsequent phases into the conceptual phase, and tightening of change control towards the end of the design process.

In comparison to the traditional sequential design process, iteration cycles are transferred to the initial phases through teamwork. Compression of the design time,

increase of the number of iterations, and reduction of the number of change orders are three major objectives of concurrent engineering (Koskela, 1992).

Re- engineering:

This concept refers to the radical redesign (or reconfiguration) of processes and tasks, especially with respect to implementation of information technology. Recognizing and breaking away from outdated rules and fundamental assumptions is the key issue in re-engineering (Hammer, 1990).

Value Management

Value based management according to Carothers & Adams (1991) refers to conceptualized and clearly articulated value as the basis for competing. Firms driven by value-based strategies, just like lean thinking, are customer oriented, in contrast to competitor-oriented firms. Continuous improvement to increase customer value is also one essential characteristic of value-based management.

Employee Participation:

Prompt response to problems requires empowerment of workers. This involves allowing employees to be part of the planning and decision making process. According to Lillrank and Kano (1989), continuous improvement is heavily dependent on day-to-day observation and motivation of the workforce. In order to avoid waste associated with division of labour, multi-skilled and/or self-directed teams have been established for product/project/customer based production.

2.2.3 Lean Thinking in the Construction Industry

Many ideas from the manufacturing industry have been rejected by the construction industry on the basis that construction is different. Howell (1999) in explaining the peculiarity of the construction industry from the manufacturing sector states that "manufacturers make parts that go into projects but the design and construction of unique and complex projects in highly uncertain environments under great time and schedule pressure is fundamentally different from making tin cans".

According to Ballard and Howell (1998), what is referred to as "construction" spans a spectrum ranging from slow, certain, and simple (stodgy) projects on one end to quick, uncertain, and complex (dynamic) projects on the other end. For the former, a manufacturing strategy is appropriate (i.e., making construction more like manufacturing through such initiatives as standardization). For dynamic projects, however, a manufacturing strategy is not sufficient. Learning how to manage uncertainty, complexity and quickness within the characteristics of construction conditions of site production, unique product, and temporary organization should therefore be the task.

The Uniqueness of Construction Production:

The construction industry as a result of its peculiarities is often seen in a class of its own, different from manufacturing. These peculiarities are often presented as reasons - or excuses – for failure to implement such well-established and useful concepts as lean production from the manufacturing sector (Koskela, 1992).

Construction peculiarities according to Koskela (1992), Tatum & Nam (1988) and Warszawski (1990) refer especially to the following characteristics:

i. One of a kind nature of projects

ii. Site production

iii. Temporary multiorganisation

iv. Regulatory intervention

Ballard and Howell (1998), in response to the question: what kind of production is construction, describes construction as being "essentially the design and assembly of objects fixed-in-place, and consequently possesses, more or less, the characteristics of site production, unique product, and temporary teams". Ballard and Howell (1998) are however of the opinion that other types of production also possess one or several of these characteristics seen as peculiar to construction.

i. One of a kind nature of projects:

Warszawski (1990) explained that the one-of-a-kind nature of construction products and processes is caused by different needs and priorities of the client, different sites and surroundings, and different views of designers on the best design solutions.

Koskela (1992) observed that the general problem in the production of one-of-a-kind buildings is the configuration of the flows has to be specifically designed. There are activities in the flow that are difficult to control because of novelty. Besides in one-of-a-kind tasks, figuring out the respective goals and constraints is error-prone and time-consuming.

The one-of-a-kind nature covers most often the overall form of the building or facility. Materials, components and skills needed for projects are usually the same or similar and from the point of view of contractors and design offices, there is continuity and repetition: roughly similar projects and tasks recur. Therefore, it has to be stressed that the problems associated with one-of-kindness affect only certain processes in any project (Koskela, 1992).

Ballard and Howell (1998) in differing from the view that "project uniqueness" differentiates construction from manufacturing, observes that product uniqueness is becoming ever more characteristic of manufacturing as the sector is striving to realise the vision of instantaneously producing uniquely custom products.

ii. Site production:

Construction production process is usually carried out at the final project delivery site. According to Koskela (1992) this leads to such problems as little protection against elements or intrusion thus rendering operations prone to interruptions. Besides the spatial flow of work stations (teams) has to be coordinated (in contrast to a factory, where only material flow through work stations is planned). Koskela further explains that in site production the working environment, unlike that within factories, is continuously evolving, making layout planning laborious and visual controls difficult to implement.

Ballard and Howell (1998) in challenging the position that site production is peculiar to construction, points out that even though 'site production' differentiates construction from shipbuilding and airplane building (fellow members of the 'fixed position manufacturing' category), construction however shares this site production characteristic with agriculture and extractive industries such as timber, mining, and fishing, which are at the very beginning of manufacturing's value streams.

iii. Temporary multiorganization:

A construction project organization is usually a temporary organization formed for the purpose of the particular project. It is made up of different companies and practices, which have not necessarily worked together before, and which are tied to the project by means of varying contractual arrangements to form a multiorganization. Its temporary nature extends to the work force, which may be employed for a particular project, rather than permanently (Koskela, 1992).

Temporary multiorganization, as observed by Koskela (1992), faces the difficult challenge of achieving goal congruity across the project organization as well as stimulating and accumulating improvement inside an organization with a transient workforce. Ballard and Howell (1998) however stated clearly that 'Temporary multi-organizations' are not peculiar to construction and that the tendency to 'projectise' appears to have no industry bounds.

iv. Regulatory intervention:

The design solution and many work phases in a construction project are subject to checking and approval by regulatory authorities. These interventions by the authorities, according to Koskela (1992), cause uncertainty and constraints to the process. Getting an approval for a design solution is not only made unpredictable but can also cause delays. Codes may be barriers for innovation, if they rigidly require a procedure, rather than a performance.

The growing need to protect the environment from the impact of factory activities as well as ensuring the safety of consumers of factory products has led to strict regulatory intervention in the manufacturing sector. One can, therefore, argue that regulatory intervention is not unique to construction.

2.2.4 Principles of Lean Thinking in Construction

Lean construction embraces new principles and procedures for product development and production management specifically customised for the Architecture, Engineering and Construction industries. It advocates the simultaneous consideration of product and process development, using tools like concurrent engineering among others (Tommelein, 2002).

According to Tommelein (2002), the principles of lean construction include:

1. Creating reliable work flow: e.g., the Last Planner should make only quality assignments;
2. Reducing waste;

Ohno, who articulated the lean production philosophy and implemented it in Toyota's production system, classified sources of waste as follows (8 added by Womack and Jones 1996):

i. Defects in products;

ii. Over-production of goods not needed;

iii. Inventories of goods awaiting further processing or consumption;

iv. Unnecessary processing;

v. Unnecessary movement of people;

vi. Unnecessary transport of goods;

vii. Waiting by employees for process equipment to finish its work or for an upstream activity to complete;

viii. Design of goods and services that fail to meet user's needs.

3. Promoting process transparency by clearly documenting, updating, and constantly reporting the status of all process flows to all involved;
4. Pulling work, materials, and information through the production system to meet specific customer needs;
5. Reducing overall process cycle time by minimizing each machine's change-over time; and
6. Synchronizing and physically aligning all steps in the production process.

2.2.5 Implementing Lean Thinking in Construction

Applying lean thinking in construction, in the opinion of some practitioners, requires that construction's differentiating characteristics be softened or given less recognition.

This strategy is advocated by those who believe that a successful implementation of lean principles in construction will call for making construction more like manufacturing from where lean thinking originated. For instance Koskela (1992) in suggesting an approach to the one-of-a-kind nature of construction stated that those unique solutions in a project not absolutely necessary but due to client or site idiosyncrasies or artistic expression of the designer should be eliminated. In this way, Koskela further explains, proven standard work flows and associated components, skills, etc. can be used.

Koskela (1992) again suggested actions like standardizing components, utilizing modularization and prefabrication as well as using enduring teams, as measures to reduce the uniqueness of construction and bring it closer to manufacturing. Warszawski (1990) has also indicated that closed or open industrialized building systems provide solutions to be considered and that recently, construction companies have begun to offer concept buildings (office buildings, schools, day nurseries, etc.), which are pre-engineered solutions that can be adapted to different needs.

Ballard and Howell (1998) are however of the opinion that following the line of thought of making construction more like manufacturing, successive waves of implementation would leave ever smaller remainders that are not yet reduced to manufacturing, and consequently not yet capable of being made lean. Even though the approach of making construction like manufacturing offers tremendous opportunity for reducing the time

and cost of constructed facilities, the real challenge, according to Ballard and Howell, is to understand the peculiar characteristics of the remainder and how to make it lean.

A two part strategy of implementing lean in construction has therefore been proposed by Ballard and Howell (1998): (i) Claiming for construction what actually belongs to contemporary product manufacturing and minimizing construction's peculiarities in order to take advantage of lean techniques developed in manufacturing, (ii) Developing lean techniques adequate to dynamic construction, the remainder that resists the first approach.

The industrialisation movement which advocates initiatives like manufactured housing seems to be adopting the first strategy of minimizing construction's peculiarity. An example of actions to minimize construction's peculiarities includes simplifying site construction to final assembly and testing. The second strategy of developing lean techniques adequate to dynamic construction poses the greatest difficulties for implementing lean thinking (developed in manufacturing) because it proposes to make lean a type of production that is explicitly not manufacturing (Ballard and Howell, 1998).

Ballard and Howell (1998) in explaining lean thinking in dynamic construction further observed that product and process design can be standardized for standard products, but for non-standard products it is necessary to standardize at the meta-level of planning and control. Therefore, standard procedures for planning and managing the design and

installation of unique facilities have to be developed. The industrial sector's lead in this direction, according to Ballard and Howell, seems to be based on their control of the entire process, as opposed to the extreme fragmentation in the construction sector. It is however changing as specialists come together to pursue design-build as well as modular building opportunities. This social unity is a prerequisite for process mapping and streamlining that can maximize customer value and minimize waste.

2.2.6 The Lean Project Delivery System (LPDS)

The Lean Project Delivery System (LPDS) was developed by the Lean Construction Institute (LCI) to apply principles pioneered in manufacturing to construction. LPDS tools facilitate planning and control while maximizing value and minimizing waste throughout the construction process. Ballard (2000) describes LPDS as a production management-based approach to designing and building capital facilities in which "the project is structured and managed as a value generating process".

The Lean Project Delivery System is formulated as a philosophy, a set of interdependent functions (at the systems level), guidelines for decision making, steps for execution of functions, and as implementation aids and tools, including software where appropriate (Ballard, 2000). The limits of the domain of LPDS, states Ballard (2000), are defined by an intersection of projects and production systems known as project-based production systems.

