Sudan University of Science and Technology

College of Graduate Studies

Applying Lean Construction Concepts to Construction Industry in Sudan

تطبـيق مفاهيم التشييد الرشيق على صـناعة التشـييد في السودان

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master in Civil Engineering (Construction Engineering)

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Dedication

I am endlessly grateful to my parents for their affection, efforts, and their supports in helping me reach this far.

Special dedication to the soul of my dearest sister, Manasik

I also would like to dedicate this study to my brothers and sisters.

Lastly, my dedication goes to my friends and class-mates during all my levels of education.

Ibrahim Mohammed-2016

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First of all I would like to thank Allah for helping me completing this research successfully.

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Abstract

The construction industry in Sudan plays a major role in the economy via its significant share in the Sudanese Growth Domestic Product (GDP). The Sudan's construction industry faces numerous problems and obstacles which lead the projects to sink into troubles, and negatively affect the workflow. Lean construction is a technique newly implemented in many countries to overcome most of the problems that hinder the projects' success via more optimum productivity, better usage of resources and eliminating the wastes.

The main objectives of this study are to determine the awareness about lean construction within the engineers who work in the construction industry in Sudan, and to identify the factors that affect the workflow of construction projects in Sudan. The main question of this study is about the challenges that may face the implementation of lean construction in Sudan. The methodology of the study adopted both qualitative and quantitative methods in identifying the problem statement, literature review, collection and analysis of data and discussion of the results.

After results interpretation in the light of the theoretical part, the study ended with many results which are: The majority of the engineers who work in construction industry in Sudan have no idea about lean construction, while they have high potential to work in a lean construction site, the main factor that impacting the workflow of construction project in Sudan is the delays in financing the project, and in delivery of the materials and the main two challenges will face the implementation of lean construction in Sudan are the resistance of the top management to adopt the concept, and the difficulties in understanding the concept itself.

المستخلص

تلعب صناعة التشييد في السودان دوراً رئيسا في الإقتصاد من خلال مساهمتها الكبرى في الناتج القومي الإجمالي. تواجه صناعة التشييد في السودان العديد من العقبات التي تقود إلى دخول المشروعات في العديد من المشكلات، كما تؤثر سلباً على سير العمل. التشييد الرشيق عبارة عن تقنية تم تطبيقها حديثاً في العديد من الدول من أجل تخطي معظم العقبات التي تعيق نجاح المشروعات عن طريق التحسين المثالي للإنتاجية،تحسين استخدام الموارد ، و استبعاد كل انواع الهدر.

من الأهداف الرئيسة لهذا البحث قياس مدى معرفة المهندسين العاملين في صناعة التشييد في السودان عن التشييد الرشيق ، و لمعرفة العوامل التي تؤثر سلباً على سريان عملية التشييد في السودان. السؤال الرئيس لهذا البحث حول العقبات التي يمكن أن تواجه تطبيق التشييد الرشيق في السودان. المنهجية المتبعة في هذا ابحث هي المنهجية الكمية الوصفية عن طريق تعريف مشكلة البحث ، أدبيات البحث ، و تجميع البيانات و تحليلها و مناقشة النتائج.

بعد تفسير النتائج على ضوء الجزء النظري انتهت الدراسة إلى العديد الدراسة من النتائج منها أن غالبية المهندسين العاملين في قطاع التشييد في السودان ليس لديهم أي معرفة بالتشييد الرشيق، لكن لديهم حماس عالي للعمل في موقع يستخدم مفاهيم التشييد الرشيق، العامل الرئيس المؤثر على سريان العمل في مشروعات التشييد في السودان هي التأخيرات في تمويل المشاريع و توريد المواد و التحديان الرئيسيان الذان سوف يواجههما تطبيق التشييد الرشيق في السودان هما معارضة الإدارة العليا لتبني هذا المفهوم و الصعوبات في فهمه.

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List of Abbreviations

BIM……	Building Information Modeling
CII……..	Construction Industry Institute
CPM……...	Critical Path Method
GC…….	General Contractor
GDP……...	Growth Domestic Product
IGLC…….....	International Group for Lean Construction
ILO……	International Labor Organization
JIT…….	Just In Time
LC…….	Lean Construction
LCI……	Lean Construction Institute
LP…….	Last Planner
LPDS……	Lean Project Delivery System
LPS……	Last Planner System
P-Value…….	Probability Value
SPSS…….	Statistical Package for the Social Science
TPS……	Toyota Production System
TQM……..	Total Quality Management
UK…….	United Kingdom
USA……...	United States of America
VM…….	Visual Management
WWP……..	Weekly Work Plan

Chapter One

Introduction

Chapter One

Introduction

1-1: Background:

Construction industry is a significant sector which plays basic role in both developed and developing countries by creating employment, establishing social infrastructures such as hospitals, schools, bridges, highways, water resources, etc., hence contributing to the gross domestic product(GDP) of those countries (SSE 2008) . The Sudan's construction industry plays very important role via its gigantic contribution to the development of country's economic, it presents many employment opportunities and attracts the foreign investments which contributes to the country's GDP grossly (Mohamed 2015).

Sudan, as a developing country, has gained obvious developments during the previous decades. These developments took place in many fields, of which the construction industry is a significant one (Elkhalifa & Shaddad 2008). However, the construction industry in Sudan faces many problems and obstacles, such as: shortage of materials, fluctuation of construction materials prices, inaccurate estimation of the time, defects during the process of construction, cost overrun, too much pressure on project stakeholders, etc. (Mohamed 2015).

To overcome all above challenges, managing construction nowadays requires knowledge of modern management

philosophies, techniques and tools. One of the new revolutionary practices which rooted from the industry of car manufacturing is "lean production". Since the early 1990s, lean production has taken the attention of numbers of researches in the field of construction industry, those people who refer to lean production, created the new term "lean construction" (Tezel 2007).

Lean construction became one of the most important trends in the construction industry recently (Mehay 2015), it is a combination of practical development and original research in both design and construction with an adaptation of the concept of lean production principles and practices to the design and construction process (Dhivyamenaga & Kothai 2014). The lean production in construction industry "lean construction" has its movements that led to form an institute, a group and a refereed journal dedicated to lean construction completely, especially via the universities which located in the continent of America and Northern Europe (Tezel 2007).

1-2:Research Objectives:

The research objectives are:

- To discuss the factors that affect the workflow in construction projects in Sudan.
- To provide enough information about lean construction.
- To determine the awareness of lean construction within the engineers who work in construction industry in Sudan.
- To discuss the suitability of applying lean construction among the construction in Sudan.

1-3: Research Problem:

Out of the researcher's experience in the field of construction in Sudan and his observations, there are many obstacles and problems facing the construction industry in Sudan. The construction management suffers from the misunderstanding and sometimes ignorance of new managerial tools and techniques such as lean construction.

The lean construction concepts are not widely applied among the construction industry in most of developing countries; in spite of the positive results can be obtained from the application. This study focusing on how the Sudanese construction industry can implement Lean construction to benefit from its advantages to overcome and solve all problems and obstacles that hinder the projects' success in Sudan.

1-4: Research Questions:

1- Can lean construction be successfully implemented in Sudan?
2- What are the challenges will face the implementation of lean construction in Sudan?

1-5: Research Importance:

This research is considered to be of a great significance impact on the construction industry in Sudan. Now that the current situation of the industry in Sudan has its problems and obstacles, such as lack of quality, lack of safety, inferior work conditions, cost overruns, lack of skilled labor, lack of productivity, etc. All the above difficulties can be solved if new managerial concepts such as lean construction be successfully implemented; thereby engineers and contractors should be aware about lean construction.

To the best of the researcher's knowledge; this study in this field (lean construction) is the very first one in Sudan. This will provide basic information for future researchers in Sudan to investigate on lean construction particularly or any other related area of studies.

1-6: Research Hypotheses:

- The main factor affecting the workflow of construction processes in Sudan is the delay in material delivery.
- The majority of the engineers who work in construction industry in Sudan have no knowledge about Lean construction.
- The reason behind non-application of Lean construction in Sudan so far is the ignorance of the concept.
- The major obstacle will face the application of Lean construction in Sudan is the difficulties in understanding the concept.

1-7: Research Methodology:

The research methodology included how the structure of the framework for this study was conducted. The main methods were descriptive, explanatory and quantitative. Literature reviews have been taken from books, articles, researches, websites, papers as well as printed materials to describe main concepts about Lean construction.

The quantitative was done by collecting data by standardized questionnaire which was distributed to the participants' sample, then all outcome data of the survey was analyzed by using

the Statistical Package for the Social Sciences (SPSS) software program.

1-8: Research Structure:

Chapter One: outlines the background, research objectives, problem statement, research questions, research importance, hypotheses, and methodology.

Chapter Two: Comprises of the literature review about construction industry in Sudan which contains of the definition of construction industry, characteristics, challenges of the industry, and future vision of the industry.

Chapter Three: Comprises of the literature review about lean construction which involves the historical background about lean construction, definition, principle of lean, waste types, lean construction tools, and an overview about applying lean construction in different countries.

Chapter Four: Describes the Methodology used to conduct the research. Precisely the respondents, the data collection tool (Questionnaire), the sampling techniques and the analysis procedure.

Chapter Five: Discusses the data analysis and the result obtained from the study. Also the chapter deals with the conclusion and recommendations.

Chapter Two

Sudan's Construction Industry

Chapter Two

Literature Review: Sudan's Construction Industry

2-1: Preamble:

One of the fundamental sectors in economy is construction industry, which permeates most of the other sectors as it directly transforms the resources into constructed physical infrastructure necessary for socio-economic development. It embraces the process by which the physical infrastructure are planned, designed, procured, altered, repaired, constructed or produced, maintained, and demolished (Construction Industry Policy 2004).The construction industry's major participants include the architects, management consultants, engineers, general contractors, subcontractors, labor, owners, operators, and users of the facilities of construction (Moavenzadeh & Rossow 1975).

From the normal arrangement of construction, the process includes necessary activities match to effectively control final output of the production of the project, and the input of the process which decided by the owners' demands to the project, through a number of series of cooperated and interactional activities. The final output of construction project process management is the product of construction project which can meet the owners' demands, and the life span of construction process contains several main steps: project idea, feasibility studies, project development, pre-

design, design, tender, building or production and finally handing over (Ren2012).

2-2: The Construction Industry:

2-2-1: Definition & Principles:

Construction can be defined as an activity of the physical structure of infrastructure, superstructure and related facilities (Wells 1984).The activities include the procuration of raw materials, the manufacturing of construction materials and components (Plescis 2002).The construction industry can be also defined as, "the sector of an economy which, plans, designs, construction, alters, maintains, and eventually demolishes buildings of all kinds of civil engineering structures and other similar works" (Ofori 1990).

The construction industry divided into many categories, heavy sector (sewer lines, pipe lines, highway, etc.), house building sector (the on-site building, repair, maintenance, decoration, demolition, etc.), industrial, commercial, and institutional sector (manufacture, assembly, installation on a construction site of any equipment, machinery, fixtures, etc.) (Salim 2010). There is another classification that construction normally falls into one of two general categories: (1) Repetitious and routine activities which fulfill volume needs, such as highway and bridges, manufacturing, commercial and industrial buildings. (2) Socialized and sophisticated activities which fulfills one or two-time needs, such as huge dams and power plants (Moavenzadeh & Rossow 1975).

Construction industry contains of persons and organizations that include individuals, companies, or firms working as consultants, main

contractors, equipment suppliers, labors, builders, dealers, etc. (Construction industry policy 2004). All duties in the construction industry are done by contractors. A contractor can be a man or company, the general contractor (GC) or builder is a company that does rehabilitations of structures or build a new structure. General contractors usually manage and hire different subcontractors to build structures or do major renovations (Salim 2010). Construction's manpower requirements range from highly skilled professionals to completely unskilled laborers. In developing countries physical construction activities alone employ from 2 to 6 percent of the total labor force, while the ancillary operations provide an additional 2 to 4 percent (Moavenzadeh & Rossow 1975).

2-2-2: The Characteristics of Construction:

Construction is an old industry, its culture and many of its basic methods have their roots to periods before explicit scientific analysis. However, especially after the World War II, there have been different initiatives to understand construction and its problems for developing corresponding solution and improving methods (Wells 1984). The nature and size of construction's operations make an attractive area for development, adaptation, and transfer of technologies consistent with the developmental goals of any country (Moavenzadeh & Rossow 1975).

The construction industry is labor-intensive; this is the main characteristic of the industry in both developed and developing countries. Characteristics of construction industry's products, include the nature of custom-made, immobility, fluctuation of labor demand, complexity, and many other features of the industry in both developed and developing countries (Moavenzadeh & Rossow 1975).The construction system contains variety of sub-systems, which interrelated, interacted and

influenced each other, the system of the industry is influenced by internal and external factors, such as weather conditions, country's policies, budget, technique issues and resources, each of these factors can affect the construction project (Ren 2012).

The immobility of the construction product, which requires final assembly at the place to be readily used, that makes construction a unique industry. The constructed facilities definitely cannot be transported, the stability of local demand is of particular importance. The specialized character of each facility, seasonality, the project-oriented, nature of production, and the industry's susceptibility to demographic and economic influences, that all combine making construction demand inherently unstable. To better understand the nature of construction is by useful looking at the construction process itself, a complex procedure involving a variety of steps and participants (Moavenzadeh & Rossow 1975).

The participants in the construction industry are traditionally divided into three groups, the clients, the professionals, and the contractors, an arrangement which is quite different from that in manufacturing where the designer and producer are in a single sector and the client enters only at the end. The temporary nature of construction work due to its project-orientation and the periods of unemployment which most workers encounter between projects are probably equally serious in both developed and developing countries (Moavenzadeh & Rossow 1975).