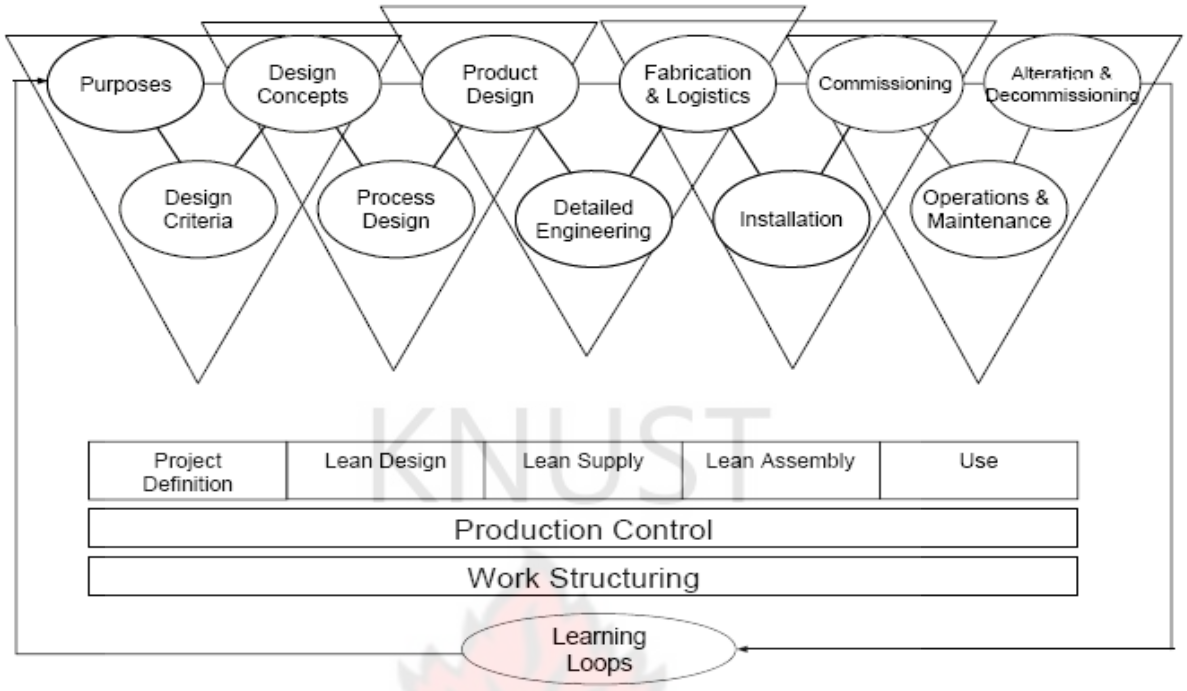


Figure 2.3: Lean Project Delivery System (Ballard 2003)

The LPDS model, according to Ballard (2003), consists of modules organized into interconnecting triads representing five different project phases (Figure 2.4). Each phase is represented by a triangle containing essential steps that lead to the completion of projects. There are also two production control modules and the work structuring module, both conceived to extend through all project phases. The post-occupancy evaluation module (also known as learning loops) links the end of one project to the beginning of the next.

Components of Lean Project Delivery System (LPDS):

i. Project Definition Phase:

This is the first phase in the Lean Project Delivery System with activity modules including: needs and value determination, design criteria formulation, and conceptual design generation. Conceptual designs will be generated and evaluated

with a view to needs determination and design criteria development. Project Definition is usually managed by the project manager who is responsible to the client for the entire project, including designing and building. Collaborative production and decision making at this stage will include clients and stakeholders; e.g., design and construction specialists; suppliers of materials, equipment, and services; facility operators, maintainers, and users; representatives of financiers, insurers, regulators, and inspectors (Ballard, 2000).

Costing and project duration estimating are integrated with the formulation of the project definition, rather than being done after the definition is produced. Where appropriate, a target cost will be established for the facility to be designed or the client makes a decision regarding cost within the definition process (Ballard, 2000).

Ballard further states that work structuring is applied in the Project Definition phase to produce rough cut strategies and plans for project execution. The interim strategies and plans are linked to product architecture options, in advance of the more detailed integration of product and process design to be accomplished in subsequent phases. Production control will be applied in the Project Definition phase once a plan for the phase has been developed. The Project Definition phase transitions to the Lean Design phase when there is alignment between: customer needs and stakeholder demands; design criteria for product and process; and conceptual design(s) (Ballard, 2000).

ii. Lean Design Phase:

Lean Design consists of Conceptual Design, Process Design, and Product Design.

The Lean Design phase develops the conceptual design from Project Definition into product and process design, consistent with the design criteria produced in Project definition. Product and process design decisions are made simultaneously in dialectic to customer needs as well as to design criteria. "Should an opportunity emerge for increasing customer value by expanding customer needs, and if there is sufficient time and money, the project definition process will be reengaged to align needs, criteria, and design concepts" (Ballard, 2000).

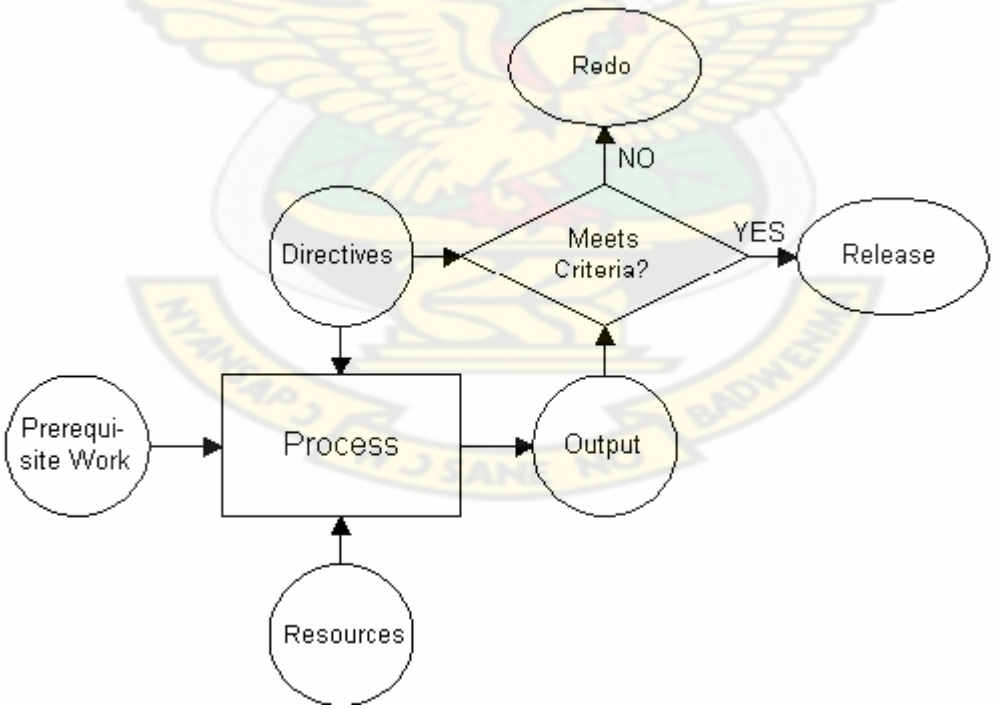


Figure 2.4: Activity Definition Model (LCI 2004)

The design process which is the first process to be designed is developed by the design team using team planning techniques and employing the Activity Definition Model (ADM) (Figure 2.5). The Design Structure Matrix (DSM), according to Ballard is applied in this phase to resequence design tasks in order to reduce negative iteration. Every effort will be made at this stage to maximize value to customers in the making of trade-offs between needs and objectives.

Specialty contractors will either serve as designers or will participate in the design process, assisting with selection of equipment and components as well as with process design. Where specialty contractors do not perform the design, designers will produce only those deliverables needed for obtaining permits or needed by specialty contractors and other suppliers for detailing (Ballard, 2000).

Design decisions, states Ballard (2000), will be postponed until the last responsible moment provided this gives an opportunity to increase value to customers. However a single conceptual design will normally be selected before the end of this phase because the last responsible moment for making that decision will have usually passed.

3D/4D modelling and web-based collaborative design software are the IT tools to be employed in the Lean Design phase of the delivery system. 3D/4D is best used in the design phase as a simulation tool for exploring and evaluating design alternatives. The shared geometry needed to minimize interferences and conflicts in the detailed engineering module may also be provided by 3D/4D tools.

The Lean Design phase evolves into Lean Supply when the product and process design have been developed from the design concept consistently with the design criteria. The design concept and criteria are seen to be adequate expressions of customer needs and stakeholder demands. The alignment will be scrutinized and approved by the design/build team and the client before the shift to the next phase of the lean project delivery system (Ballard, 2000).

iii. Lean Supply Phase:

The Lean Supply phase is made up of detailed engineering of the product designed at the Lean Design stage, fabrication or purchasing of components and materials, and then logistics management of deliveries and inventories. Decisions at this stage on the engineering, production, or delivery of materials and components are made with the view to maximizing customer value (Ballard, 2000).

Detailed engineering will be carried out using3D modelling and where possible, the 3D model will directly drive of fabrication. Design inputs developed on different platforms will be integrated into a different model by employing collaborative design tools.

Once site deliveries begin, this phase begins to change to the Lean Assembly phase. According to Ballard (2000), Site deliveries may be initiated within a fast tracking strategy that decouples facility systems or components so that assembly of one component can begin while detailed engineering of subsequent components is still

underway. In no case will all fabrication and procurement of components be completed before site installation is initiated.

iv. Lean Assembly Phase:

The activity modules within this phase of the delivery system include fabrication and logistics, installation, and commissioning. Lean Assembly begins with the first delivery of tools, labour, materials or components to the site and ends when the keys are turned over to the client (Ballard, 2000).

A key task here is the coordination of deliveries to ensure that intimately connected operations are managed as continuous flow processes by promoting multiskilling in shops and site installation. According to Ballard, the technique of in-process inspection both in shops and on site will be developed in this phase.

v. Use Phase:

The commissioning module transitions the Lean Assembly Phase into Use Phase, the last phase of the Lean Project Delivery System. Other modules in this phase, apart from commissioning, include operations and maintenance, alterations and decommissioning (Ballard, 2000). It is at this stage that final feedback on the success of the lean system to deliver a project that meets the overall needs and a value determined at project definition phase is obtained.

At this stage collaborative assessment of the project and appropriate actions to be taken to maximize customer value will include clients and stakeholders; e.g., design and construction specialists; suppliers of materials, equipment, and services; facility operators, maintainers, and users; representatives of financiers, insurers, regulators, and inspectors. Project participants determine if the executed project successfully met customer needs. They can then channel their experience into a learning loop to guide lean delivery efforts on future projects (Howell and Ballard 1999).

vi. Work Structuring:

According to the Lean Construction Institute (LCI), Work Structuring is a term used to indicate the development of operation and process design in alignment with product design, the structure of supply chains, the allocation of resources, and design-for-assembly efforts. The purpose of work structuring, according to Ballard (2000), is to make work flow more reliable and quick at the same time delivering value to the clients.

Work structuring decisions cut across all project phases. For example, decisions regarding supply chain structure may be made in the project definition phase, while seemingly small details like the selection of a specific component in detailed engineering can impact how work flows within the assembly process (Ballard, 2000).

vii. Production Control:

Production Control and Work Structuring are complementary and are managed concurrently during all phases of Lean Project Delivery System (Tsao, 2005). The

components of Production Control include workflow control and production unit control. Workflow control is carried out using the look ahead process technique and Production unit control is accomplished using weekly work planning (Ballard, 2000).