2-2-3: The Role of Construction in Economic Development:

The main purpose of development is growth of the economy, during the early development process economic growth seems to be generally high, and construction, along with manufacturing, tends to play an increasingly important role in the economy (Moavenzadeh & Rossow

1975). The construction industry has historically linked with the process of urbanization and industrialization, particularly since the industrial revolution. Canals and railways systems played an important role in the connecting of different areas of Europe, North America and in some regions of Latin America (Rostow 1963).Transport infrastructures played a major role in facilitating trade and co-operation between countries, also the construction industry played a key role in the reconstruction of the war-ravaged Europe. The clear example of the industry's contribution in the reconstruction of Europe is the vast construction improvement of housing and social infrastructure, beside its contribution to the national output (Ruddock et. al. 2010).

The importance of the construction industry also has been recognized obviously in the context of nations affected by natural hazards (Ruddock et al. 2010), besides its multiplier effect on other infrastructure sectors which can protect the natural and built environment and contribute to sustainable development (Lopes et al. 2011).While the direct contributions of construction to development are significant, it also stimulates a sizeable amount of economic growth. Requirements of construction for goods and services from other industries are considerable; the development of the construction industry therefore stimulates these ancillary industries, thus encouraging for more economic growth (Moavenzadeh & Rossow 1975).

The construction industry normally contributes intensively to economic development by ensuring some of the basic objectives including generation, support, creation of employment, and improving the income (Moavenzadeh & Rossow 1975). Construction is the only sector of an economy that is recorded twice, firstly in the national account as a component of GDP and Gross Domestic Capital, secondly the International

Labor Organization (ILO) reports construction employment as a separate entry in the labor statistics report (Turin 1980). Most developing and developed countries put more than 55% of their GDP investing to create the physical facilities, including infrastructure (Moavenzadeh & Rossow 1975). The construction contributes 7% to 10% into GDP of developed countries, and about 3% to 6% for developing countries (Lowe 2013).

2-2-4: Challenges & Obstacles of Construction Industry in developing countries:

Construction industry has numerous challenges and problems facing it recently, some are old and some are new to the industry. Majority of these challenges are a direct result of operations of construction, whereas others a result of indirect activities (Muir 2005). As a result of construction industry, no country free from major problems and challenges of these industry. Some of the problems are concern in all nations but, generally, developing countries suffer more from the problems, and resources more scarce (Ofori 1980).

Construction is viewed as one of the most undesirable industries in attraction to work. The nature of construction is dangerous, dirty, unstable and hard work, other industries often preferred work environments which are safer, cleaner, and more desirable (Muir 2005). The main problems in construction industry at the phase of construction can divided into four categories: management, capital, labor, and materials (Moavenzadeh & Rossow 1975).

Management of manpower has its problems almost in all developing countries, management training and education is time consuming, and difficult because it relies basically on the in-site training. Immobility of the labor force and the problem of remoteness of the most construction sites,

erratic availability of the labor force because of a seasonal return to the agriculture, worker's poor health and inadequate nutrition, di-skill, and law productivity(Moavenzadeh & Rossow 1975).

There are many problems related to capital are high interest rates, lack of credit with rental equipment, delays in payments, and practice of withholding a portion of the payment as a guarantee against poor quality of workmanship. The main problems of the materials in construction of developing countries is the lack of material's availability in local markets, problems in the materials' production, quality and control, the price of the building materials is sensitive to both the transportation costs and the amount of production (Moavenzadeh & Rossow 1975).

2-2-5: Future Vision of Construction Industry **(Medermott 2009)**:

Construction industry has been studied widely to predict the future of this industry. The main goal of each study is to develop a better understanding of the construction industry's future. There is no specific standard model to show how to conduct a study, future studies of all types have some bias of the researchers involved embodied in the findings. Conferences often try to address the state of affairs of the future. They have the advantage of being in an environment with some of people responsible for making decisions present at the conference.

In construction industry there is an overlap between the design and the execution. Normally, Design solutions impact delivering the project. In design of project there are many developments that are changing the way future projects will be designed. There are many technologies give the designer tools to be better in design; another departure from present design will be much greater use of standardized design solution. One of the technologies which has allowed for better coordination between project

design and execution, is Building Information Modeling (BIM). The basic concept with BIM is to assemble as much project information tied to a visual three-dimensional model a possible prior to a project actually being constructed. As BIM adopted by more and more players within the industry, its uses and applications will have a major impacts to construction. By making a large scale of implementing BIM, the construction may begin to gain increases in productivity.

Recently, there are wide variations of methods that employed for construction projects. In some applications, project teams have been able to use fully modular construction in which projects are constructed in a controlled environment using manufacturing and factory techniques. These large modules are then lifted into place and installed with minimum field labor. The construction sites have its developments. Since the early 1980s, predictions have been made that robotics would be used commonly on construction projects. As of yet, the prediction has not become a reality, there are some using of robotics in today's construction sites that make the exciting to envision the construction site of the future probably to happen.

Construction craft workers may have personal assistant machines that eliminate much of the physical exertion they endure on daily basis. The tasks of these machines could be overhead pipe fitting and welding, transporting and lifting materials, as well as operating vibratory equipment that can lead to physical damage after extended period of use. Construction sites may also implement integrated safety systems in which all personnel are outfitted with communication equipment to track safety. When one worker spots a situation that may create a safety hazard they can create an electronic tag in the location. The system would also be equipped with proximity sensors that could defect equipment locations and other hazards. The following table shows a comparison between construction management

currently and the future construction management. The main points of comparisons consists of the role of project manager, Location of construction site, project design, and organization structure:

Table 2-1: Comparing Construction Project Management: Present Day to 2025:

Construction Project Management - Current	**Construction Project Management - 2025**
Role of the Project Manager	
*Reactive problem solver *Emphasis on technical knowledge *Known stakeholders	*Proactive system designer *Emphasis on interpersonal skills *Many stakeholders
Location	
*Mostly onsite management *Largely regionally focused	*Centralized Location * Global Teams
Project Design	
*2D contract drawings *Non Standard Design * BIM for coordination and planning	*BIM for integrated information * Rule based design
Project Execution	
*Onsite fabrication *Physical Labor * Paper Documents	*Prefabrication, modularization *Automation techniques *Digital and virtual documents *Automated knowledge management
Organizational Structure/ Corporate Strategy	
*Adversarial relationships *Contracts often split by trade *Fragmented industry * Project-based metrics	*Collaborative partnerships *Contract structure to allow new techniques *Constant training and education *Program and portfolio management metrics

Source: Medemott (2009)

2-3: Construction Industry in Sudan:

2-3-1: The Role of the Construction Industry in Sudan's Development **:**

2-3-1-1: Sudanese Economy Overviews:

Sudan is a low income country, its income per capita of less than $400, with its vast geographic area and varied natural resources (Salim 2010). Instability is the main characteristic that dominates the performance of the Sudanese economy. Since independence and till now, a number of plans were put under application, most of these plans were not carried out properly and had not follow the time schedule set for the plans. The political instability was the main reason behind the failure in the application of different economical plans. The economical instability resulted clearly on higher inflation rates, instable and fluctuations in exchange rates, and low level of investments. Similar to many developing countries, corruption has been a major characteristic of the Sudanese economic scene (Elkhalifa & Shaddad 2008).

The Sudan's GDP growth declined from 5% in 2010 to 2.8% in 2011 due to the secession of South Sudan reducing the population by about 20% and oil revenue by 75%. Average inflation surged to 20% in 2011, up from 15% in 2010, owing to the rise in food prices and the depreciation of the Sudanese pound. The current account deficit fell to 7.5% of GDP in 2010, but it is expected to rise to 10.5% of GDP in 2011. Sudan's budget deficit was 5.0% in 2011 and is estimated to increase to 5.4% of GDP in 2012 due to the loss of oil revenue, intensifying armed conflicts and increased security threats, the creation of new states and the financing of peace agreements (African economic outlook 2012).The following table

shows the percentage of participation of the economic sectors in Sudan's GDP.

Table 2-2: GDP by Sector (percentage of GDP) in Sudan's economy comparison between years 2006-2011:

Sector of economy	**2006**	**2011**
Agriculture, forestry, fishing & hunting	32.9	33.1
Mining and quarrying	9.6	10.1
Manufacturing	7.4	8.6
Electricity, gas and water	2.2	1.8
Construction	4.4	4.7
Wholesale and retail trade, hotels and restaurants	15	15.6
Transport, storage and communication	13.9	12.5
Finance, real estate and business services	6.7	6.6
Public administration, education, health & other social & personal services	5.6	5.3
Other services	2.1	1.9
Gross domestic product at basic prices / factor cost	100	100

Source: African Economic Outlook 2012

2-3-1-2: Role of Construction Industry in Sudan's Economy:

Sudan continued to witness a dynamic construction activity as a result of infrastructure rehabilitation and the increased demand upon private and business property. No doubt that the performance of all the markets and submarkets in the construction industry is subject to the goodness or badness of the general economy performance in the market

boundaries. The highest rate of growth the sector ever enjoyed was as high as 161.4% in 1998(Alkhalifa 2011).

The contribution of the construction industry to the Sudanese national income has fluctuant considerably during the past twenty years but has average of 4% of the GDP (the value of one's year production of goods, and services by the nation) compare to 10% of the GDP accounted for the manufacturing industry, the contribution of the construction amounts to one third of the total industrial output. It is therefore a major source of employment in construction amount, to one third of employment in the entire industrial sector as a whole (Hassan 2002).

From 1997 up to date, Sudan has been working with the international Monterey fund to implement economic reform, including a manage float of the currency exchange rate. The average share of the industry's total contribution to GDP is as follow (Salim 2010):

-Manufacturing: 56% of total sectorial contribution of GDP.

-Construction: 30% of total sectorial contribution of GDP.

-Electricity and petroleum refining: 14% of total sectorial contribution of GDP.

2-3-2: An overview of Sudan’s construction industry:

The Sudan's construction sector is characterized by many small and large projects, and high labor intensity, it is also highly dependent on public regulations and public investments. The construction industry of Sudan also has a number of factories, and material suppliers that provide building materials and special fittings. The scope of Sudanese construction industry is very wide, includes residential construction, building construction of commercial, irrigation, roads, tunnels, transportation, facility building, and

heavy engineering construction which refer to infrastructure construction and industrial construction (Gaber et al. 2014).

The construction sector has been thriving in Sudan lately. The sector is benefiting from the revamping of the urban infrastructure estimated to cost some US$ 7 billion. The Merowe Dam is one of the major infrastructure projects estimated to cost some US$ 2 million, with China heavily investing in it. Another example is the US$ 500 million the new Khartoum airport. In addition, a number of new projects targeting businesses and foreign investors are coming into the country. The current capacity of cement plants in Sudan is only about 500,000 tons, whereas the overall demand is projected to rise up to 4 million tons over the next few years (Abdalrahman 2009).

The economic policies and strategies imposed by the present government now days, encourage investment, encourage the imported of trucks, encourage foreign companies to invest, etc. all that caused a positive effect on the construction industry productivity. In Sudan, construction of building segment includes contractors usually called general contractor (GC), who build residential, industrial, commercial, and other building. Heavy construction contractors responsible to build roads, sewers, bridges, and other projects. Such contractors are international with cooperation with national contractors (Salim 2010).

2-3-3: Challenges Facing Sudanese Construction Industry:

The Construction everywhere, given its special problems and requirement, faces problems and challenges are present a long side a general situation of socio-economic stress, chronic resource shortages, institutional weaknesses and a general inability to deal with the key issues (Ofori 2000). Sudan's construction industry in general is characterized by

the unfavorable environment, with corruption, favoritism bias, and high risks and uncertainties due to the political instability (Elkhalifa & Shaddad 2008).

The main challenges of construction industry in Sudan is the lack of motivation, traditional methods, and the lack of training program had been behind the deterioration of the productivity in Sudan. The absence of motivation and training programs is leading to declining productivity of site's workers. That is not mean there is no progress in the construction productivity in Sudan is cooping the improvement which taking place worldwide (Salim 2010). The country in general suffers from the high level of taxes and fees on the production, transportation, and sales of building materials, taxation, custom duties, zakat, highway taxes, and provincial fees beside other types of fees contribute to the high prices of building materials (Elkhalifa & Shaddad 2008).

Delay in construction projects has been a major issue in the Sudanese construction industry over the past decades (Mohamed 2015). In fact, there are many external factors such as lack of materials on the market, lack of equipment and tools on the market, poor weather conditions, poor site conditions (location, ground, etc.), poor economic conditions (currency, inflation rate, etc.), changes in laws and regulations, transportation delays, and external work due to public agencies (roads, utilities and public services) (Abdalrahman et al. 2009).

Chapter Three

Lean Construction

Chapter Three

Literature Review: Lean Construction

3-1: Preamble:

Manufacturing and construction differ in the physical features of the end product significantly. In manufacturing, finished products can be moved as a whole to the end customer or to the retailers; on the other hand, construction deals with larger units that cannot be transported. The construction generally has other features which distinguish it from manufacturing: on-site production, complexity, and one-of-a-kind projects (Koskela 2002). Manufacturing and construction strive to add value to their products via high returns on investment, both employ different methods and means to achieve their objectives (Salem et al. 2006). Although there are many differences between manufacturing and construction, the construction has some characteristics of both production and services systems which led the construction to take some steps toward applying some manufacturing concepts such as lean production (Howell 1999).

After World War II Japan adopted the Toyota production system (TPS), which was based on a scenario of fluctuating demand the required swift assembly line alterations due to the large number of different parts to be produced (Ohno 1988). Lean production was developed by Toyota motor company led by Engineer Taiichi Ohno. The term "lean" was coined by the research team working on international auto production to reflect both the reduction nature of the Toyota production system to contrast it with craft and mass forms of production (Womack et al. 1991).