Explaining the complimentary role of Production Control and Work Structuring through all the phases of Lean Project Delivery, Tsao (2005) illustrated that "Typically, during the Project Definition and Lean Design phases, planners develop and compare various Work Structures to determine an appropriate one for use on the project. During the Lean Supply and Lean Assembly phases, project participants begin executing the selected Work Structure. If they find they cannot execute certain aspects of the selected Work Structure, they may modify it to better match their capabilities. Thus, Work Structuring is an ongoing, adaptive process. Finally, during the facility's Use phase, project participants determine if the executed Work Structure successfully met customer needs. They can then funnel their experience into a learning loop to guide Work Structuring efforts on future projects"

Features of Lean Project Delivery System (LPDS)

Ballard (2000) has identified the essential features of LPDS as:

i) The project is structured and managed as a value generating process

ii) Downstream stakeholders are involved in front end planning and design through cross functional teams

iii) Project control has the job of execution as opposed to reliance on after-the-fact variance detection

iv) Optimization efforts are focused on making workflow reliable as opposed to improving productivity

v) Pull techniques are used to govern the flow of materials and information through networks of cooperating specialists

vi) Capacity and inventory buffers are used to absorb variability

vii) Feedback loops are incorporated at every level, dedicated to rapid system adjustment.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Research Design

The research made use of investigative and descriptive study design with reference to the pre-contract processes of selected Ghanaian consultancy and construction firms. The study involved representative samples of the various Ghanaian consultancy and construction firms located in various parts of Ghana. This was an opportunity to critically explore and examine the steps in the pre-contract activities of Ghanaian consultancy and construction firms – site survey, design brief formulation, sketch and detailed design, obtaining permits, preparation of bills of quantities, tender documentation and contract documentation.

The Lean Project Delivery System (LPDS) model, developed by Ballard (2003), was used as the basis for assessing the extent to which the various steps of the pre-contract activities of Ghanaian firms fall in line with the concept of lean thinking. The steps were examined and assessed within the broad framework of lean project definition, lean design, lean supply, lean assembly and use.

3.2 Sources of Data

The study depended on both primary and secondary data. Primary data was made up of first-hand data collected under the control and supervision of the candidate through the use of questionnaires, interviews and observation.

The secondary sources of data were obtained using relevant books, journals, magazines and research papers. The books, journals, magazines and research papers provided information for reviewing literature relevant to the study.

The review sought to understand the historical evolution of the concept of lean thinking, the key principles of the concept, and how the concept could be adopted for implementation in the construction industry given the peculiarity of the construction industry compared to the manufacturing industry (from where the concept of lean thinking originated). The literature was reviewed to also understand the peculiar characteristics of the Ghanaian construction industry especially with respect to pre-construction procedures and requirements.

3.3 Research Instruments

The research data was collected mainly with the aid of questionnaires. Extensive field observations and interviews were also employed as complementary instruments to the questionnaires in the data collection process.

Questionnaire Design

The questionnaires, which consisted of seven (7) different sets of closed-ended objective questions (See Appendix I.), was designed to obtain data on the familiarity of Ghanaian consulting firms with the concept of lean thinking, the extent to which current pre-contract activities fall in line with the principles of lean thinking, the existing obstacles to the implementation of the concept of lean thinking, and possible ways of

ensuring successful implementation of the principles of lean thinking by Ghanaian consulting firms.

For purposes of obtaining more specific information and to understand the systems better, interviews were also used. The interviews were targeted at consultants, contractors and clients. Personal observation of the flow of design and documentation processes within some firms was also undertaken.

3.4 Target Population

The core target population for data collection using questionnaires consisted of consultants (architects, engineers, quantity surveyors, etc). The focus on the consultants in the administration of the questionnaire was due to the key role consultants play in pre-contract activities. Contractors (building and civil) and clients (public and private) were also interviewed in some special cases.

Consultants provided information such as the design and documentation activities at the pre-contract stage of construction projects as well as the level of involvement of other stakeholders in the project delivery process. Information on the level of integration of the consultant's and contractor's role was obtained from the consultants and contractors. Apart from their level of involvement, the clients also provided information on their perception of value and waste in the project delivery process.

3.5 Sampling Procedure

A representative sample of firms involved in design and documentation activities at the pre-contract stage of construction projects was required for the study. The sample size for the study was therefore obtained by using the following formula (according to Saunders, M. *et al.,* 1997):

$n = n' / 1 + \{n'/N\}$

Where n is the minimum sample size;

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

N is the total population. 101 registered architectural firms were in good standing as at 2006 (Daily Graphic, July 20, 2006) while 58 practicing quantity surveying firms existed in 2006 (The Quantity Surveyor Magazine, issue3, July-Sept. 2006). A total population of 159 (i.e. 101 + 58) registered architectural and quantity surveying firms was therefore considered. This implies N=159.

Therefore $n = 25 / 1 + \{25/159\} = 22$.

Within each of the minimum 22 firms that were sampled, three professionals (architect, quantity surveyor and engineer) were the target respondents to the questionnaire. This

brought the total number of minimum respondents to the questionnaires to 66 (i.e. 22x3).

Assuming a non-response rate of 10%, the final sample of respondents to the questionnaire became 73 (i.e. 66+ 0.1x66).

3.6 Procedure for data collection

A sample of 25 firms providing design and documentation services at the pre-contract stage of construction projects across the country were considered for the administration of the questionnaires. Three professionals (architect, quantity surveyor and engineer) in each of the firms were identified and given the questionnaire for their responses. In the case of the firms who did not have all the professionals in-house, their associate professionals were contacted for their responses to the questionnaire.

The questionnaires were distributed personally to respondents mainly in their offices. There were however instances whereby contacts were made on phone and questionnaires mailed to respondents. Some of the respondents, especially those who were totally unfamiliar with the concept of lean thinking, were taken through the questionnaire before their responses were given.

A personal observation of some activities of some of the selected firms also provided an opportunity to obtain special information for the study. Ten major clients of some of the selected firms as well as some fifteen contractors who have worked with them were also

interviewed to obtain information especially on their level of involvement by the firms at the pre-contract phase of the project delivery process.

3.7 Analysis of Data

A qualitative and quantitative approach to data analysis was employed for the study. The data collected was edited, sorted, and coded. Statistical Package for Social Scientists, version 15 (SPSS Version 15) and Microsoft excel were then used to analyse the data. Frequency tables, percentages, bar charts and other descriptives were used to analyse the results. The results from these analyses provided the basis for finding out what patterns and common trends run through the responses with respect to the practice of lean thinking principles by firms in Ghana. The basis for deviations from the common trends running through the responses was also established from the analysis.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND DISCUSSION

4.1 Introduction

The main objective of the study was to conduct an assessment of the design and documentation processes at the pre-contract phase of construction projects to find out the extent to which these processes fall in line with the principles of lean thinking. The various limitations to the practice of lean thinking by Ghanaian firms at the pre-contract stage of construction projects was also to be established by the study.

The resulting information has been used to identify possible areas of improvement in the steps of pre-contract activities in line with the tenets of lean thinking. Strategies for the smooth incorporation of lean production principles in the production operation systems of Ghanaian firms will then be established so that there is maximization of value and minimization of waste in the construction project delivery process especially at the pre-contract stage.

This chapter will focus on the presentation, analysis and discussion of the data obtained from the study. The findings of the study are then compared with the data collected from secondary sources so that meaningful conclusions will be drawn and appropriate recommendations made.

4.2 Extent of Practise of Lean Thinking by Ghanaian Firms

4.2.1 Familiarity of Firms with the Concept of Lean Thinking

It was observed that there is some level of awareness among Ghanaian consultants regarding basic principles of managing production systems to minimize waste but maximize value for clients in the project delivery process. There is however a very big gap between the awareness of these basic principles of waste minimization and value maximization on one hand, and a conscious effort by the firms to establish project delivery systems that focus on waste minimization and value maximization on the other hand.

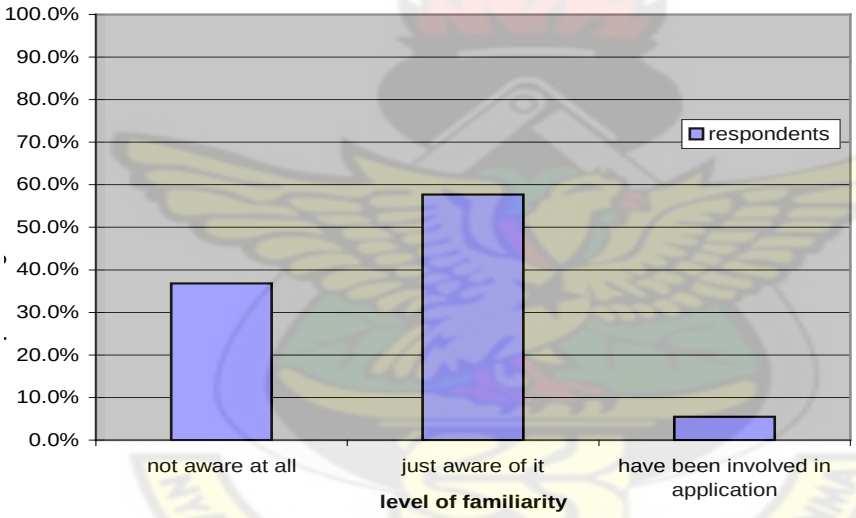


Fig. 4.1: Familiarity of consultants with lean thinking concept

The survey revealed, as shown in Figure 4.1, that more than 57% of the selected consultants were just aware of the existence of the concept of lean thinking. The indication was that even though the term "lean thinking" was largely unfamiliar, more than half of the professionals within the selected firms were aware that there is a production management concept that seeks to minimize waste but maximize value in the project delivery process. More than 36% of the consultants were however

completely unaware of such a production management concept as lean thinking which seeks to minimize waste and maximize value in the project delivery process.

It is worth noting that even though about 5% of the respondents gave an indication that they have been involved in the application of the concept of lean thinking, they however admitted that no special lean production system like the lean project delivery system (LPDS) was applied. Their intimation was that once they try to basically ensure that waste was reduced even in the conventional project delivery system, they were applying the concept of lean thinking.

4.2.2 Level of Participation / Involvement of Project Participants in Pre-Contract Activities.

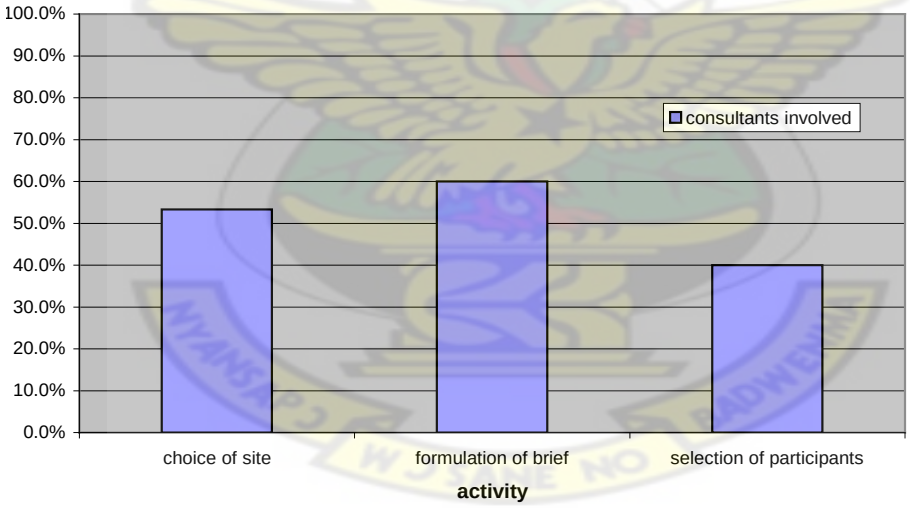


Fig. 4.2a: Consultants' Participation in Some Pre-contract

According to Harris and McCaffer (2001), achieving good results with lean thinking requires, among others, some common tools of production management like the integration of design and construction, multi-functional task groups and employee

participation. All these production management tools require a high level of involvement and participation among such key stakeholders in the project delivery process as consultants, clients, contractors and specialist/suppliers.