Ohno (1988) shifted attention to the entire production system from the narrow focus of craft production on worker productivity and mass production on machine. He also followed the work of Henry Ford and continued the development of flow based production management, but unlike, Ford who had an almost unlimited demand for a standard product; Ohno wanted to build cars to customer order. Starting from efforts to reduce machine set up time and influence by TQM, he 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).

In construction the application of the lean production model stems from a discussion of Professor Lauri Koskela's work in 1992, as well as aspects related to converting inputs into finished products as an important element to the creation of value over the life of the project (Koskela 1992). Lean standard of perfection, but the construction industry has rejected some ideas from manufacturing, because of the belief that construction industry is different. Managing construction under lean is different from typical contemporary practice because (Howell 1999):

- It has a clear set of objectives for delivering process.
- It is aimed at maximizing performance for the customer at the project level.
- It applies production control throughout the life of the project.

3-2: Lean Production:

3-2-1: What is Lean? :

Lean is a term used to describe a high performance and effective method for managing organizations and delivering their main aim in the

most effective and efficient manner. Lean is an ethos, a way of doing business. It looks for maximizing the generation of customer value by driving all forms of wastes out, ensuring high quality, reducing timescales and minimizing cost (O'Connor & Swain 2013). Thinking of the process as a lean, means high quality machine, no wasted efforts, everything works smoothly, and efficiency at all-time is high (Anthony& Konka 2011).

Lean is a set of concepts, principles, approaches, and methodologies that can be applied individually or organizationally. When lean principles are used a method to management they are continuously performed and can become a long-term philosophy for directing organizations to be easy, clear and well-managed. “Lean” operating principle began in manufacturing environments and is known by a variety of synonyms; Lean Manufacturing, Lean Production, Toyota Production System, etc.(Kilpatrick 2003).

It is commonly believed that Lean started in Japan (Toyota, specifically), but Henry Ford had been also using similar concept about Lean as early as the 1920’s, as evidenced by the following quote:" The most important reason about keeping the price of Ford products low is gradual minimizing the production process. In manufacture process, developing long production cycle must be increased the production budget"(Kilpatrick 2003).

3-2-2: Toyota Production System (TPS):

3-2-2-1: Historical Background (Toyota production system 2016):

The Toyota production system (TPS) arose out necessity in response to the circumstances surrounding the company. Many of the fundamental concepts are old and unique to Toyota while others have their roots in more traditional sources. The oldest part of the production system is the concept of **Jidoka**, which was created by Sakichi Toyoda the founder

of Toyota in the year 1902. This concept pertains to notion of building in quality at the production process as well as enabling separation of man and machine for multi-process handling. The origins of this notion began in the Toyoda Spinning and Weaving Company which was started by Sakichi Toyoda. Sakichi invented a loom that automatically stopped whenever it detected that a thread was broken.

Later on in 1924, he created an automatic loom that allowed one person to operate multiple machines. The rights to manufacture the loom outside of Japan for were eventually sold to the Platt Brothers Ltd. in England. This money was then partially used to start an automotive division that was later spun off in 1937 as a separate business and company under Kiichiro Toyoda, the Sakichi's son. After World War II, a promising engineer in the Toyoda Spinning and Weaving Corporation called Taiichi Ohno was brought over to the automotive side of the business. He was given the task of improving operational productivity and driving in the concepts of **Just-In-Time** and **Jidoka**. He was eventually appointed machine shop manager of an engine plant and experimented with many concepts in production between the years of 1945-1955.

The effort and work of Ohno is largely what resulted in the formulation of what is now acknowledged as the **Toyota Production System**. There are numerous other people inside the company that contributed to the overall development of the company and the production system. There are also many other tools and techniques that were developed in Toyota such as 7 Wastes, Standardized Work, 5S, Visual Control, Error Proofing, as well as many others. Other influences such as Henry Ford, Fredrick Taylor, and Dr. W. Edwards Demming.

3-2-2-2: The Toyota Production System Model (Toyota production system 2016):

There are two primary pillars of Toyota Production System. The first and most famous pillar of the system is Just In Time (JIT). The JIT concepts aim to deliver and produce the right parts, in the right amount, at the right time using the minimum necessary resources. This system reduces inventory, and strives to prevent both early and over production. The second pillar of the system is Jidoka (Build in quality) which means automatic or automation. Jidoka has two elements: (1) Building in quality at the process and, (2) Enabling separation of man from machine in work environments.

Jidoka aspires for processes that are capable of making intelligent decisions and shutting down automatically at the first sign of any unusual condition such as defects, or any other problems. The goal is not to work continuously, but stopping the work automatically when trouble arises. This automatic stop function helps stop defects from escaping downstream, limits machine damage, prevents injury, and enables a better look at the current condition whenever there is a problem. The second component of Jidoka is separation of man from machine. When machines possess the ability to stop in the event of a problem then there is no need for workers to stand and watch machines.

3-2-2-3: Types of Wastes in Toyota Production System:

In the Toyota Production System (TPS), and in lean today, waste is divided into three main categories: Muda, Mura, and Muri.

Muda (Ren 2012) (Anthony& Konka 2011) (Toyota production system 2016):

It means traditional waste, which is divided into seven subcategories, as follow:

1-Transportation:

Wasted motion occupies time and energy. Ideally all unnecessary movements or actions are eliminated from the work process. Much of this wasted motion is often overlooked because it has become such a part of the process. Work processes should be designed so that items are positioned close to each other. Unnecessary amounts of turning, lifting and reaching are eliminated.

2-Waiting:

Time is a limited resource. In the manufacturing world, time is money, customer requirements are calculated to the second. Any waiting due to changeovers, delays, breakdowns, poor layout or work sequence needs to be eliminated. Thorough preventative maintenance and rapid changeovers are essential to global competitiveness. Reducing cycle time by eliminating waiting within the work sequence can also have a profound effect on productivity.

3-Overproduction:

There are two types of overproduction, producing too much and producing too early. Overproduction invites more waste because it hides problems beneath a veil of inventory, producing more than the customer's demands. The amount of production is depending on a pull system, which means the manufacture will produce the market real needs. The number of market products will be ordered from the market, the manufacture must produce according to the market requirements. In this way, the production will avoid waste and help the customer save budget.

4-Defects/ Correction:

Any defects in production process will bring a series of negative effects. Materials are wasted when production errors occurred, according to this; labor force must be in need to make a correction, extra labor force will cause extra budget. Obviously, defects will cause a series of drawbacks.

5-Excess Inventory:

Preventing unnecessary inventory is critical to the success of the Toyota Production System. The smooth and continuous flow of work through each process ensure that excess amounts of inventory are minimized. If work-in-process develops because of unequal capabilities within the process, efforts need to be made to balance the flow of work through the system.

6-Excess Motion:

The wasted motion is often undesirable because it has become such a part of the process. Work processes should be designed so that employees and workers in manner to eliminate unneeded movement.

7-Overprocessing:

Over processing is as wasteful as insufficient processing. Any process step that is not adding value to the production is by definition a kind of wastes. It means doing more than is required to meet design requirements, which leads to excessive time and/or cost. The following figure illustrates the 7 Muda wastes:

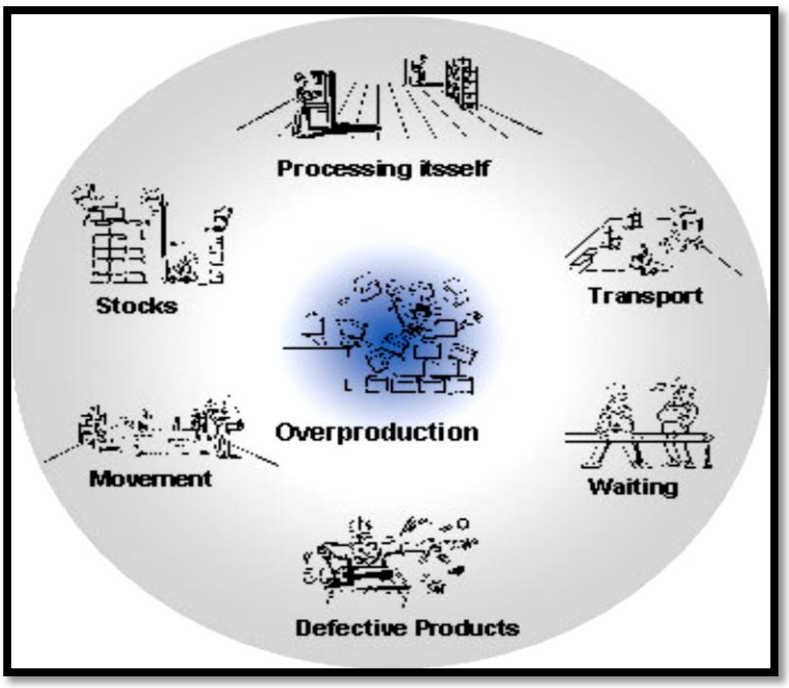

Figure 3-1: The seven wastes (Ahrens 2006)

Mura:

It means unevenness or variation. Variation is the enemy of quality; it is a classification of waste because the variation expends time and energy to measure the product to determine the amount of variation present, and to see whether the product can satisfy the customer. If the organization produce exactly the same every time, that would eliminate all waste steps (Anthony& Konka 2011).

Muri:

It means overburden, it has to do with asking too much of employees and processes of the organization. Working overtime is often considered a good thing by employees looking to pick up a little extra money, but for example working too much overtime can tire the employees, and increase the probability of safety incidents on the job(Anthony& Konka 2011).

3-2-3: Lean Production Principles:

Lean production eliminates the figure of the foreman supervising the work of many specialized workers that perform repetitive tasks. The lean production idea is to create teams of multi-skilled workers led by a team leader. Members of a team are expected to perform any activity within the team's operation and work collectively to improve the process. Additionally, any member of the team may stop the entire production line in case there is any problem. The team leader accesses the conditions of the problem, and any member has the opportunity to participate in the solution. Lean production also eliminates the space in the assembly line reserved for rework. The reasoning is that rework should not be a part of the production process and therefore should not exist. Likewise, no dumpers are placed in the assembly plant; if a part has to be thrown away, the production line stops and corrections are made (Almeida 2002). There are five main principle of lean production as follow (Womack & Jones 2003):

1-**Identify Value:**

To make a clear vision and mission from customers and through negotiate with customers to build a common goal and pursue the jointly value.

2-**Map Value stream:**

The value stream is a series of actions produced by an organization to create value for the customer. Analyzing the value stream aims to identify value-adding activities that are necessary for producing and delivering a product or service to the customer. Through Map Value Stream can clear

the task details and identify the unnecessary steps. To build a common goal with stakeholders can avoid divergence in the later process.

3-**Create Flow:**

The objective is to make parts move from one value-adding step directly to the next value-adding step, and then to the customer without waiting downtime or waste within or between the steps. To create steps by logical order according to the value stream that helps the task finish smoothly by logical flowing. And it is easier to see the defects from the flow.

4-**Establish Pull:**

Pull means that nothing should be produced upstream until the downstream customer asks for it. In an ideal one-by-one flow, the product flows continually to the customer only after the signal from the requesting customer. The rational business relation from customer and manufacture is formed through Pull system which is the amount of manufacture produce is according to the customers need.

5-**Seek Perfection:**

The drive for perfection becomes very strong when you are able to make the value flow faster and expose more hidden waste that needs to be removed. It dawns on those involved that there is no end to the continuous process improvements while offering value that is increasingly closer to the customer's real needs.

3-3: Lean Construction:

3-3-1: General Overview:

The construction industry has adopted the lean production philosophy, which has contributed to the manufacturing industry under name "Lean Construction". Lean construction concept has been tried to be created and promoted by some researchers, institutes, governmental reports, some occupational organizations…etc. The most two famous organizations which have been working to develop the lean thinking in construction, are the International Group for Lean Construction(I.G.L.C), and the Lean Construction Institute(L.C.I) (Tezel 2007) (Almeida 2002).

The first research introduced the lean movement in manufacturing to the construction industry in the year 1992 was by Professor Lauri Koskela by presenting of the initial investigations involving lean construction through a technical report developed at Stanford University . He also hosted the first conference of IGLC in Espoo, Finland in 1993. In that conference a group of researchers adopted the name "Lean Construction". Since 1993, the IGLC has been organizing academic conferences annually, hosted by local universities and institutes from different regions around the globe. The LCI in America was founded in 1997, which has been publishing an international refereed journal devoted to lean construction practice journal. This journal includes papers, reports, and book reviews from industry practitioners and academia (Tezel 2007).

3-3-2: Lean Construction Definition:

Lean construction defined as:" a way to design production systems to minimize waste of materials, time, and effort in order to generate the

maximum possible amount of value" (Koskela et al. 2002). Abdelhamid(2008) defined lean construction as " a holistic facility design and delivery philosophy with an overarching aim of maximizing value to all stakeholders through systematic, synergistic, and continuous improvements in the contractual arrangements, the product design, the construction process design and methods selection, the supply chain, and the workflow reliability of site operations".

On the other hand, Lean Construction Institute (2004) defined lean construction as: "a production management-based approach to project delivery -- a new way to design and build capital facilities. Lean production management has caused a revolution in manufacturing design, supply and assembly. Applied to construction, Lean changes the way work is done throughout the delivery process. Lean Construction extends from the objectives of a lean production system - maximize value and minimize waste – to specific techniques and applies them in a new project delivery process".

3-3-3: Waste in Construction Industry:

Waste defined as any inefficiency that results in the use of equipment, material, capital, or labor in larger quantities than those considered as necessary in the production of a building. Waste includes both the incidence of material losses and the execution of unnecessary work, which generates additional costs but do not add value to the product (Ingle & Waghmare 2015). Construction industry has numerous processes that cause wastes; the cost of poor quality for example turns out between 10 to 20 % of the total project costs (Garas et al. 2001). Another study by Raghavan et al. (2014) showed that the total cost of wastes varied from 5.4% to 14.7 % of the cost of the projects which has been studied. The waste in reinforcing

steel in Egypt was 5 % , while in Brazil was 21 %, waste in cement of average 5 %, waste in timber frameworks in an average of 13%, waste of sand was 9% .