The indication by consultants of their level of involvement in the initial pre-contract activities stood at 60.0% for design brief formulation, 53.3% for choice of site, and 40.0% for selection of other project participants like contractors and other consultants (fig 4.2a). Clients were seen to be exercising some level of domineering control when it came to choice of site, design brief formulation, and selection of other project participants like contractors and specialists.

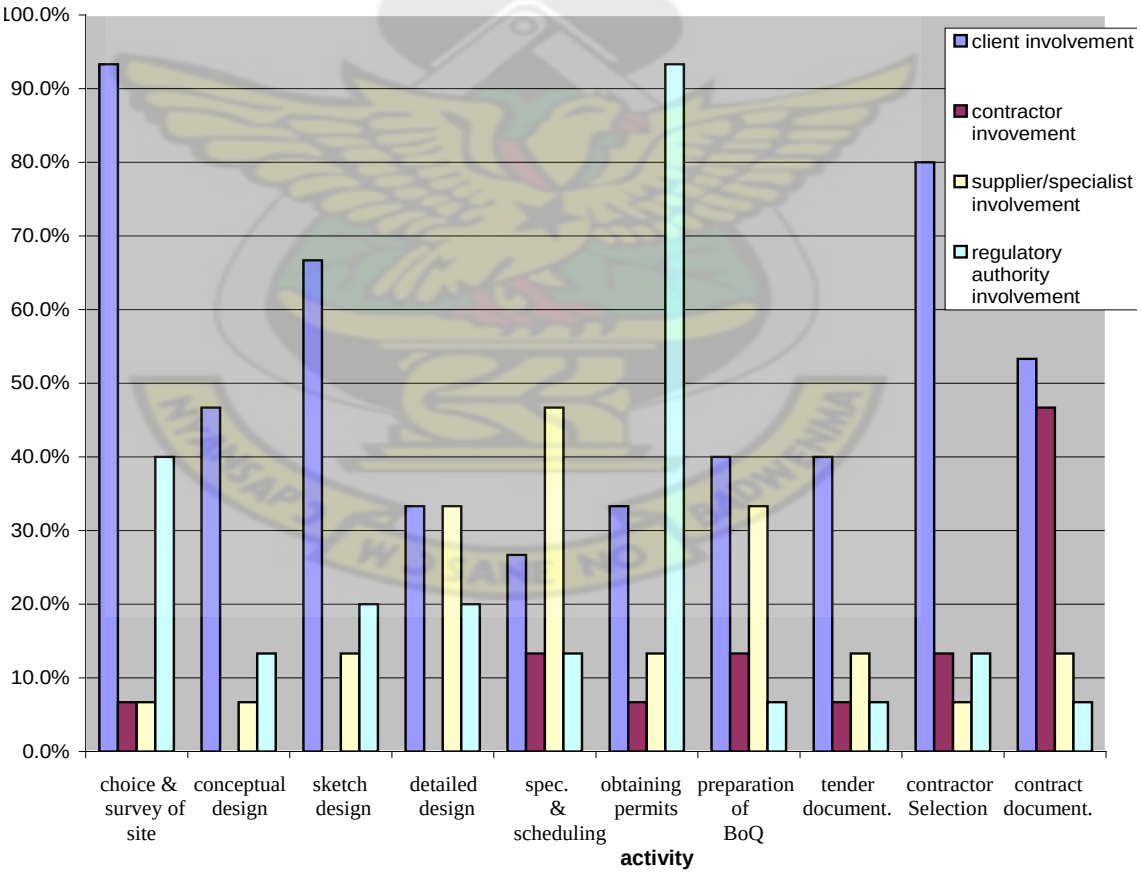


Fig. 4.2b: Involvement of Project participants in Pre-contract activities

Involvement of contractors across the various stages of pre-contract activities was very minimal. The highest indication of involvement of contractors by consultants was at the contract documentation stage which stood at 46.7%. The rest of the indications of involvement of contractors ranged between 6.7% - 13.3%. None of the respondents however involved contractors in conceptual design, sketch design and detailed design as shown in fig 4.2b.

The indication of involvement of specialist/suppliers, though higher than that of contractors, was also minimal. While 46.7% of the consultants indicated that they sort the participation of specialists/suppliers in scheduling and specification, only 33.3% involved specialists/suppliers at the detailed design phase of pre-contract activities.

The domineering role of clients in the choice of site and selection of project participants was reflected in the indication by more than 93% of the respondents that clients participate in selection of site and 80% indicating that they involve clients in the selection of contractors and suppliers/specialists. The significant influence by regulatory authorities in the acquisition of development permits and certificates, sometimes seen as limitations to continuous flow, was confirmed by more than 93% of the consultants.

4.2.3 Control and Regulatory Measures

Ensuring the delivery of value and minimization of waste in construction projects requires some form of control at every point. Control, according Ballard and Howell (1999), is causing events to conform to plan. They further explain that control in the

concept of lean thinking is the progressively more detailed shaping of material and information flows, (i.e. the physical production process) to cause the desired future.

i) Quality control of design and documentation

The survey focused on the level of application of various systems of control at the pre-contract stage by Ghanaian firms to enhance quality of output. The main control systems employed by the consultants to enhance the quality of their output was limited to on-site tests, statutory regulatory requirements, checks by team members and constant checks with needs of client.

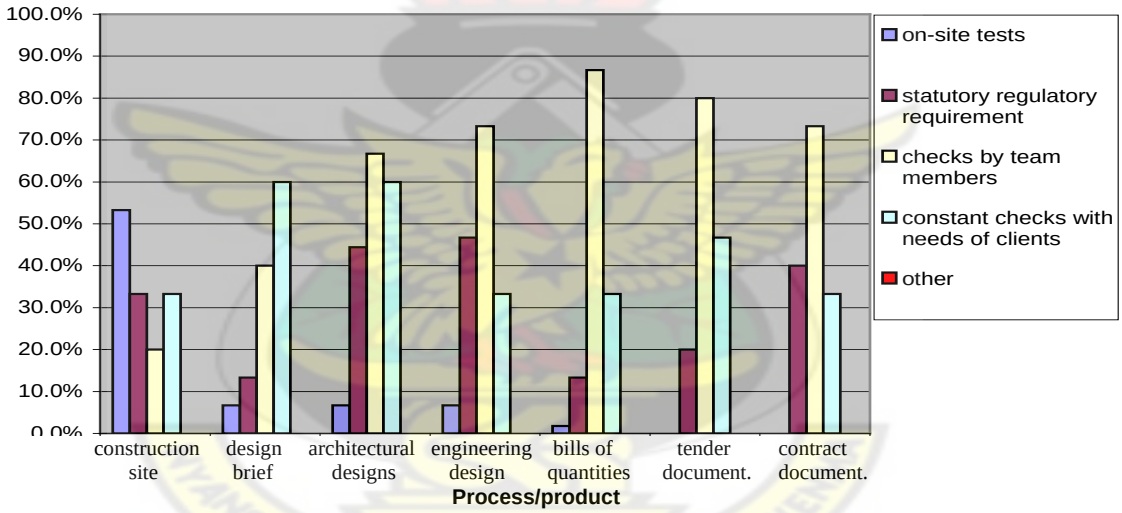


Fig. 4.3a: Quality Control of Design and Documentation

Checks by team members were the most widely employed system of control as shown in fig. 4.3a. About 87% of the consultants used this system to control the preparation of bills of quantities. A constant check with needs of clients was the second highly used system of control, with 60% of the respondents employing this system in the preparation of design brief and architectural designs.

Though not high, the requirements of statutory regulations were seen to be used by some consultants through out the various stages of pre-contract activities. A highest response of 46.7% was for the use of statutory regulatory requirement in the control of engineering designs while the lowest response, 13.3%, was for the use of regulatory requirements in design brief formulation and preparation of bills of quantities. While 53.3% of the consultants confirmed the use of on-site to control activities related to construction sites, the indication for the use of this system was either very minimal or null for the other pre-contract activities.

ii) Progress control of design and documentation processes

Table 4.1: Design and Documentation Progress Control Tools

Progress control tool used	**Consultants**	
	n = 68	
Periodic meetings with design team and client	41	60.3%
Activity programme/progress reports by tasks groups	45	66.2%
Identifying and eliminating non-value adding steps in design process	10	14.7%
Other	0	0

Source: field survey

Monitoring and controlling the progress of design and documentation activities was carried out by some firms using periodic meetings with team members, activity programme / progress reports, and the identification and elimination of non-value adding steps in design process. Identifying and eliminating non-value adding steps in design process is one of the important tools for controlling waste in the application of

lean thinking. However, only 14.7% of the consultants indicated that they had attempted using that system as a means of controlling design and documentation progress.

iii) Permit and Certification requirements

Compliance with various requirements for obtaining development permits and certificates is one of the means of controlling activities at the pre-contract stage of construction projects. Most of these requirements for permits are statutory and meeting them can sometimes cause delays and inhibition of continuous flow. The common statutory development permits and certificates that are obtained by consultants include building permits, environmental permit and fire premises / precautions certificate.

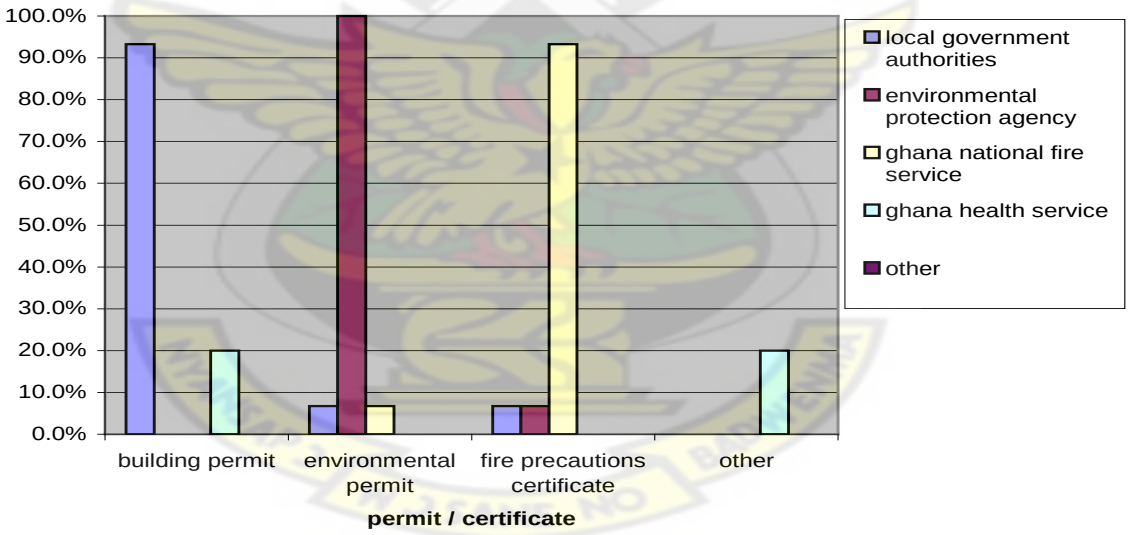


Fig. 4.3b: permit and certification requirements

The indication was that building permits are issued by local government authorities like District, Municipal or Metropolitan Assemblies. The Environmental Protection Agency (EPA) is responsible for issuing the environmental permit while Ghana Fire Service issues the fire certificate. In obtaining all these permits and certificates, consultants are

expected to undertake design and documentation activities to comply with standards stipulated in the national building regulations, the environmental regulations and the fire precautions / premises regulations.