Bossink and Brouwers (1996) classified stages of construction that generates waste into six groups:

1- Operational. 2-Design.

3-Residual (Debris). 4- Procurement.

5-Other (Theft etc.). 6- Materials handling.

The following table illustrates examples of waste types in Construction projects

Table 3-1: Examples of waste types in Construction projects:

Waste in time due to:	**Material waste due to:**
Idle (waiting periods)	Overordering/ excess
Stoppages	Overproduction
Clarifications	Wrong handling
Variation in information	Wrong storage
Re-work	Manufacturing defects
Ineffective work	Theft or vandalism
Interaction between various specialities	
Delays in plan activities	
Abnormal wear of Equipment	

Source: Garas et al. 2011

Zhao and Chua (2003), performed a detailed network analysis on various 8 projects from a flow point of view, stated the most man-hour consuming wastes in order of importance:

1- Waiting due to crews interference.
2- Waiting due to inspection.
3- Equipment used by other crew.
4- Waiting due to equipment's installation.
5- Waiting for instruction.
6- Rework due to design change.
7- Stock problem.
8- Material vendor delay.

The following figure shows classification of waste in construction:

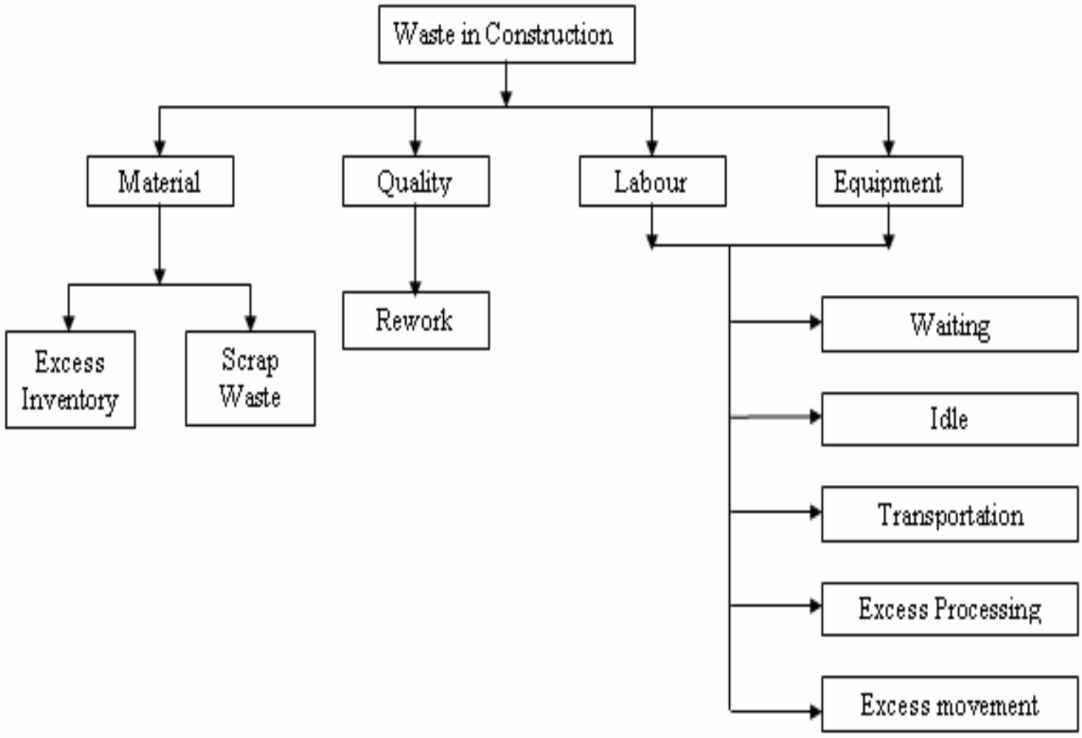

Figure 3-2: Construction Waste Classification (Raghavan et al. 2014)

The following table shows a Comparison between waste in lean manufacturing and lean construction:

Table 3-2: Comparison between Lean Manufacturing and Lean Construction Waste:

Type of Waste	Manufacturing	Construction
Overproduction	Production of too many units or parts due to push nature of manufacturing.	Overbuilding a particular aspect of a project, either because it was over-engineered or a process was started before it was really needed.
Waiting	Time spent waiting for the next batch of parts to arrive from the previous conversion process. Time spent waiting for a machine to finish.	Time spent waiting for other work crews to finish their particular conversion process so that the next conversion process may begin. Time spent waiting on crew members of a specific team. Time spent waiting for parts or instructions.
Transport	Wasted effort to transport materials, parts or finished goods into or out of storage between processes.	Wasted effort to transport building components or tools into or out of job trailers or storage between processes.
Extra Processing	Doing more work than is required.	Waste associated with rework, re-handling or storage caused by defects in design, fabrication or construction activities.
Inventory	Maintaining excess inventory of raw materials, parts in process or finished goods.	Maintaining excess inventory of construction components, equipment or tools.
Motion	Waste associated with unnecessary worker/equipment movement between work stations.	Waste associated with unnecessary worker/equipment movement around the construction site.
Defects	Repair or rework.	Deficiencies in the finished product that require additional work or rework to correct punch list items.

(Source: Diekmann et. al. 2004)

3-3-4: Lean Construction Tools:

Lean Construction is using the same principles as lean production to reduce waste and increase the productivity and effectiveness in construction

work. The most important determinants of construction are supposed to be workflow reliability and labor flow, but lean construction has changed the traditional view of the project as transformation, and embraces the concept of flow and value generation. Similarly, it shares the same objectives of lean production, e.g., cycle time reduction, elimination of waste, and variability reduction. Continuous improvement, pull production control, and continuous flow have been the direction for the implementation of lean construction (Paez et al. 2005).

The tools of lean construction can be classified the operative techniques utilized in lean construction through three levels. The classification is summarized in Table 3-3 (Paez et al. 2005):

1- Level One: Direct application of the techniques from lean manufacturing.
2- Level Two: Modification of the techniques taken from lean manufacturing.
3- Level Three: The all-in-all lean construction specific techniques.

Table 3-3: Classification of Lean Methodologies/Tools:

Levels	**Lean Construction Technique**	**Related Lean Manufacturing Technique**
Level One	-Material Kanban Cards	-Kanban System
Level Two	-Visual Inspection -Quality Management Tools -Concurrent Engineering	-Visual Inspection (Poka-Yoke Devices) -Multifunctional Layout -T.Q.M
Level Three	-Last Planner System -Plan Conditions of Work Environment (P. C. W. E.) -Daily Huddle Meetings	-Kanban System -Production Leveling -Toyota Verification of Assembly Line (T. V. A. L.)

Source: Paez et al. 2005

The following section will discuss some of the lean construction tools/ techniques which are: Concurrent Engineering, JIT, visual management, 5Ss, Kaizen and Last Planner System

3-3-4-1 Concurrent Engineering:

Concurrent engineering is "the parallel execution of different development tasks in multidisciplinary teams with the aim of obtaining an optimal product with respect to functionality, quality, and productivity" (Paez et al. 2005). Also concurrent engineering defined as: An attempt to optimize the design of the project and its construction process to achieve reduced lead times, and improved quality and cost by the integration of design, fabrication, construction and erection activities and by maximizing concurrency and collaboration in working practices (Evbuomwan & Anumba 1998).

Many enhancements can be accomplished by using concurrent engineering. Scheduling could be recovered by network analysis (CPM and PERT). Many other opportunities can be achieved through overlapping activities, splitting activities and reducing the transfer time between different activities (Paez et al. 2005). It is a combined effort that incorporates the parties involved in a product or a production system design with a strong client needs orientation. While simultaneously executing their own tasks, multi-disciplinary teams should sustain extensive communication and information sharing with customers and each other and some serious risk analysis and resource allocations under time pressure (Tezel 2007).

The basic principles of an extended concurrent engineering/construction: integration of the design phases, simultaneous inclusion of the information related to the construction life cycle (design, procurement, commissioning and so on.), multi-disciplinary composite teams,

division of the work into smaller parts and proactive integration of the work and the information throughout a construction life cycle (Jaafari 1997).

3-3-4-2: Just In Time (JIT):

JIT represents a management philosophy created and developed within the Toyota Production System shortly after the end of World War II and involves three basic aspects: people, plant, and systems. Initially introduced as a methodology for reducing inventory levels. The system evolved into an extensive managerial philosophy that optimizes quality-cost related elements (Almeida 2002).

The term 'Just-In-Time' (JIT), used for instance to describe the delivery of materials to a construction site, suggests that materials will be brought to their location for final installation and be installed immediately upon arrival without incurring any delay due to storage in a laydown or staging area. JIT is a concept developed by the Japanese who created the Toyota Production System, later translated into English as the lean production system. The ultimate objective of JIT production is to supply the right materials at the right time and in the right amount at every step in the process (Tommelein & YiLi 1999). Following is a short view of the three elements of JIT(Almeida 2002):

1) **People:** A fundamental element of JIT refers to the involvement and support of people that are related to the mission of the organization, such as stockholders, employees, labor organizations, suppliers, managers, and costumers.
2) **Plants:** The implementation of JIT requires substantial changes in plant layout for maximum flexibility and flow. Also, the plant layout should facilitate de implementation of "pull-strategy", where demand indicates when (and how much) production should initiate. Finally, the plant

organization must allow workers the flexibility to inspect the production and halt the system whenever he/she encounters a defective part.

3) **Systems:** Involve the processes applied to coordinate activities and materials. JIT envision the involvement of a limited number of specialized suppliers for each part or material the firm buys. Those suppliers work in conjunction with the organization and receive financial and technical support as well as the assurance of long-term contractual relationship. In exchange, suppliers are expected to promptly deliver defect-free parts in the quantities needed. Quality is a key issue as the parts must be ready for assembly; the supplier must comply with the "quality at the source" thinking, which is the opposite of the traditional "after the fact" inspection/quality control.

JIT system reduces the cost of material handling and storage. In accordance with Taiichi Ohno's vision of non-value added activities, the JIT method eliminates waste resulted from any activity that adds cost without adding value, such as moving and storing. Moreover, it reduces waste from overproduction, transporting, unnecessary motion, and waste resulted from producing defectives parts. Some of the most important characteristics of the JIT process are (Almeida 2002):

- **Limited number of suppliers:** In order to operate, JIT companies must rely on a few suppliers who will make frequent deliveries in small lots. Suppliers must be willing to make deliveries as much as several times a day, and in the exact quantities specified by the buyer. Dependability is essential for the process.
- **Plant Layout:** To implement JIT in a proper manner, companies must improve the manufacturing flow lines. All machines needed to make a particular product are put together in one location, called manufacturing cell, a "factory within a factory."

- **Flexible workforce:** Workers on a JIT line must be multi-skilled and flexible, they must perform minor repairs, and they must do maintenance when their cell is idle.
- **Setup time:** Efforts toward decreasing setup time in a JIT manufacture is essential. Most equipment are dedicated to a single product or a single product line so setups are largely eliminated and products can be produced in any batch size.
- **Defective parts:** Companies that apply JIT are committed to a minimum level of defective parts because it is critical to avoid any delay in the process. Those companies tend to reach a goal of zero defects.

3-3-4-3: Visual Management (VM):

Visual Management is done to make things easy to see. The principle behind VM is that people are usually attracted by what they see. It is used in every part of an organization where there is an immediate need for unambiguous information to be clearly communicated and understood at a glance. Visual management is already used in many forms on construction sites, such as notice boards signs used to indicate dangerous or hazardous situations, color-coding of fire extinguishers and electrical wiring etc. In a Lean construction environment it would also use (O'Connor & Swain2013):

- Team or work area based communication boards to display look-ahead work plans, site layouts marked up to show areas of work and often color-coded by trade, traffic and material logistics plans, performance measures displayed on charts or graphs, issues and action sheets, improvement successes etc.
- Markers to define the amount of work to be completed in a given time period and to show progress of work to an agreed rate of working.

- Floor markings to highlight walkways and the location of tools, materials and plant to ensure safe and efficient working condition.

Good visual management enables consistent high performance through effective communication processes. This makes it easy to see and understand the plan, the status and achievement to plan, performance, any issues that have affected the plan and/or performance and the status of any actions to resolve any outstanding issues, supports safe and efficient working improves quality and productivity, supports collaborative working etc (O'Connor & Swain2013).

3-3-4-4: 5S Work Organization:

5S is a fundamental building block of Lean and continuous improvement. 5S provides a structured method for achieving, maintaining and improving the standard set-up, organization and layout of a work area so as to ensure safe and efficient operations, with minimal waste. The Five S's (5S) are some rules for workplace organization and in-house keeping which aim to organize each worker's work area for maximum efficiency and to reduce waste associated with the workplace organization (O'Connor & Swain 2013).

The Five S's are in every internal customer's responsibility to create a working environment of which people are proud. It is believed that people who are proud of their workplace can produce high quality products easier. 5S applies to any work area (i.e. site areas of work, materials storage areas, offices). It can also be applied to improve the set-up and organization of a desk or office. A 5S improvement activity should be carried out by the people who work within the area/process. The five S's are (Tezel 2007) (O'Connor & Swain 2013):

1. **Seiri (Sort):**

Sort frequently needed things and lesser needed things so that frequently needed things are available nearby and as easy to find as possible.

2. **Seiton (Set/Straighten):**
   Arrange essential things as accessible as possible to reduce the waste related to a worker's motion in locating or acquiring a needed thing.
3. **Seiso (Shine):**
   Keep work areas and machines clean in order to reduce the waste related to uncleanness and increase workers' satisfaction.
4. **Seiketsu (Standardize):**
   Standardize and diffuse the first 3 S's throughout the working place by means of clear procedures.
5. **Shitsuke (Sustain):**
   Sustain through training, promotions, control, and consistent application to become part of the everyday way of doing work.

The 5S's activities are very useful for the construction site, because they create a safer working environment, make things in site easier to see, promotes a good working environment resulting in improved morale and image.

3-3-4-5: Kaizen (Continuous Improvement):

Tazel (2007) mentioned that continuous improvement is of the very basic core elements of the lean production system. In fact, there are two types of continuous improvement; gradual improvement and periodic big leaps. The form of continuous improvement in the lean production philosophy has been gradual, yet frequent continuous improvement (Kaizen) from the beginning (Ohno1988). It is about being unsatisfactory with the current situation, correcting defects on their actual places, implementation of the agreed ideas immediately, aiming for high, appreciating and rewarding effort, finding

opportunities in difficulties, searching for the real reasons, holistic thinking, taking ideas from different people, experimentation of ideas and believing in infinity of development.

Continuous improvement is in the focus of every process, training mechanism, equipment and principle of a lean production system. Additionally, creating a fulfilling and safer work environment with satisfied workers is also in the scope of Kaizen. In order to perform an effective continuous improvement within a system, both quantitative (statistical) and qualitative tools are highly employed. Continuous improvement takes place within the Deming's famous P. D. C. A. (Plan- Do- Check- Act) improvement circle. Processes are constantly measured. A challenging improvement target is determined and compared to the current situation. Improvement suggestions are applied and processes are re-measured. The working or bettering suggestions are standardized. The cycle turns back to the measurement stage (Tezel 2007).

3-3-4-6: Last Planner System (LPS):

The Last Planner System defined as a system for collaboratively managing the network of relationship and conversations required for program coordination, production planning delivery, by promoting conversations between trade foremen and site management at appropriate levels of detail before issue become critical(Mossman 2005). The Last Planner System based on principles of Lean Construction was developed by Glenn Ballard. It is based on a "Should, Can and Will" approach (Ballard 2000). Last planner System has been demonstrated to be a very useful tool for the management of construction process, and continuous monitoring of planning efficiency (Mossman 2005).

Last Planner System aims to shift the focus of control from the workers to the flow of work better assignments to direct works through continuous learning and corrective action, and to cause the work to flow across production units in the best achievable sequence of rate (Aziz & Hafez 2013). Last planner System is based on a traditional planning system, and is performed by field foremen; the condition of (Should- Can- Will – Did) is implemented (Howell& Ballard 1998). Fig 3-3 represents the diagram of the Last Planner System:

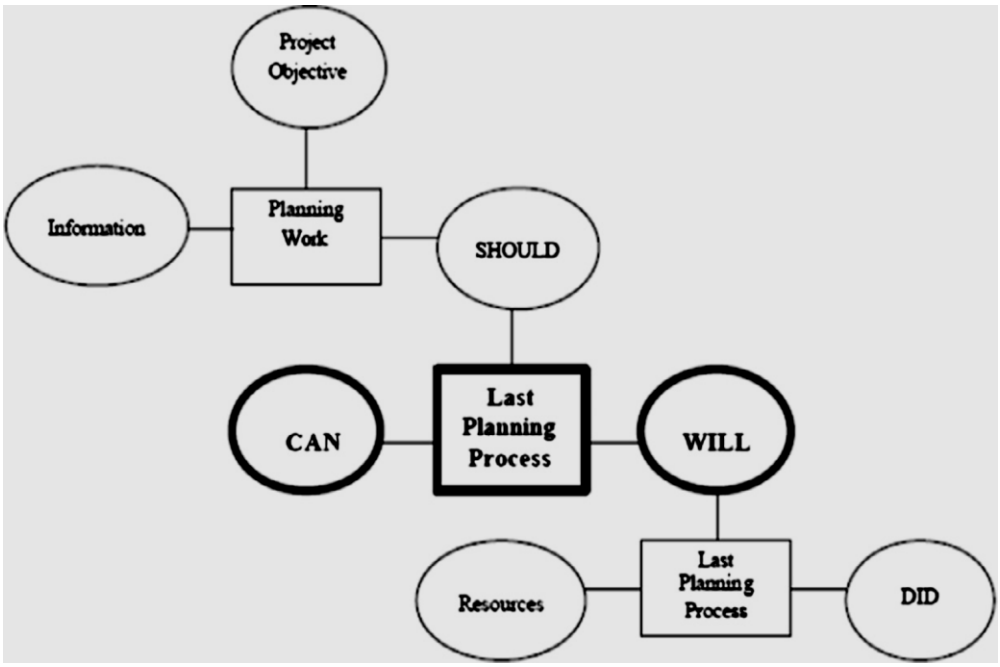

Figure 3-3: Last Planner System (Howell & Ballard 1998)

The Last planner is the individual, who decides the work that is to be done tomorrow. He is typically a superintendent, foreman, or site supervisor (Javkhedkar 2006). Last planners can reasonably commit to completing the tasks on weekly work plans that meet these criteria. To be effective, production management systems must tell what should be done, what can be done, and what will be done; then, they compare what was done to improve planning (Howell & Ballard 1998).

The term SHOULD is considered as: Hopefully; CAN means: Probably; and WILL means: Absolutely. In figure 3-2 above, a reliable assignment determines what WILL be done, after considering what SHOULD and CAN get done based on the situation at hand (Aziz & Hafez 2013). The Last Planner System has four levels which are (Howell 2000):

1. **Master Schedule:** setting milestones and strategy identification of long lead items.
2. **Phase Schedule:** Pull planning (specifies handoffs identify operational conflicts).
3. **Look-ahead Plan:** Make Work Ready Planning (to ensure that work is made ready for installation; re-planning as necessary).
4. **Weekly Work Plan (WWP):** commitments to perform work in a certain manner and a certain sequence.

3-3-4-7: Lean Project Delivery System (LPDS):

The Lean Project Delivery System is a set of interdependent functions, rules of decision making, procedures for execution of functions, and as implementation aids and tools, including software when appropriate, and is a conceptual framework developed by Glenn Ballard to guide the implementation of lean construction on project-based production systems LPDS was depicted as a model with five main phases, where each phase is comprised of three modules (Ballard 2000). The following figure interprets the interdependence between the phases is represented by sharing one module between two subsequent phases:

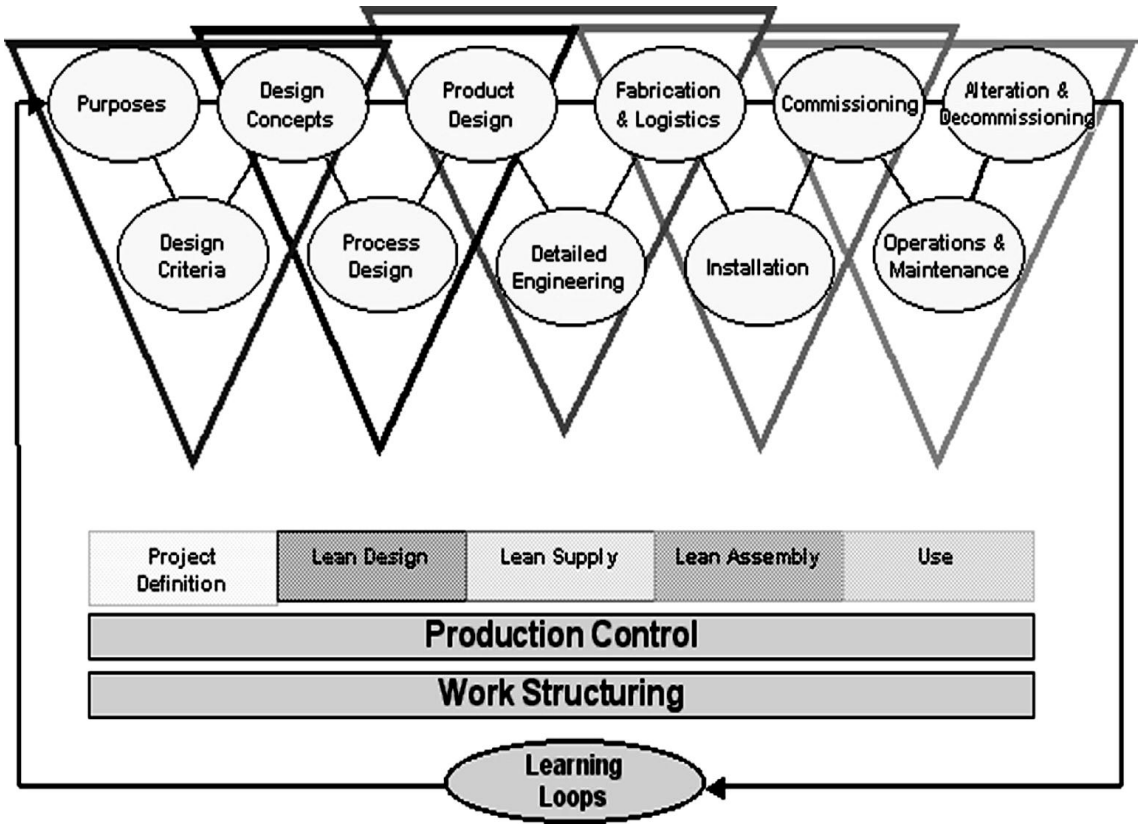

Figure 3-4: Lean Project Delivery System **(**Construction Industry Institute (CII) 2007**)**

The LPDS model consists of 13 modules, 11 organized in 4 interconnecting triads extending from project definition to design to supply to and assembly, plus 2 production control modules and work structuring module both conceived to extend through all project phases, and the post-occupancy evaluation module, which links the end of one project phase to the beginning of the next (Aziz & Hafez 2013):

(1) Project Definition: (a) Needs and Values Determination; (b) Design Criteria; and (c) Conceptual Design

(2) Lean Design: (a) Conceptual Design; (b) Process Design; and (c) Product Design.

(3) Lean Supply: (a) Product Design; (b) Detailed Engineering; and (c) Fabrication/Logistics.

(4) Lean Assembly: (a) Fabrication/Logistics; (b) Site Installation; and (c) Testing/Turnover.

(5) Production Control: (a) Work Flow Control; and (b) Production Unit Control.

3-4: Lean Construction Application in Foreign Countries:

3-4-1: An Overview of Applying Lean Construction in different Countries :

The lean construction philosophy views a project as a promise delivered by people working in a network of commitments. Smooth work flow is dependent on having the parties to a project keep promised that they made concerning the project. When waste is weeded out from a process, workflow becomes more predictable, performance increases and projects can be completed more rapidly (Lichtig 2006). Lean construction distinguishes significantly from traditional project management practice; the processes are actively controlled, and metrics are used in planning system performance to assure reliable workflow and predict project outcomes (Forbes & Ahmed 2011).

Traditional construction approaches reward individual crew performance , crews may focus on their tasks to the detriment of other crews. In lean construction, all involved disciplines are rewarded for completing major sections of the project. Lean construction has therefore complimented traditional construction management by producing successful capital projects in Brazil, Finland, Germany, and Singapore (Abdullah et al. 2009).Table 3-4 below indicates many benefits of implementing lean construction in many

different countries which has an increased number of firms have implemented lean construction practices in order to attempt improving performance in construction projects (Alarcon & Calderon 2003). Many companies, and also many researchers, have reported satisfactory results from the implementation of lean construction (Emuze & Ungerer 2014).

The benefits from implementing lean construction include increased workflow reliability, reduced project delivery time, improved communication among project participants, improved supply chain integration, fewer daily problems, and improved quality of work (Fernandez-Solis et al. 2013). Lean thinking is a new way to manage construction because its principles and techniques have formed the basis for a new project delivery process (Forbes & Ahmed 2011). The flow attributes of lean processes facilitates waste reduction and value maximization that should redefine the way people think about, and carry out construction activities (Novak 2012).

Creating a culture of collaboration, transparency and systems integration is essential to the success of any Lean project. The key driver is to select trade partners, designers and engineers based on value added to a team rather than overall cost. Business owners can require contractors, architects and designers to design and construct a space that meets their established values without compromise to the projected target costs. These two goals work in tandem with a lean team to drive innovation and by seeking out and eliminating waste, resulting in timely project delivery and profitability (Ingle & Waghmare 2015).

For lean to be successfully implemented, certain concepts must be applied to suit each organizational goal. These include (Emuze & Ungerer 2014):

- **Awareness:** Lean awareness and enlightenment campaigns are necessary to sensitize stakeholders within the construction industry of the opportunities and benefits of lean implementation within the industry.
- **Training:** The first step towards the effective implementation of lean construction process is training involves teaching stakeholders and practitioners of the lean tools and techniques available to them.
- **Application:** The implementation of lean techniques within organizations requires high level commitment and involvement of top management.
- **Policy**: The organizational policy typically describes the principles that guide decisions, procedure and it should establish why the organization supports lean principles and tools, and the policy should also show how and what areas should be applied and in what projects.

Table 3-4: Experienced benefits of lean construction:

Benefits	Countries
Improved project delivery methods	Japan, UK, USA
Supporting the development of team work and transfer the responsibility on the supply chain	Finland, Japan, Korea, USA
Continuous improvement within projects	Germany, Singapore, UK
Delivery of products and services that enable clients goals to be met	Korea
Efficient use of resources	Brazil
Delivery of products and services on time and within budget	Finland, Germany, Singapore
Delivery of custom products instantly without waste	Brazil, Finland, UK
Reduction on direct cost and time in transportation and communication	Brazil, UK

Well informed business case design at all project level	USA
Improved quality control and minimization of risks	Korea
Minimization of conflicts that can dramatically change budget and schedule	Germany, Singapore, UK
Improved reliability, accountability, certainty and honesty within the project environment	Germany, Singapore, UK
Reduced owners design related request eliminate wastes	Portugal
Mitigation and reduction of project risk factors	Egypt

Sources: (Emuzu&Ungerer 2014); (Mossman 2009); (Martins and Cachadinha 2013); (Issa 2013)

Lean construction practices have developed quite well, and have lived up to their potential in many different countries around the world, bringing in continuous improvement, inclusive culture and improved levels of certainty in projects. The extent of gains can be seen as influenced by many soft aspects, such as the culture of the site and the organization, planning and engineering expertise available, commitment and support from top management and site management (Raghavan et al. 2014).