4.2.4 Consciousness of the core principles of lean thinking

The practice of lean thinking requires adherence to some primary principles. These principles according to Mathew Hunter Associates (2005) include, among others, delivering what clients want, establishing continuous flow, driving out waste and involving the whole project team.

Table 4.2: Consciousness of lean thinking principles by consultants

Principle	**Consultants**	
	N=68	
	Number	percentage
delivering what client wants	59	86.8%
establishing continuous flow	55	80.9%
doing right first time	55	80.9%
avoiding defects	59	86.8%
avoiding rework	63	92.6%
driving out waste	45	66.2%
Involving the whole project team	50	73.5%
Constantly seeking better ways of doing thinks	63	92.6%
Mean	56.1	82.5%

Source: field survey

There was an indication from the survey that most of the consultants in carrying out their activities try in principle, to observe such tenets of lean thinking as delivering what the client wants, avoiding defects and rework, driving out waste and so on. On the average each lean thinking principle, as shown in table 4.2, had 82.5% of the consultants giving an indication that they are conscious of it. Seeking better ways of doing things, and the avoidance of reworking were the two principles with as high as

92.6% of the respondents indicating that they are aware of each of them in design and documentation activities.

Though the responses on these principles, as shown in table 4.2 may look impressive, it is worthy of note that none of the consultants approached the application of these principles by consciously putting in place a special production management system like the lean project delivery system. It is, therefore, common to see these principles not being collectively applied, but rather some being traded off for others.

Table 4.3: Measures for maximizing value and minimizing waste

Measure	**Consultants**	
	n=68	
	number	Percentage
integrating design and construction process	40	58.8%
undertaking process design simultaneously with product design	10	14.7%
involving contractors and specialists in design process	27	39.7%
involving clients in design process	63	92.6%
involving regulatory authorities in design process	40	58.8%
specifying standardised and prefabricated components	50	73.5%
Mean	38.4	56.4%

Source: field survey

A survey on the possible measures that consultants would adopt to minimize waste and maximize value in the project delivery process revealed just over 14% of consultants considering undertaking process design simultaneously with product design as one of the measures. Involvement of clients in design and documentation processes was chosen by 92.6% of the respondents as one of the means of minimizing waste and maximizing value (table 4.3).

4.2.5 Waste in design and documentation

One of the important requirements in the practice of lean thinking is the ability to identify and eliminate waste in the project delivery processes. Waste, according to Koskela and Huovila (1997), refers to what is unnecessary for task completion and value generation. Unnecessary or non-value adding steps are seen to be associated with various design and documentation processes thus leading to a lot of waste generation.

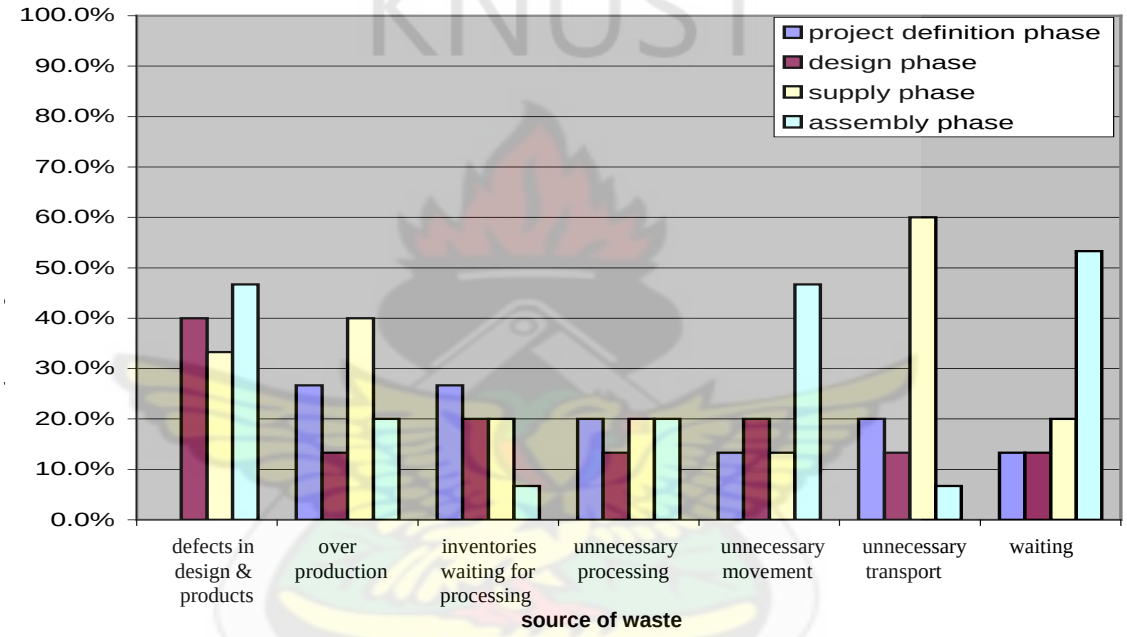


Fig. 4.4: Recognition of Sources of Waste in Project Delivery Process

The survey revealed a low level of recognition by consultants of the incidence of waste across the various phases of project delivery process. A very small fraction of the consultants associated waste with project definition and design activities. The highest recognition of waste in design process was surprisingly 40% and this was seen to be arising from defects in design. Only 13.3% of the respondents saw waiting as a source of waste that could arise during design and documentation activities. Unnecessary

processing was the least recognised source of waste, with only 13.3% - 20% of respondents associating this source of waste with the various project phases.

Table 4.4: Understanding waste in design and documentation

Waste in design and documentation	**Consultants**	
	N=68	
	number	percentage
that which is unnecessary for task completion and value generation	50	73.5%
negative iteration (non-value generating design options)	18	26.5%
design errors	27	39.7%
Other	0	0
Mean	23.7	34.9%

Source: field survey

Based on the assumption that project design and documentation are by nature iterative and generative processes, 73.5% of the respondents understood waste in design and documentation to be 'that which is unnecessary for task completion and value generation'. Just over 39% of the consultants recognised design errors as a form of waste as shown in table 4.4.

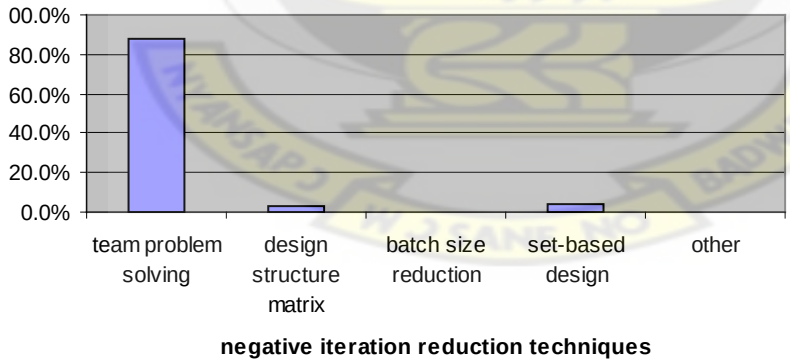


Fig. 4.5: Techniques for Reducing Negative Iteration in Design

Though negative iteration is one of the major sources of waste, it was understood by only 26.5% of the respondents. It was however discovered, as shown in fig. 4.5, that if negative iteration or non-value generating design options is understood to be waste, the

popular technique of reducing it will be team problem solving. About 88.2% indicated familiarity with the team problem solving technique while less than 5% showed familiarity with techniques like design structure matrix and set-based design. No one was familiar with batch size reduction as a technique of reducing negative iteration.

4.2.6 Application of the Lean Project Delivery System (LPDS)

The Lean Project Delivery System was developed by the Lean Construction Institute (LCI) as a planning and control tool that helps to minimize waste and maximize value throughout the construction process. It was revealed from the survey that most activities carried out by the consultants at the pre-contract stage are outside the context of the lean project delivery system.

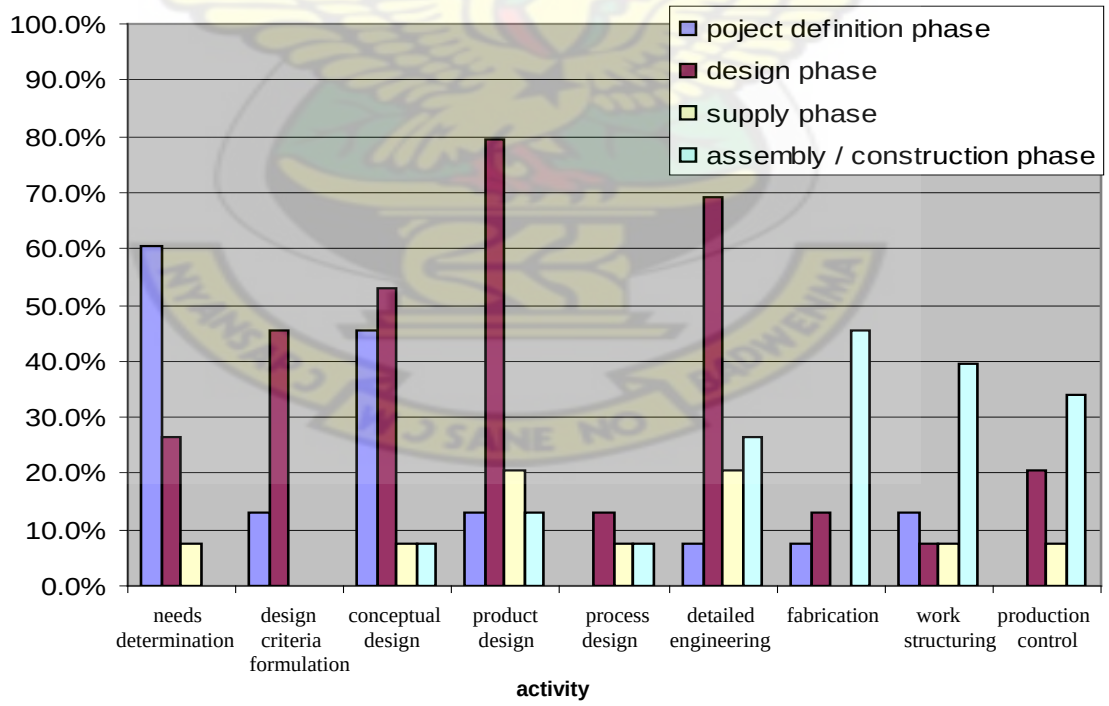


Fig. 4.6: Activities Undertaken in the Project Delivery Process at Various Phases

The Production management base of lean thinking concept makes process design at the design phase of project delivery a very important activity in the lean project delivery system. However only 13.2% of the respondents gave an indication that they undertook process design at the design phase of projects. It was also revealed from the study that product design was undertaken only at the design phase by most consultants contrary to a requirement by the lean project delivery system that the product design process be balanced between the design and supply phases. While about 80% indicated that they undertook product design at the design phase, only about 20% gave an indication that they undertook some form of design at the supply phase of the project delivery process.

The less integration of design and supply activities by Ghanaian firms is further manifested in the indication by 69.1% of the respondents that they undertook detailed engineering at the design phase while only 20.6% indicated an undertaking of detailed engineering at the supply stage. Another significant deviation from the requirements of the lean project delivery system is reflected in the fact that design criteria is not only uncommon in the activities of the consultants, but also mostly concentrated at the design stage by the few who undertake it. The requirement of the lean project delivery system is that design criteria formulation should be carried out at the project definition phase.

Work structuring and production control are required by the lean project delivery system to be carried out across all the various phases of the project delivery process. The survey however showed that work structuring and production control are undertaken by very few consultants especially at the project definition, design, and

supply phases of the project delivery process. Only 20.6% and 7.4% of the respondents indicated that at the design stage they undertook work structuring and production control respectively.

4.3 Limitations to the Practise of Lean Thinking by Ghanaian Firms

A number of impediments exist against the smooth incorporation of lean thinking principles in the construction industry in general. The peculiar construction environment in Ghana may however deepen some of these general constraints to the practice of lean thinking, or result in more constraints arising. The levels of technological development as well as the regulatory framework in Ghana, for instance, are peculiar elements in the construction industry that can lead to special limitations to the implementation of lean thinking Ghana.

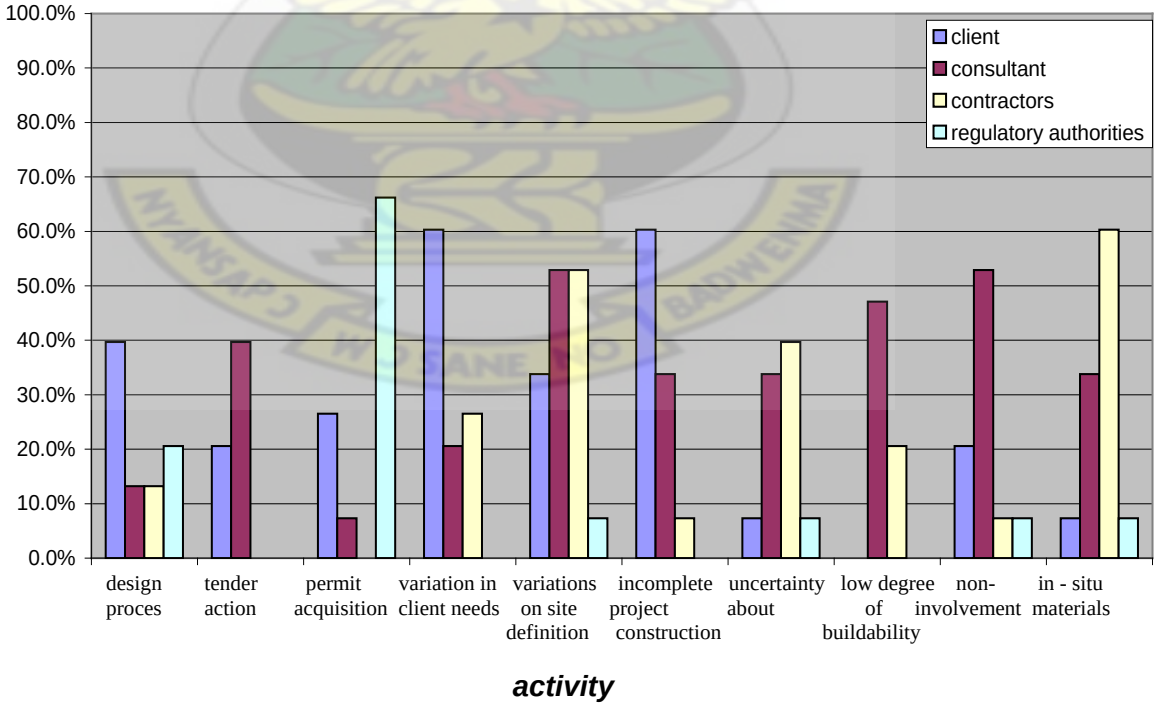


Fig. 4.7: Limitations to continuous flow

One of the important strategies for the implementation of lean thinking in the project delivery process is to identify and eliminate non-value adding steps while ensuring continuous or reliable flow among value adding activities. According to Ballard (1999), improving work flow reliability is important for enhancing the productivity of linked production units, and consequently for project cost and duration.

The level of appreciation of possible factors that could inhibit reliable or continuous flow among activities during project delivery was low. Activities like designing and documenting received a very low recognition of their likely adverse effect on continuous flow. Only 13.2% of respondents saw design as a continuous flow impeding factor arising from consultants. Consultants were seen as the dominant source of the factors that were identified as possible limitations to continuous flow. Acquisition of permits and certificates arising from regulatory authorities received the highest recognition of 66.2% as possible limitations to continuous flow as shown in fig 4.6.

A number of problems were identified by the consultants as possible obstacles against the practice of lean thinking in Ghana. It can be seen from table 4.4 that as high as 88.2% of the respondents recognized less integration of design and construction processes as an obstacle against the practice of lean thinking. The absence of the culture of lean thinking in most consulting firms in Ghana was also recognized by more than 88% of the consultants as a limitation to the implementation of lean thinking principles. It is however worth noting that only 47.1% of the consultants saw slow design process as an obstacle to the practice of lean thinking.

Table 4.5: Limitations to the practice of lean thinking

Causes of inability to practice lean thinking	**Consultants**	
	n=68	
	number	Percentage
less integration of design and construction process	60	88.2%
non-involvement of project participants by clients in project definition	50	73.5%
less involvement of contractor and specialists in design process	50	73.5%
delayed consultant /contractor selection process	41	60.3%
slow design process	32	47.1%
lack of team approach to design process	60	88.2%
delayed processing of statutory approvals	41	60.3%
a high degree of variations during project execution	50	73.5%
absence of the culture of lean thinking	60	88.2%
inability of contractors to understand design intentions of consultants	50	73.5%
difficulty associated with buildability of designs	54	79.4%
high dependence of designs on in-situ materials	45	66.2%
Mean	49.4	72.7%

Source: field survey

4.4 Discussion of Findings

4.4.1 Application of the Principles of Lean Thinking by Ghanaian Firms

i) Level of familiarity with the lean thinking concept

The survey revealed a low level of familiarity of Ghanaian firms with the concept of lean thinking. The few consultants who are even aware of the concept of lean thinking have never adopted a special system like the lean project delivery system (LPDS) to consciously reduce waste and maximize value to clients. The traditional procurement system whereby the design and documentation activities are completely separated from construction activities is still the most widely used system in the project delivery process. Procurement systems such as design and build though fall short of some lean thinking principles, are the common alternatives to the traditional system towards ensuring speedy delivery of projects.

ii) Waste in the Project Delivery Process

Even though some level of consciousness regarding the waste associated with project delivery steps exist in Ghanaian firms, design and documentation processes at the pre-construction stage still typify such sources of waste as waiting, delays, defects and inventories. These sources of waste despite having serious adverse effect on the speedy delivery of value to clients, seem too subtle to be tracked by consultants. Responses from consultants during the survey for instance revealed that about 73% and 60% were unaware of negative design iteration and design errors respectively, as sources of waste. Given that one of the primary activities in the effective application of lean thinking requires identifying and eliminating waste, an inability to recognize waste in design and documentation is a big setback towards implementing lean thinking principles.

iii) Process Design

Process design is hardly carried out at the pre-construction stage by consultants. Most of the consultants focus only on the design of the product while the process of fabricating or constructing the product is seen as entirely the responsibility of the specialist or the contractor to be carried out during the construction phase of projects. This has led, in most cases, to problems of buildability resulting in a lot of waste arising from waiting, delays, over processing and over production during construction. Just about 13% of the consultants indicated during the survey that they occasionally undertake some form of process design during the design and documentation stage. The low level of involvement of specialists and contractors during design and documentation partly accounts for the neglect of process design during pre-construction activities. Most

contractors and specialist interviewed indicated that uncertainty about construction process was one of the problems that affected progress of work on site.

iv) Involvement of project participants

Management of design and documentation activities at the pre-contract stage by most Ghanaian firms falls short of what is required by the tenets of lean thinking to minimize waste and maximize value to clients. The level of involvement of various project participants in the various stages of design and documentation processes is very low thus limiting continuous flow in design and documentation, as well as resulting in waiting, delays and unnecessary processing.

The activities of the architect at the design stage, for instance, were found in most cases to be separated from that of the structural engineer and services engineer. The architect would therefore usually complete his designs without the involvement of the structural and services engineer and then gives the completed detailed architectural designs to them for the structural and services details. This practice will clearly inhibit continuous flow in the design process and result in waiting and delays.

v) Planning and control of design and documentation processes

Most of the projects in all surveyed consultancy firms were being designed and documented without reference to any activity programme or work plan specifically drawn for the design and documentation processes. Most of the consultants admitted that even though as a result of demands from some clients they tried to provide an activity schedule for some design and documentation activities, it was not part of their usual practice to draw activity schedules and work plans when designs were being

undertaken. It was therefore not surprising that lean design techniques involving the use of the activity definition model, set based design and design structure matrix were completely unfamiliar to virtually all the consultants. It is thus obvious that planning and control of design activities and processes to minimize waste but maximize value is generally not common among consulting firms in Ghana.

4.4.2 Limitations against the Practice of Lean Thinking in Ghana

The adoption of the concept of lean thinking (having originated from the manufacturing industry) in the construction is bound to face some general difficulties due to the peculiar characteristics of the process and products of construction compared to manufacturing. Koskela (1998), Tatum & Nam (1988) and Warszawski (1990) identified these characteristics of construction as one of a kind nature of projects, site production, temporary multiorganization, and Regulatory intervention as discussed in detail in chapter two. The unique environment of the Ghanaian construction industry does not only deepen some of these general difficulties, but also pose more limitations to the practice of lean thinking in construction.

i) Traditional procurement systems and the Public Procurement Act

Firms in the Ghanaian construction industry currently operate within a certain regulatory framework that create serious restrictions to the application of such lean thinking principles as continuous workflow, the integration of design and construction activities , as well as the involvement of contractors and specialists in the design process. The Public Procurement Act of 2003 (Act 663), for example, prescribes a procedure for the procurement of services in the execution of public sector projects such

that, there is less integration between design and construction. The consultant and contractor selection procedures, under the public procurement act, require that design and documentation activities be completed before tendering is carried out to select contractors and specialists. There is therefore virtually no involvement of the contractor and specialist in the design process under the application of the act. The public procurement act, to a large extent, is thus inimical to the application of lean thinking in public sector construction projects in Ghana.

ii) Statutory regulatory requirements

Statutory requirements of obtaining development permits and certificates even though constitute quality assurance measures, have become serious setbacks against continuous workflow in the design and documentation processes at the pre-contract stage of construction projects. The bureaucracy and time involved in processing and obtaining building permits, environmental permits and fire certificates makes it difficult to avoid or eliminate waiting and delay during design and documentation. The requirements of the statutory regulations for the strict compliance to stipulated standards is also against the tenets of lean thinking because it is sometimes an obstacle against the innovation of custom solutions to meet the peculiar needs of clients.

iii) Limited industrialised building systems

One of the strategies of implementing lean thinking in construction, according to some practitioners, is to soften the differentiating characteristics of construction and bring it closer to manufacturing from where the concept of lean thinking evolved. According to Koskela (1992) standardizing components as well as utilizing modularized and

prefabricated building systems is one of the remarkable ways of bringing construction closer to manufacturing. The current technological and industrial base in Ghana is however not adequate to support the use of industrialized building systems involving standardized and prefabricated components.

iv) Low level of familiarity of lean thinking concept

One other challenge that exists against the implementation of lean thinking in Ghana is that the extent of familiarity of consultants in Ghana with the concept and techniques of applying of lean thinking is low. Virtually all the consultants who were contacted during the survey had not been involved in its application. Close to 60% were just aware of it while about a third had not heard of it at all. Lean thinking application systems like the lean project delivery system (LPDS) was not known to any of the respondents. The culture of lean thinking in the activities of these firms is therefore very small or absent.