The improvements achieved in Nigeria and Brazil (being developing countries) by implementing lean construction, they achieved improvements in reducing the project duration by 31% and 25% respectively (Swefie 2013). Due to several similarities in their situation economically to Sudan, the implementation of lean construction may achieve the same or near results to those achieved in Nigeria and Brazil. Following figure 3-5 shows the improvement accomplished by different countries (developed and developing) due to their implementation of lean construction (Swefie 2013):

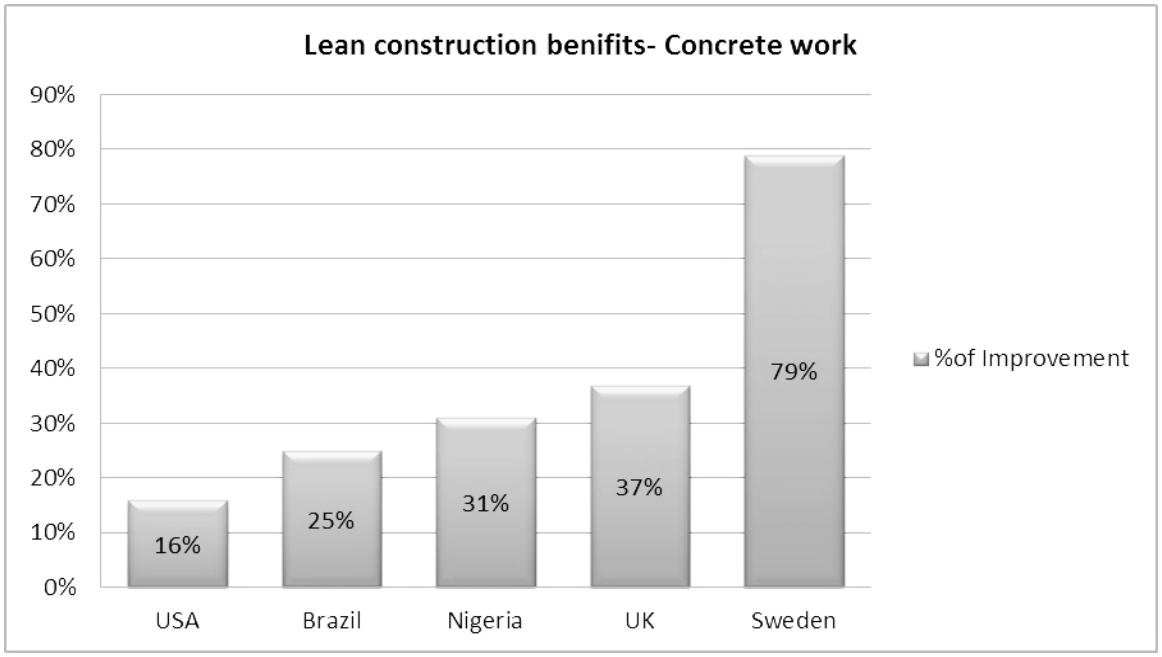

Figure 3-5: Countries using lean construction and realized performance improvement

3-4-2: Comparative Study:

Lean construction has been implementing since the initiation of it in several sectors of construction such as infrastructure, concrete, design, project planning, and other related activities (Swefie 2013). The following some researches results, some of various applications of lean construction in different countries and different trades in construction, and their results which obtained from the applications:

1) Swefie (2013) conducted a study in Egypt to examine the effectiveness of implementing lean thinking on the performance of Egyptian construction projects. The study examined the appreciation and awareness of lean construction within the Egyptian construction industry which concluded that 55% of the respondents are not aware about lean concept but have high potentials to use lean construction to improve the performance of projects. The study also presented some of lean construction tools that are effectively used in some projects in

Egypt. Also the study obtained results from proposed framework that the current state from the three work phases of the project have showed significant improvements in time reduction, process efficiency, and reduction in non-added value activities.

2) Alinaitwe (2009) conducted a study in Uganda, the study aimed to present 31 barriers and their influences on the success of lean construction initiatives. The barriers were ranked according to the ease of overcoming. Lack of buildable designs and a participative management style for the workforce are the most important barriers to successful waste reduction in terms of strength and ease of overcome.
3) Mota et al. (2008) conducted a study in Brazil during the construction phase of a residential project. The project comprised the construction of 18 houses, which managed by a small company. After implementing lean construction the project achieved a more stable workflow and the number of emergency requests decreased dramatically. The project was completed a month in advanced, this decrease in duration represented 12.5% of the project time.
4) Adamu and Howell (2012) conducted a study in Nigeria that aimed to evaluate the effectiveness of implementing the Last Planner System (LPS), by comparing it with the traditional method. The comparison was conducted to measure the time of completing 50 houses. The results obtained were 79 days of constructing the 50 houses, compared with 120 days by using the traditional approach.
5) Simonsson and Emborg (2007) conducted a study in Sweden, aimed to improve the degree of industrialization and productivity when constructing bridges. Throughout the design and planning of construction a bridge project. Intensive contacts between designer, contractor, client and material suppliers were established. The design team concluded that the production time at site reduced up to 20% and

the number of workers reduced by 50%, productivity has improved, structural quality has improved, also waste and cost has reduced.

6) Thomas et al. (2003) conducted a study to investigate the importance of labor flow for improving the workflow management in the construction process by using data from three projects of constructing bridges covering 137workdays. The flexible capacity approach was addressed as a potential area for improving construction performance. The results of this study were, the effective labor flow lead to ineffective flow management, hence, lean improvement initiatives should focus more on workforce management strategies for better labor performance.
7) Ramaswamy and Kalidindi (2009) conducted a study in India to investigate waste in Indian construction industry, focusing mainly on building projects. The wastes identified were quantified in terms of project cost by collecting data through direct observations, records and using tools such as work sampling. The result showed that waste due to non- value added activities by labor and equipment was much higher compared to material waste generated in the sites. The total cost of waste calculated as percentage of project cost, for the items studied, varied from 5.38% to 14.70% among the projects studied.
8) A study was conducted in a design and build firm in USA. The firm was adopted lean construction principles to apply it to its business. By the implementation the firm has gained reduction in times and costs of its projects up to 30%, and improvement in the work flow on sites (Lean Construction Institute 2004).
9) Enshassi & Abu-Zaiter (2014) conducted a study in Palestine aimed to investigate the extent of use of different lean construction tools in construction industry and its impact on safety conditions in construction projects in Gaza Strip. The results of the study were lean construction concepts are unfamiliar for both contractors and consultant but all of the

respondents expressed their admiration for lean construction, All participants agree with implementing lean tools enhance safety conditions in construction projects, and Training will be a key aspect of implementation and success of the lean construction techniques at the site.

10) Ingle & Waghmare (2015) conducted a study in India to highlight the cost and benefits of the potential contribution of lean construction to the achievement of productivity enhancement and waste minimization in construction industry and the extent of implementation of lean construction in India. The results of this study were Proper Training and Implementation of Lean concepts and practices can be successfully adopted in Indian construction projects and has increased keen interest from many organized players in the industry. The enabling factors included commitment of top management and site management, as well as the culture and systems of the organization will be main forces for the success of lean construction in India.

Chapter Four

Data Compilation

Chapter Four
Data Compilation

4-1: Preamble:

The main aim of this chapter is to comprise the method and the design which was used to conduct this study. In order to conduct this study a prescribed methodology was adopted. Concerning data collection the following stages were considered to collect the necessary data.

4-2: Research Population:

The population of this study composed of engineers (civil, Architecture, survey, mechanical, and electrical) that work for contracting, or consultant firms or they represent the owner in the project. The sectors namely public, private and multi sectors were all considered. The population size is according to the records of the Sudanese Council of Engineers.

4-3: Research Sampling:

As most of the local construction companies are located at Khartoum state, and their headquarters work from the capital; engineers in construction firms in Khartoum state were selected as the targeted respondents for investigation. The respondents were selected by a systematic random sampling method which represents the characteristics of the population.

Kombo & Tromp (2006) defined random sampling as the probability whereby people, place or things are randomly selected. The respondents were deemed to be an adequate representation of the population as they varied greatly in the characteristics, but they all work exclusively in the field of construction industry in Khartoum state.

4-4: Research Tool (Questionnaire):

4-4-1: Preamble:

A questionnaire is defined as "a means of eliciting the feelings, beliefs, experiences, perceptions, or attitudes of some sample of individuals"(Key 1997). In this study the questionnaire was used as a survey tool which was assumed to be the most appropriate method to achieve the study's objectives, answering the research question, test hypotheses, and compiling data perfectly. In addition, the questionnaire assumed to get a background to the respondents those who have no previous idea about lean construction.

The questionnaire included multiple choice questions which used widely in the questionnaires. The variety in these questions aims first to meet the research objectives, and to collect all the necessary data that can support the discussion, results, and recommendations of the research.

4-4-2: Questionnaire Design:

The questionnaire was designed in manner that questions could be answered easily by the respondents; so a set of questions were established to elicit the respondents' opinions about the assessment of workflow in their construction sites, and to know their knowledge about lean construction.

The questionnaire was designed and revised, and then was distributed to the respondents, 62 of the questionnaires returned out of 70 and 2 questionnaires has been excluded because they were not fully answered. The total number of the questionnaires to be analyzed was 60 questionnaires which represents 85.7% of the total population size.

The questionnaire was designed basically in English language, then it has been translated into Arabic language; for easement as it is the popular

language (see Appendix II). Some terms were translated into Arabic by providing additional explanations with English term itself; so that can help the respondents to better understand.

The questionnaire comprises of three parts that were designed related to the scope and hypotheses of this study as follow:

- **Part one:** was structured in order to investigate general information and background about the respondents' level of education, specialty, and their experience in the field of construction.
- **Part two:** it was structured to show the assessment of workflow in construction sites, and to show the degree of negative impaction of some factors on workflow of construction processes in Sudan.
- **Part three:** it was structured to examine the respondents' awareness about lean construction, and their opinion about the suitability of lean construction to be implemented in construction industry in Sudan.

4-4-3: Piloting of the Questionnaire:

The reliability and validity of the data collected largely depended on the design of the questions, the structure of the questionnaire and the rigor of the pilot testing (Saunders et al. 2003). In order to avoid measurement errors and to make sure that the data collected was reliable, the questionnaire has been piloted by two professors at Sudan University of Science and Technology, that familiar with construction management.

Those two professors gave their comments on the validity and the suitability of the questions to the research objectives and hypotheses, as well as they have commented on the clarity of the instructions. Their comments and remarks were incorporated in a modified version of the questionnaire.

4-4-4: Distribution of the Questionnaire:

The questionnaires were distributed to the respondents by using hand to hand method. Every respondent has been given enough time to answer the questionnaire's questions. Only questionnaires that were fully completed were accepted, while those partially filled were not considered for the analysis. The valid questionnaire returned for analysis were 60 out of 70 distributed copies.

4-4-5: Data Analysis:

Analysis is an interactive process by which answers are examined to see whether the results are relevant to each research question (Backstorm & Hursh-Cesar, 1981). The collected data was analyzed by using SPSS (Statistical Package for the Social Sciences) version 20, and with assistance of a qualified statistician.

Chapter Five

Data Analysis, Conclusion & Recommendations

Chapter Five

Data Analysis, Conclusion & Recommendations

5-1: Preamble:

This chapter presents the analysis of the data which was collected from the questionnaires, and was analyzed by using SPSS software program. The results were represented by using forms of graphs and tables to show the data that was collected from the questionnaire. After distribution and collection processes the returned questionnaires and the valid ones were 60 questionnaires out of 70 which represented 85.7% that have been analyzed.

Before analyzing the questionnaires which were received to be analyzed, a Cronbach Alpha test was carried out in order to ascertain the reliability of the questionnaire's questions. Cronbach Alpha test is a test of reliability that measures the internal consistency of the questions using the Likert scale (Mohamed 2015). From this test there is an internal consistency because the Cronbach Alpha coefficient of questions is 0.736. Therefore we concluded that our test and questions were reliable.

This chapter also represents a restatement of the research questions, the research methodology used and a summary of the research results, conclusions and discussion. As well as recommendations which was divided into general recommendations, and recommendation for future researches.