4.4.3 Opportunities for the Practice of Lean Thinking in Ghana

In spite of the fact that a number of limitations against the implementation of lean thinking principles in Ghana exist, some strengths and opportunities for the application of the principles in Ghanaian firms also exist. While some of these strength and opportunities exist within Ghana's domestic environment others are shared globally.

i) General consciousness of lean thinking principles

There is no doubt that even though the techniques and systems of practice are not known, most consultants in Ghana are conscious in principle, of the need to minimize waste and maximize value to clients in the project delivery process. Averagely more than 80% of the consultants contacted during the survey indicated that they were conscious of each of the lean thinking principles as stipulated by Mathew Hunter Associates (2005). It will therefore not be out of place for one to anticipate that this level of consciousness of the lean principles by the consultants is a positive foundation for them to improve their systems and practices towards a successful application of the concept of lean thinking. It is a positive signal, for instance, to realize that even though they currently don't have an effective system in place, about 92% of the consultants contacted try to avoid rework in the project delivery process.

ii) High level of recognition of possible limitations against implementing lean thinking

The level of realisation of possible limitations against a successful implementation of lean thinking in Ghana by the consultants is a positive note for a successful adoption by Ghanaian firms of lean thinking principles to minimize waste and maximize value. While about 88% of the consultants were able to recognize less integration of design and construction processes as one of the limitations to the practice of lean thinking, 73.5% of them could identify less involvement of contractors and specialists in the design process as another limitation. Therefore given the right systems and regulatory framework in place, most of the consultants can identify and eliminate most of these limitations for a smooth implementation of lean thinking.

iii) Knowledge transfer from foreign firms operating in Ghana

The current trend of globalisation offers a lot of opportunities for Ghanaian firms to get exposed to systems and techniques that support a smooth implementation of the concept of lean thinking. The use of standard building components as well as prefabricated and modular systems which is viewed by Harris and McCaffer (2001) as aspects of lean thinking practices is, for instance, becoming common in the construction industry in Ghana because of the transfer of technology from the industrialised world to Ghana. The current presence of construction and consultancy firms from various parts of the world in Ghana will also make it possible for Ghanaian firms to learn from them, new management practices that support the application of lean thinking principles.

iv) Quality assurance from compliance with statutory regulations

Though the statutory regulations as well as the process of obtaining permits are potential threats to continuous flow, compliance to the quality standards required by these regulations and permits could go a long way to enhance value delivered to clients. The national building regulations, the fire precautions regulations and the environmental protection regulations require the compliance of the design and construction of buildings to certain quality standards to not only ensure the comfort, convenience and safety of both clients and users of buildings, but also enhance the appropriateness of buildings to their desired function. The application of these regulations could therefore be a potential for the application of lean thinking in Ghana.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

A summary of the findings established from the analysis of the data have been related to the objectives of the study in this section.

i. Extent of practise of lean thinking by Ghanaian firms:

It was established from the survey that there is generally a low familiarity of the concept of lean thinking in Ghanaian firms. None of the consultancy firms contacted had been involved in the application of a special system like the lean project delivery system (LPDS) in their activities in order to minimize waste and maximize value for clients. The traditional procurement system whereby design and construction activities are completely separated is still widely used especially for public projects.

Despite the fact that some level of consciousness regarding waste associated with construction project delivery process existed, design and documentation of construction projects was still largely associated with such sources of waste as waiting, errors and inventories. Even though these sources of waste act seriously against the speedy delivery of value to clients, they continue to linger within design and documentation processes unnoticed.

ii. Limitations to the practise of lean thinking in Ghana

Apart from the general problems that are seen to be associated with the implementation of lean thinking everywhere, some peculiar problems exist in the Ghanaian construction

industry against the application of the tenets of lean thinking. One of these peculiar limitations is the Public Procurement Act of 2003 that prescribes procurement procedures involving public sector projects in line with the traditional system such that that integration of design and construction activities is undermined.

Delayed processing of development permits and certificates as well as the generally low familiarity of Ghanaian firms with the concept of lean thinking are other challenges against the implementation of lean thinking in Ghana and. Another limitation is that the current level of technology in Ghana does not support the use of industrialized and modular building systems to speed up project delivery in line with the principles of lean thinking.

iii. General problems and strategies associated with the practise of lean construction

The general problems associated with the practise of lean thinking in construction stems from some perceived peculiar characteristics of the construction industry compared to the manufacturing industry. These characteristics include: one of a kind nature of construction projects, site based production, temporary multi organisation and regulatory intervention.

It has been suggested by some practitioners that one strategy for a successful implementation of lean thinking in construction is to soften the differentiating characteristics of construction by making construction more like manufacturing. This can be achieved by standardising building components, utilizing modularisation and prefabrication as well as using enduring or multidisciplinary teams. Where it is difficult

to standardise components, it is proposed that standard procedures for planning and managing the design and construction of unique facilities have to be developed.

iv Opportunities for the practise of lean thinking in Ghana

Notwithstanding the challenges that exist against the implementation of lean thinking in Ghana, some opportunities also exist. The appreciation by Ghanaian firms, as established from the survey, of the need to minimize waste and obtain value for clients in the project delivery process is a positive step towards introducing systems in the application of lean thinking Ghana.

The need to conform to certain design standards as required by some statutory regulations can contribute immensely towards ensuring quality of products and services delivered to customers thus enhancing value delivery. Current trends of globalization is also likely to enhance the transfer of technology to Ghana to support attempts at adopting standardized and prefabricated modular building systems required in lean thinking practices.

The study also revealed that most of the respondents having understood the concept of lean thinking as the maximization of value and minimization of waste were able to recognize to a large extent, the possible limitations that may act against a successful implementation of lean thinking in Ghana. The consultants are therefore in a good position to identify and address these limitations if they have to adopt the practice of lean thinking in their operations.

5.2 Conclusion

The following conclusions can be drawn from the study regarding the practice of lean thinking at the pre-construction stage of construction projects by selected Ghanaian firms:

- There is a very low level of familiarity with the concept of lean thinking within Ghanaian firms in the construction industry. Lean thinking systems like the lean project delivery system (LPDS) is generally absent in the project delivery processes of Ghanaian firms.

- Some level of awareness exists among Ghanaian firms on the need to minimize waste but maximize value in the project delivery process. They, however, fail to consciously put in place, lean systems like the lean project delivery system to ensure waste minimization and value maximization in the project delivery process.

- The peculiarity of the characteristics of the construction industry compared to the manufacturing industry is generally a challenge everywhere in the implementation of the concept lean thinking (which originated from the manufacturing industry) in the construction industry.

- Certain peculiar circumstances in the Ghanaian construction environment like statutory obligations and requirements, low familiarity with the concept of lean

thinking as well as low industrialization and standardization of building systems are potential limitations that exist against the application of the concept of lean thinking in Ghana.

- Though some challenges currently exist against the implementation of lean thinking in Ghana, there are equally some factors that will favour the implementation of lean thinking in Ghana. The high level of awareness among Ghanaian consultants on the need to minimize waste but maximize value to clients in the project process is a positive step for the implementation of lean thinking.

- The current trend of globalization will enhance technological transfer to Ghana in order to support the production and use of industrialized and standardized building systems to speed up construction processes in line with the principles of lean thinking.

- Even though the statutory requirement of designs to comply with certain standards and codes, to some extent is an obstacle against the creation of custom design solutions, these requirements are checks that exist to ensure that designs meet a certain level of quality standard to ensure the comfort, convenience and safety of clients.

5.3 Recommendations

The following recommendations have been made to enhance the application of lean thinking principles at the pre-contract stage of construction projects in order to ensure minimization of waste and maximization of value at the pre-contract stage of construction projects:

Specific recommendations

1. Professional bodies such as the Ghana Institute of Architects (GIA), the Ghana Institution of Surveyors (GhIS) and the Ghana Institution of Engineers (GhIE) should expose their members to the concept of lean thinking through some form of continuing professional development programmes. This will address the problem of low familiarity of members with the concept of lean thinking. The systems and practices required in the application of lean thinking principles in construction should be introduced to members of these professional bodies towards ensuring that waste is minimized and value maximized in the project delivery process in Ghana. There could be collaboration with leading institutional proponents of lean construction like the Lean Construction Institute (LCI), to offer special training to the members of these professional bodies on the strategies of applying the lean thinking concept in construction.

2. Obstacles that prevent the integration of design and documentation should be eliminated or softened. For instance Laws which regulate Public procurement procedures could be modified or amended to allow for the participation of contractors and specialist in the design process of construction projects. A

process of pre-qualification based on the defined scope and brief could precede the detailed design stage of construction projects so that the pre-qualified contractors or specialists will participate in the detailed design activities of construction products and process.

3. The important role pre-fabricated industrialized building systems play in the application of lean thinking principles requires that an enabling environment be created to make it possible for the manufacture and installation of these systems in Ghana. Government's policy towards developing the technological and industrial base of the country should be strengthened to facilitate the production of standardized industrial building systems in Ghana. A supportive environment should also be created for the transfer of technology, involving the use of industrialized building systems, from foreign firms operating in Ghana, to their Ghanaian counterparts.

4. Statutory regulatory authorities like the Local Government Authorities, the Environmental Protection Agency and the National Fire Service should improve their systems of operation in order to avoid delays in the processing and issuing of permits. Apart from the need for an attitudinal change in these organizations, the human resources capacity and logistical base of these institutions need to be improved to make their operations more efficient to minimize delays and waiting. This will go a long way to ensure that continuous workflow is enhanced at the design and documentation stage of construction projects.

5. There is the need for the teaching of the concept of lean thinking to be introduced or strengthened in the academic and professional training of students pursuing construction related disciplines like architecture, structural engineering and surveying at both the undergraduate and postgraduate level. This will enhance the familiarity of these trainees with the concept.

General recommendations

1. The culture of lean thinking should be observed and strengthened at all levels of the project delivery process. This calls for a general attitudinal change on the part of clients, consultants and contractors towards making value maximisation and waste minimisation the focal point of their activities during the project delivery process.

2. A rational design and construction approach through standardisation and modularisation should generally become the drive behind the design and documentation decisions of Ghanaian consultants. The rational design and construction approach is generally recommended as a tool for saving time and reducing waste during the design, manufacture and assembly of building components.

3. There should be an increased and continuing research towards establishing strategies to bring construction closer to manufacturing by softening, to a very large extent, the peculiar characteristics that differentiate construction process and products from manufacturing process and products.

REFERENCES

Ballard, G. (2000a). "Positive Vs Negative Iteration in Design". *Paper submitted to the 8th International Conference on Lean Construction,* Brighton, pp. 2-7. http://www.leanconstruction.org/pdf/05.pdf.

Ballard, G. (2000b). "Lean Project Delivery System™." *White Paper-8(Revision 1),* Lean Construction Institute, Ketchum, Id. pp. 1-7. http://www.leanconstruction.org/pdf/WP8-LPDS.pdf.

Ballard, G. (2003). "Lean Project Delivery System™." *Lean Construction Institute: Research Agenda,* Ketchum, ID, http://www.leanconstruction.org/lpds.htm .

Ballard, G. and Howell, G. (1998). "What Kind of Production is Construction?" *Proc. 6th Annual Conference of the International Group for Lean Construction,* IGLC-6, Guaruja, Brazil http://www.leanconstruction.org/pdf/BallardAndHowell.pdf

Caldeira, E. (1999). "Learn Construction". http://www.housingzone.com/info/CA379761.html, 10/03/07, 8pm GMT

Compton, W. (1992). "Benchmarking". in: *Manufacturing systems: foundations of world-class practice*. Washington, DC. pp.100 - 106.