5-2: Data Analysis:

Section One: General Information:

Table 5-1: Respondents' Specialties

	Frequency	Percent %
Civil Engineer	46	76.6
Architect	8	13.3
Other	6	10.0
Total	60	100.0

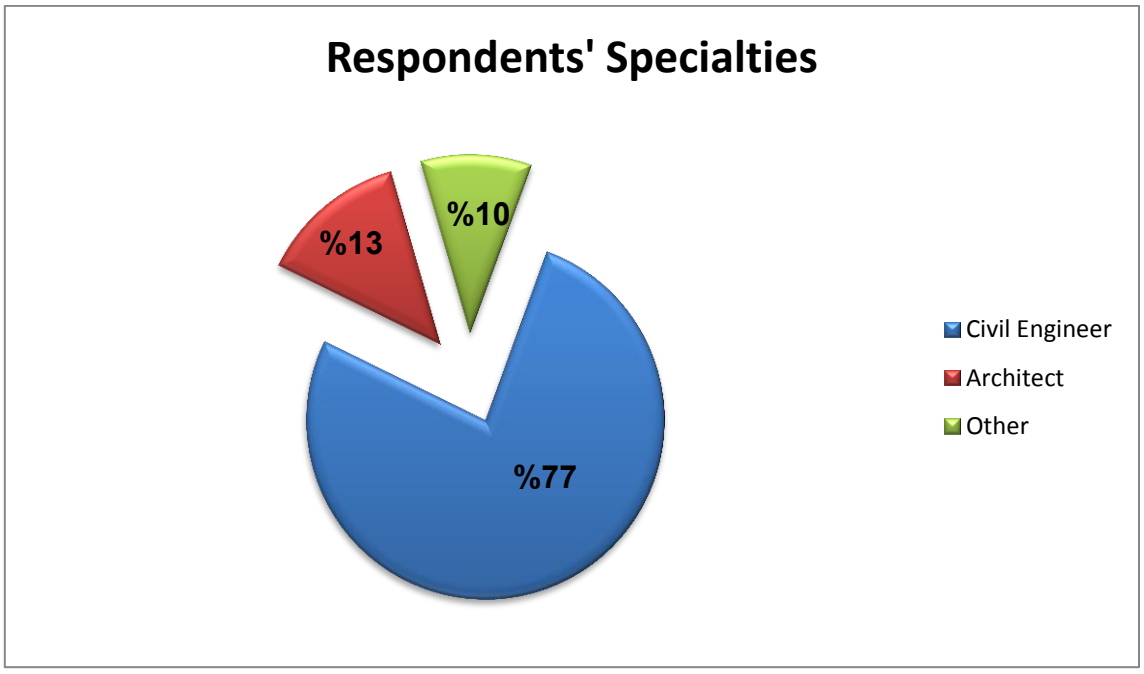

Figure 5-1: Respondents' Specialties

Table 5-1 and figure 5-1 above shows that out of the 60 questionnaires returned, 46 (76.7%) of the respondents were Civil Engineers, 8 (13.3%) were Architects, and 6 (10%) were other specialties (3 (5%) Electrical Engineers, 1 (1.7%) Mechanical Engineer, and 2 (3.3%) were Survey Engineers)

Table 5-2: Education level of the Respondents:

	Frequency	Percent %
Diploma	12	20
Bachelor's Degree	35	58.3
Master's Degree	12	20
Doctorate's	1	1.7
Total	60	100.0

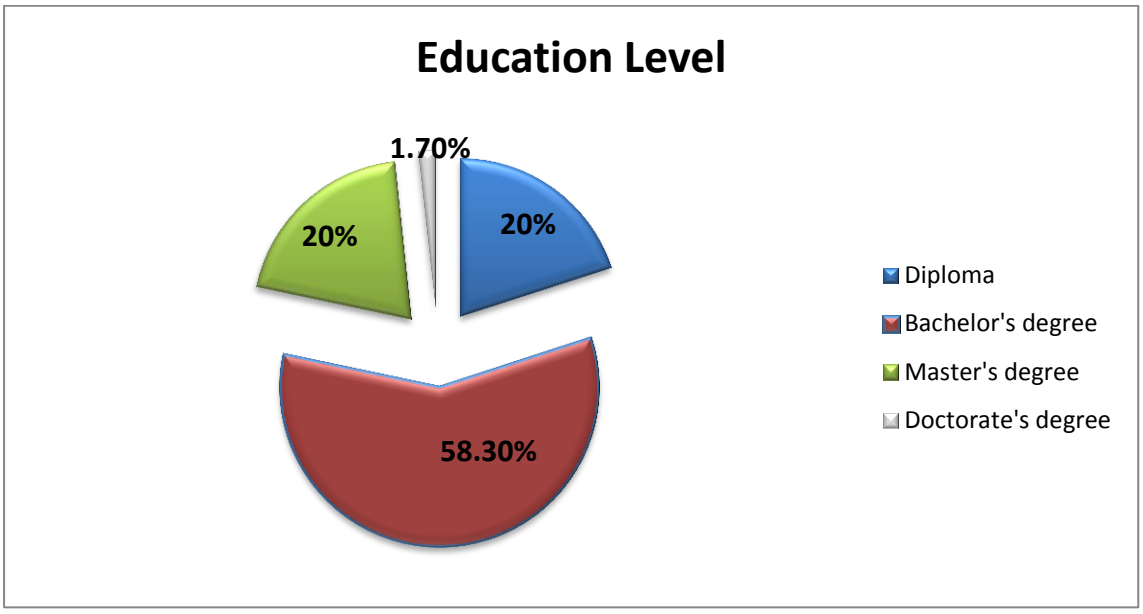

Figure 5-2: Respondents' Level of Education

The above table 5-2 and figure 5-2 present the education level of the respondents that were divided into four levels (Diploma, Bachelor's degree, Master's degree, Doctorate's degree). The respondents' level of education as follow: Diploma 12 (20%), Bachelor's degree 35 (58.3%), Master's degree 12 (20%), and Doctorate's degree 1 (1.7%).

Table 5-3: Respondents Years of Experience:

	Frequency	Percent %
0-5 years	35	58.3
5-10 years	10	16.7
10-15 years	8	13.3
More than 15 years	7	11.7
Total	60	100.0

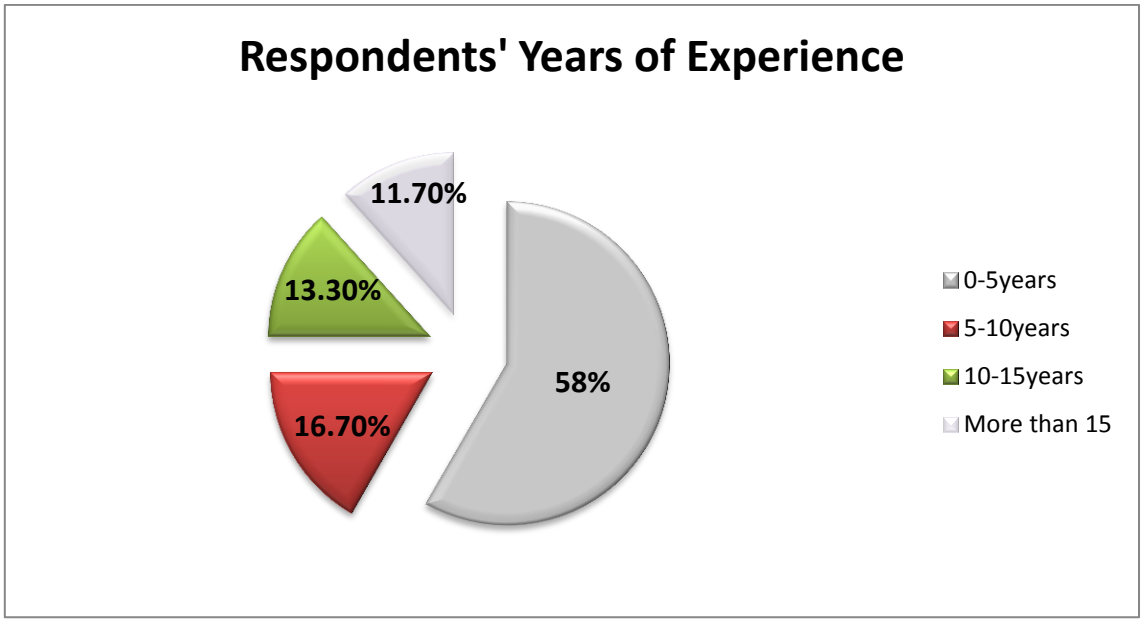

Figure 5-3: Respondents' Years of Experience

Table 5-3 and figure 5-3 present the years of experience of the respondents that were divided into four levels (0-5years, 5-10years, 10-15years, and more than 15years). The respondents' experiences were as follow: 35 (58.3%) have experience from zero to five years, 10 (16.7%) have 5-10years of experience, 8 (13.3%) have 10-15% years of experience, and 7 (11.7%) have more than 15 years of experience in the field of construction projects.

Table 5-4: Sectors Respondents Work for

	Frequency	Percent %
Public Sector	20	33.3
Private Sector	37	61.7
Multi	3	5.0
Total	60	100.0

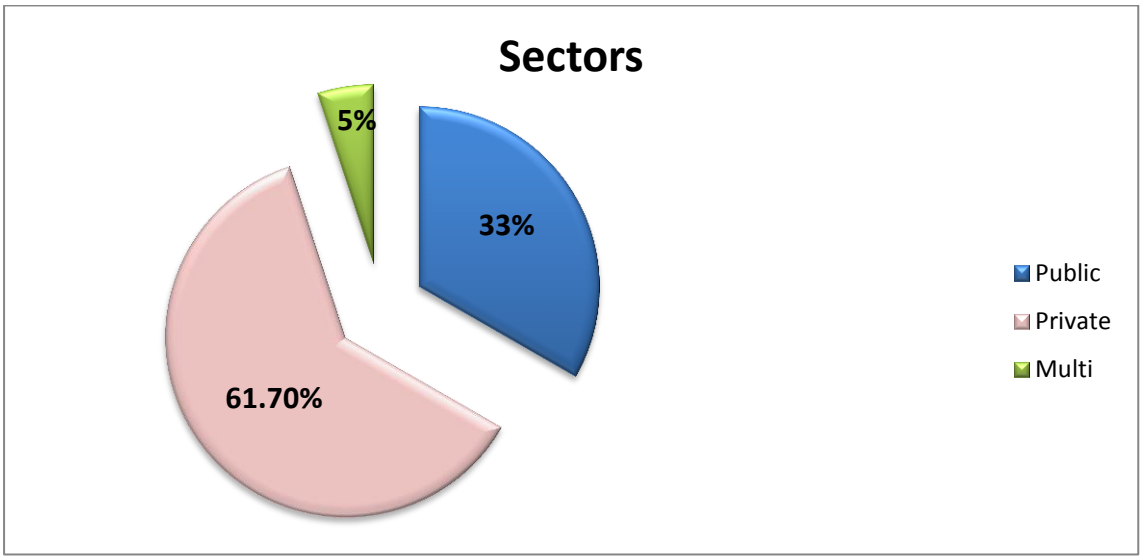

Figure 5-4: Sectors Respondents Work for

Table 5-4 and figure 5-4 above present the sectors that the respondents work for, the results were as follow: 20 (33.3%) of the respondents work for public sector, 37 (61.7%) of the respondents work for private sector, and 3 (5%) of the respondents work for multi sector.

Table 5-5: Role of the Firm in the Project:

	Frequency	Percent %
Contractor	33	55.0
Consultant	19	31.7
Client/Client Representative	8	13.3
Total	60	100.0

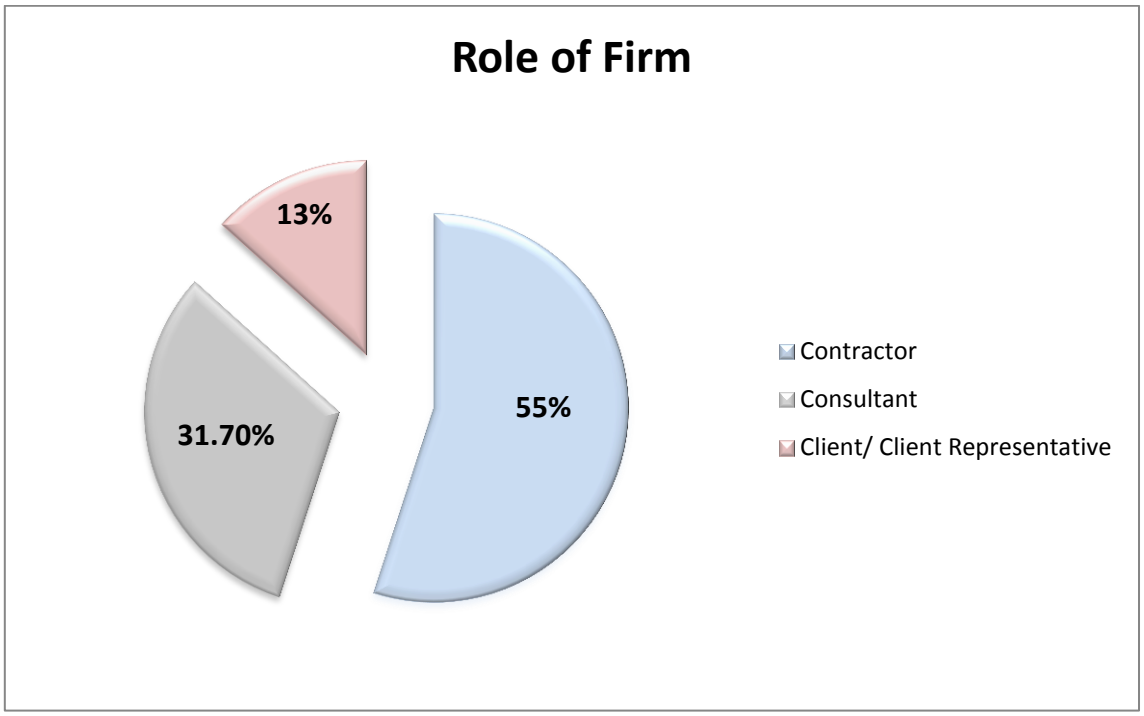

Figure 5-5: Role of the Firm in the Project

Table 5-5 and figure 5-5 above present the role of the firm in the project, the results were as follow: 33 (55%) work as contractor, 19 (31.7%) work as consultant, 8 (13.3%) work as client/ client representative.