Carothers, G. & Adams, M. (1991). "Competitive Advantage through Customer Value: The Role of Value-Based Strategies". *In: Stahl, M.J. & Bounds, G.M. (ed.). 1991. Competing Globally through Customer Value.* Quorum Books, New York. P. 32 - 66.

Government of Ghana. (1996). National Building Regulations, 1996. L.I. 1630. Accra, Ghana.

Government of Ghana. (1999). Environmental Assessment Regulations, 1999. Accra, Ghana.

Government of Ghana (2003). Public Procurement Act, 2003 (Act 663), Accra Ghana

Government of Ghana (2003). Fire Precaution (Premises) Regulations, 2003. L.I. 1724, Accra, Ghana

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

Howell, G., and Ballard, G. (1998). "Implementing Lean Construction: Understanding and Action." *Proc. 6th Annual Conf. of the International Group for Lean Construction.*, Guaruja, Brazil, http://www.leanconstruction.org/pdf/HowellAndBallard.pdf.

Howell, G. and Ballard, G. (1999). "Design of Construction Operations" *White Paper-4* (unpublished), Lean Construction Institute Ketchum, ID,http://www.leanconstruction.org/.

Howell, G. and Ballard, G. (1999). "What is Lean Construction?" *Conference of the International Group for Lean Construction*, 1999. pp.1-3 http://www.acci.unsw.edu.au/Documents/LeanConstruction.pdf

Hammer, M. (1990). "Reengineering Work: Don't Automate, Obliterate". *Harvard Business Review*, July-August, pp.104-112.

Harris F. & McCaffer R. (2001). "Modern Construction Management", Blackwell Science Ltd., UK pp. 31-32

Koskela, L. (1992). "Application of the New Production Philosophy to Construction", *Technical Report No. 72, CIFE, Dept. of Civil Engrg*., Stanford University, CA, pp.75. http://www.ce.berkeley.edu/~tommelein/Koskela-TR72.pdf

Koskela, L. & Huovila, P. (1997). "On Foundations of Concurrent Engineering" in Anumba, C. and Evbuomwan, N. (eds.). *Concurrent Engineering in Construction*
CEC97. London 3-4 July. The Institution of Structural Engineers, London, PP.22- 32

Kotelnikov, V. (2007). "Lean Production – Doing More With Less", *Ten3 Business e-Coach, version 2007a.* http://www.1000ventures.com, 10/03/07, 8pm GMT

Kwakye, A. (2006). "Maintenance of Construction Products". *The Quantity Surveyor*, Issue 1, 2006. pp.2

Lillrank, P. & Kano, N. 1989. Continuous Improvement: Quality Control Circles in Japanese Industry. Michigan papers in Japanese Studies: no. 19. Center for Japanese Studies, The University of Michigan, Ann Arbor, MI. p.294

LCI (2004). Lean Construction Glossary. Lean Construction Institute, Ketchum, ID, http://www.leanconstruction.org/glossary.htm.

Nam, C.H. & Tatum, C.B. 1988. “Major characteristic of constructed products and resulting construction technology”. *Construction Management and Economics*, 1988. pp.6, 133 - 148.

Nicco-Annan, J. (2006). “Partnering in Construction”. *The Quantity Surveyor*, Issue 1, 2006. pp.14-19

Mader, R. (2005). “Lean Thinking Works in Construction Too”. http://www.contractormag.com/articles/newsarticles.cfm. 10/03/07, 7pm GMT

Matthew Hunter Associates. (2005). “Lean Construction – Key Principles” http://www.matthewhunter.co.uk/index.htm, 10/03/07, 8pm GMT

Saunders, M. *et al.*, (1997) *Research Methods for Business Students*, Great Britain*:* Pearson Professional Ltd. pp 412-413

Shingo, S. (1984). “Study of 'TOYOTA' Production System”. *Japan Management Association*, Tokyo. pp.359.

Shingo, S. (1988). Non-stock production. pp. 454.

Tommelein (2002), D. “Lean Construction” http://www.ce.berkeley.edu/~tommelein/lean.htm. 10/03/07, 7pm GMT

Tsao, C.Y. (2005). “Use of Work Structuring to Increase Performance of Project-Based Production Systems”. PhD. Dissertation, University of California, Berkeley, U.S.A.

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

Warszawski, A. (1990). “Industrialization and Robotics in Buiding: A Managerial Approach”. Harper & Row, New York. pp.466

Womack, J.P., Jones, D.T., and Roos, D. (1991). *The Machine That Changed The World: The Story of Lean Production*. New York. 1st Harper Perennial Ed.

Womack, J.P. and Jones, D.T. (1996). “Lean Thinking: Banish Waste and Create Wealth in your Corporation”. Simon and Schuster, New York, NY. pp.350

APPENDIX I

QUESTIONNAIRE TO CONSULTANTS

Institution: Kwame Nkrumah University of Science and Technology (Department of Building Technology)

Programme: MSc Construction Management

Research Topic: Ghanaian Firms and the Practice of Lean Thinking* at the Pre-Contract Stage of Construction Projects.

QUESTIONNAIRE FOR CONSULTANTS

Introduction

The purpose of this questionnaire is to conduct an assessment of the design and documentation processes at the pre-construction phase of construction projects to find out the extent to which these processes fall in line with the principles of lean thinking*. The resulting information will be used to identify possible areas of improvement in line with the tenets of lean thinking so that there is maximization of value and minimization of waste in construction project delivery process in Ghana.

You may add an additional sheet if required

Please tick the appropriate box [√]

SECTION 1: GENERAL

1.1 What is the focus of your consulting services?

Building Construction	Civil Works	Building & Civil Works	Other

*Lean Thinking is a production management concept which seeks to minimize waste but maximize value to clients in project delivery process.

1.2 What is the nature of your services?

Only Design and Documentation	Design, Documentation and Supervision	Design and Build	Other

1.3 Ownership of firm:

State Owned	Private Owned	Other

1.4 How long has your firm been in existence?

1 – 2 years	3-4 years	5-10 years	> 10 years

1.5 Who are your major clients?

Government of Ghana	Private Corporate Organizations	Private Individuals	Other

1.6 What is the strength of your staffing?

Just adequate	Inadequate	More than is required	Other

1.7 How familiar are you with the concept of lean thinking?

Not aware of it at all	Just aware of it	Have been involved in its application	Other

SECTION 2: PRE-CONTRACT ACTIVITIES

2.1 Which of the following initial pre-contract activities are you involved in?

Choice of site	Formulation of design brief	Selection of project participants	Other

2.2 Which participants do you involve in the following pre-contract activities?

Activity	**Participants**			
	Client	Contractor	Specialists/ Suppliers	Regulatory Authorities
Choice and Survey of Site				
Conceptual Design				
Sketch Design				
Detailed Design				
Scheduling and Specification				
Obtaining Permits and Certificates				
Preparation of Bill of Quantities				
Tender Documentation				
Selection of Contractors / Suppliers				
Contract Documentation				

2.3 Which of the following activities do you undertake in the project delivery process? (Indicate at which phase of the project you undertake each activity).

Activity	**Project Phase**			
	Project Definition	Design	Supply	Assembly/ Construction
Needs Determination				
Design Criteria formulation				
Conceptual Design				
Product Design				
Process Design				
Detailed Engineering				
Fabrication and Logistics				
Work Structuring				
Production Control				

SECTION 3: LIMITATIONS TO CONTINUOUS WORKFLOW

3.1 Which of the following factors inhibit continuous flow in construction project delivery process?

Factor	Source of factor			
	Client	Consultant	Contractors	Regulatory Authorities
Design Process				
Tender action				
Acquisition of permits and certificates				
Variation in client needs				
Variations on Site				
Incomplete project definition				
Uncertainty about construction processes				
Low degree of buildability of designs				
Non-involvement of contractors at Design Stage				
High dependence on in-situ materials				

SECTION 4: APPLICATION OF LEAN THINKING PRINCIPLES

4.1 Which of the following principles do you apply in the design and documentation processes of construction projects?

Principle	Response	
	Yes	No
Delivering what the client wants		
Establishing continuous flow		
Doing right first time		
Avoiding defects		
Avoiding reworking		
Driving out waste		
Involving the whole project team		
Constantly seeking better ways of doing things		

4.2 What measures do you take to minimize waste and maximize value in project delivery process?

Measure	Response	
	Yes	No
Integrating design and construction processes		
Undertaking process design simultaneously with product design		
Involving contractors, sub-contractors and suppliers in design process		
Involving clients in the design process		
Involving regulatory authorities in design process		
specifying standardized and prefabricated components in order to speed up construction process		

SECTION 5: SOURCES OF WASTE IN CONSTRUCTION PROJECT DELIVERY PROCESS

5.1 Which of the following do you consider as source of waste in the project delivery process? Under what phase of the project does the waste arise?

SOURCE OF WASTE	**Project Phase**			
	Project Definition	Design	Supply	Assembly
Defects in products / design				
Over production				
Inventories of products / designs waiting for further processing				
Unnecessary processing				
Unnecessary movement of people				
Unnecessary transport of products and services				
Waiting by employees for a preceding activity to complete				

5.2 Assuming that design is by its nature an iterative and generative process, how do you understand waste in design?

That which is unnecessary for task completion and value generation	Negative iteration (or non-value generating design options)	Design errors	Other

5.3 Negative iteration (or non-value generating design alternatives) is an important source of waste in design. What techniques do you apply to reduce negative iteration?

Team problem solving	Design structure matrix	Batch size reduction	Set-based design	Other

SECTION 6: REGULATIONS AND CONTROL

i. **<u>Quality control of designs and documentation</u>**

6.1 What system of regulation and control do you use to ensure quality in respect of the following?

Process / output	**Regulation / control system**			
	On-site tests	Statutory regulatory requirements and certification	Checks by team members	Constant checks with needs of clients and users
Construction site				
Design brief				
Architectural designs				
Engineering designs				
Bill of quantities				
Tender documentation				
Contract documentation				

ii. **Progress control of works**

6.2 What system do you have in place for controlling and monitoring the progress of design and documentation activities?

Periodic meetings with team members and client	activity programme / progress report by tasks groups	Identifying and eliminating non-value adding steps in design process	Other

iii. Certification and permit requirements

6.3 Which of the following certifications and permits do you obtain for designs from various regulatory authorities?

Authority	**Permit / Certificate**			
	Building permit	Environmental permit	Fire precautions certificate	Other
Local Government Authorities				
Environmental Protection Agency				
Ghana National Fire Service				
Ghana Health Service				
Other				

SECTION 7: LIMITATIONS TO THE PRACTISE OF LEAN THINKING IN THE PROJECT DELIVERY PROCESS

5.1 What are the possible causes of an inability to achieve speedy delivery of value and minimization of waste in construction project delivery process?

Problem	**Response**	
	Yes	No
Less integration of design and construction processes		
Non-involvement of project participants in the project definition process by clients		
Less involvement of contractor and specialists in design process		
Delayed consultant/contractor selection process		
Slow design process		
Lack of team approach to design process		
Delayed processing of statutory approvals and permits		
A high degree of variations during project execution		
Absence of the culture of lean thinking in the organization		
Inability of contractors and specialists to understand design intentions of consultants		
Difficulty associated with buildability of designs		
High dependence of design specifications on in-situ materials and components rather than standardized and industrialized prefabricated components		

Thank You.