Section Two: Factors Affect Workflow of Construction Processes:

Table 5-6: Evaluation of workflow processes in the projects:

	Frequency	Percent%
Weak	5	8.3
Good	33	55.0
Very Good	17	28.3
Excellent	5	8.3
Total	**60**	**100.0**

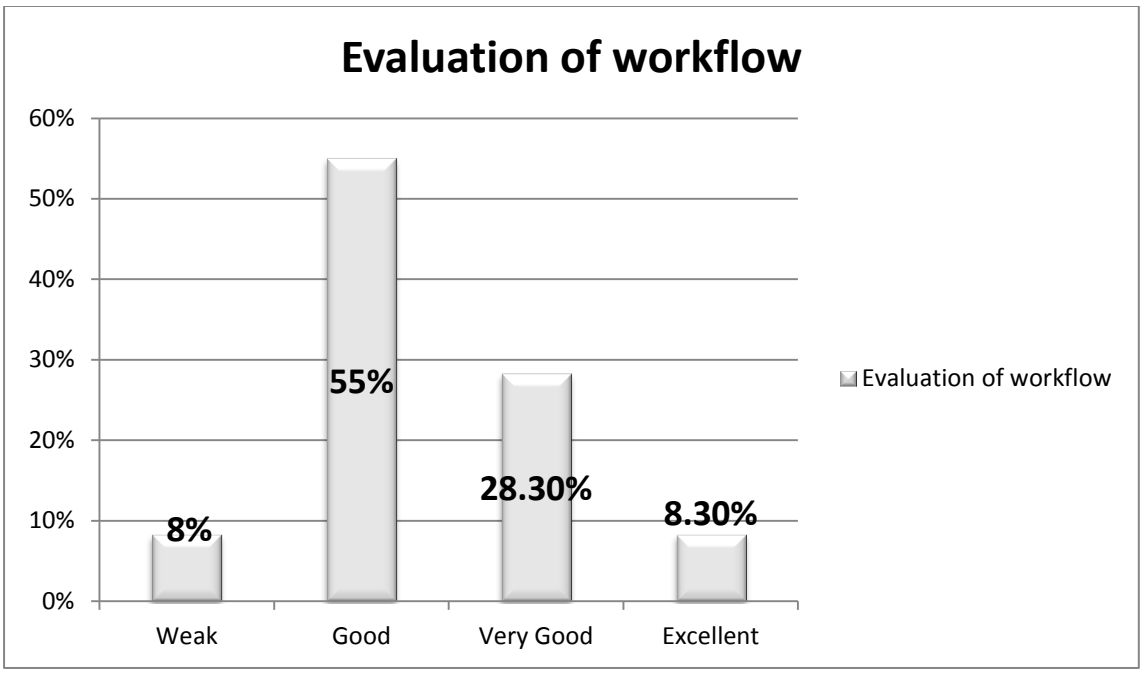

Figure 5-6: Evaluation of Workflow in the construction project

Table and figure 5-6 above present the evaluation of the respondents on the workflow in the construction sites that they work at. Their responds were as follow: 5 (8.3%) of the respondents assessed the workflow in their work

sites as weak, 33(55%) assessed the workflow as good, 17 (28.3%) assessed the workflow as very good and 5 (8.3%) assessed the workflow as excellent.

Table 5-7: To What Degree the Workflow should Improve

	Frequency	Percent %
Strongly Disagree	0	0.0
Disagree	4	6.7
Neutral	6	10.0
Agree	37	61.7
Strongly Agree	13	21.7
Total	**60**	**100.0**

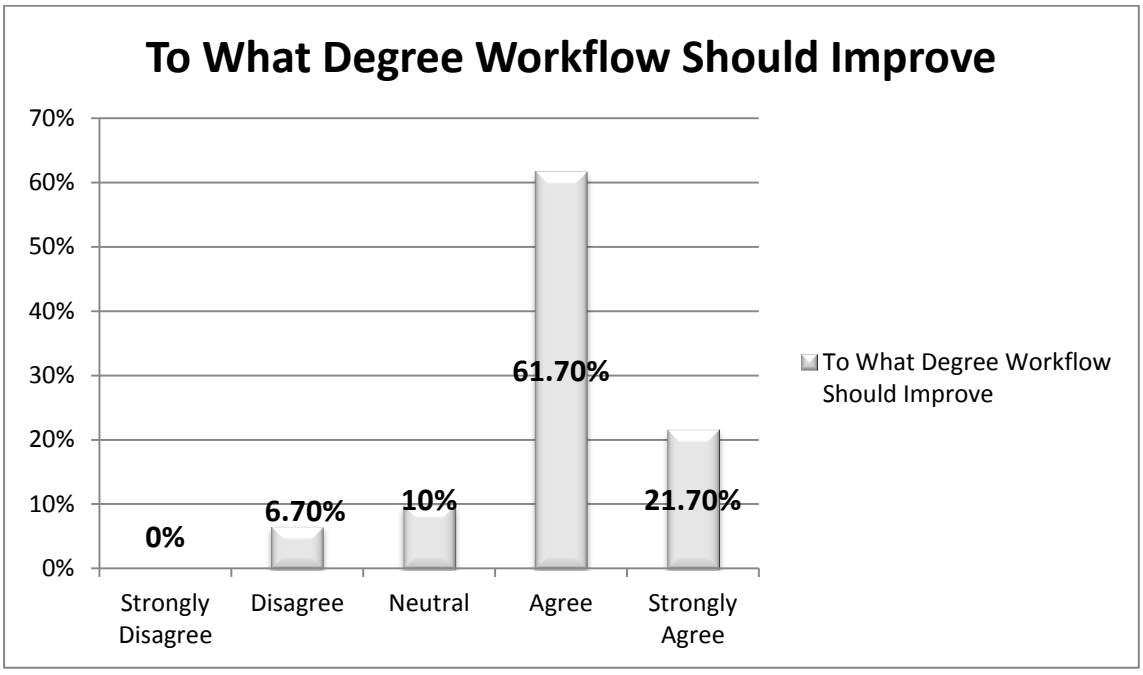

Figure 5-7: To what degree the workflow should improve

Table and figure 5-7 above present the opinions of the respondents whether they agree that the workflow in their work sites need improvement or not. The results were as follow: 4 (6.7%) were disagree, 6 (10%) were neutral, 37 (61.7%) were agree, and 13 (21.7%) were strongly agree.

Table 5-8: Factors Affect Workflow of Construction Processes:

Factors	Disagree	Neutral	Agree
Delays in Financing the Project	8 (13.3%)	18 (30%)	34(56.7%)
Change Orders/Specifications during construction	4 (6.7%)	33(55%)	23 (38.3%)
Improper Construction Methods	13 (21.7%)	31 (51.7%)	16 (26.7%)
Mistakes in Design Documents	4 (6.7%)	28 (46.7%)	28 (46.7%)
Unqualified Labors	5 (8.3%)	28 (46.7%)	27 (45%)
Unorganized Worksite	6 (10%)	30 (50%)	24 (40%)
Delays in Material Delivery	7 (11.7%)	21 (35%)	32 (53.3%)
Inadequate Details of Drawings	4 (6.7%)	30 (50%)	26 (43.3%)
Improper Cost Estimation	13 (21.7%)	22 (36.7%)	25 (41.7%)
Inefficient Communication between project Stakeholders	5 (8.3%)	36 (60%)	19 (31.7%)
Total	**60 (100%)**	**60 (100%)**	**60 (100%)**

Table 5-8 above illustrates the degree of negative impact of ten factors on the workflow of construction processes. The choices were disagree, neutral, and agree.

Table 5-9: Are there any procedures follow to prevent stoppages

	Frequency	**Percent %**
Strongly Disagree	1	1.7%
Disagree	8	13.3%
Neutral	12	20.0%
Agree	31	51.7%
Strongly Agree	8	13.3%
Total	**60**	**100.0%**

Table 5-9 above presents the responds about the question that if there any processes followed to prevent stoppages can occur during construction. The choices to respond this question varied from strongly disagree to strongly agree. The results were as follow: 1 (1.7%) were strongly disagree, 8 (13.3%) were disagree, 12 (20%) were neutral, 31 (51.7%) were agree, and 8 (13.3%) were strongly agree.

Section Three: The Extent of Knowing Lean Construction:

Table 5-10: Respondents' Awareness about Lean Construction

	Frequency	Percent %
Very Low	44	73
Low	14	23.3
Average	2	3.3
Good	0	0.0
Very Good	0	0.0
Excellant	0	0.0
Total	60	100.0

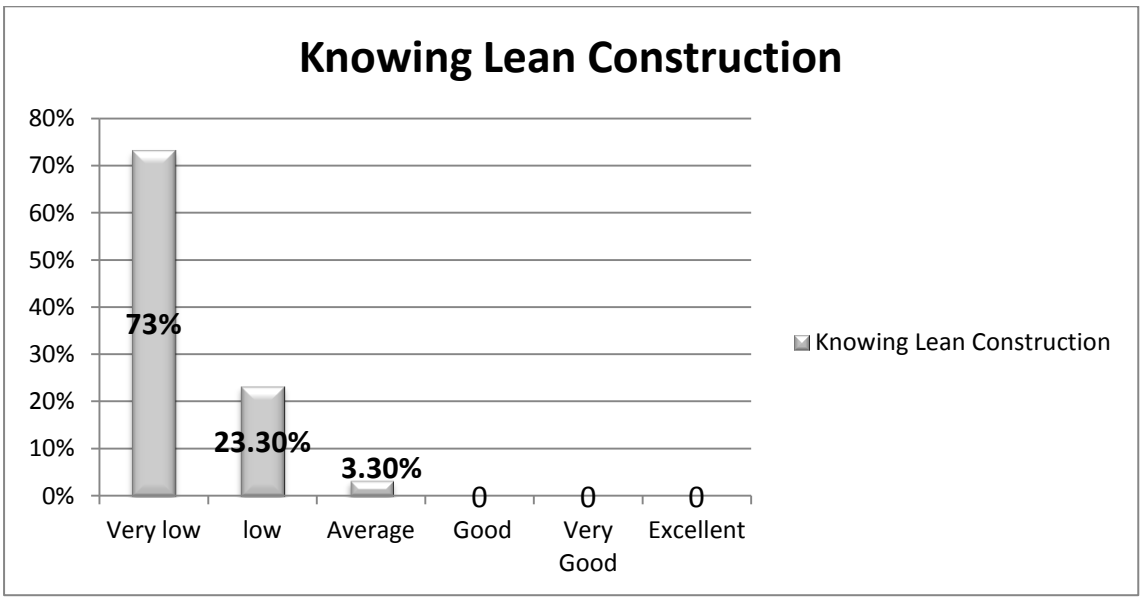

Figure 5-8: Respondents' Awareness about Lean Construction

The above bar chart presents the extent of respondents' knowledge about lean construction, the respondents answers were as follow: 44 (73.3%) are not aware about lean construction, 14 (23.3%) have little knowledge about lean construction and 2 (3.3%) have good knowledge about lean construction.

Table 5-11: Reason behind Non-application of Lean Construction in Sudan

	Frequency	**Percent %**
Unavailable researches about lean construction in Sudan	15	25.0%
Resistant to change	10	16.7%
Upper-level management satisfied with status que	8	13.3%
Ignorance of the concept	27	45.0%
Total	60	100.0%

The above table presents the respondents' opinions about the reason behind non-application of lean construction in Sudan so far. 15 (25%) of the respondents suggested that the reason is unavailable researches about lean construction in Sudan, 10 (16.7%) of the respondents went with the choice resistant to change, 8 (13.3%) of the respondents went with the choice that upper-level management satisfied with status-que, and 27 (45%) of the respondents did choose the choice that ignorance of the concept is the reason.

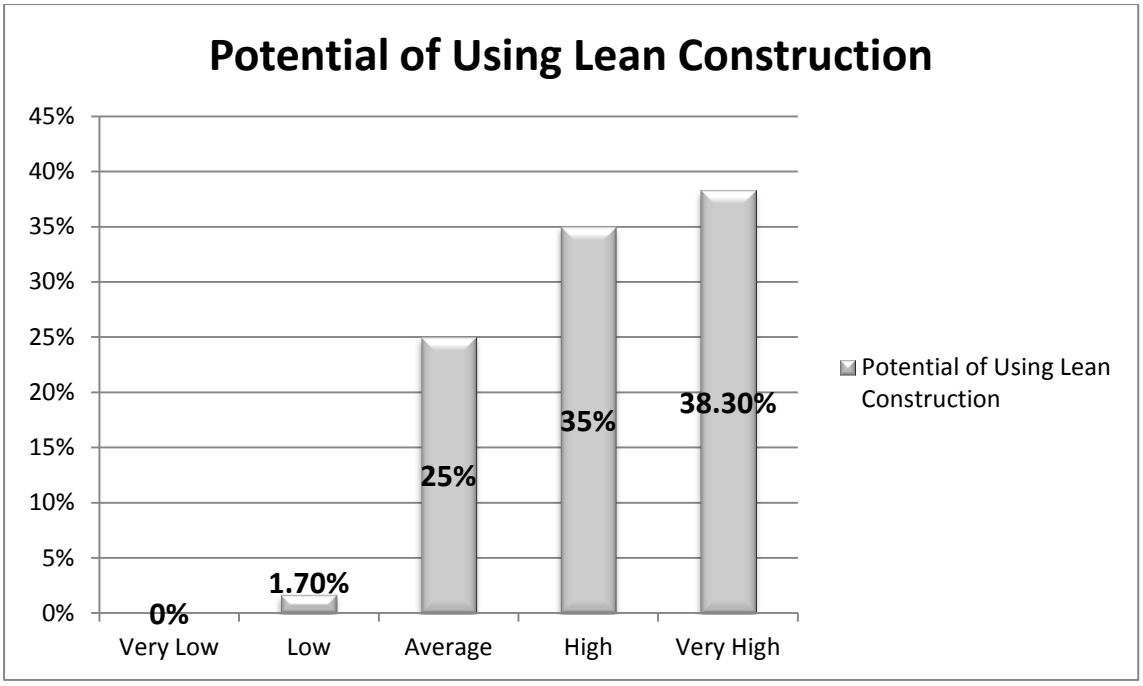

Figure 5-9: Potential of working in a lean construction site

The above bar chart presents the responds about the question: To what degree you have potential to work in a construction site uses lean construction tools and techniques? The responds were 1 (1.7%) of the respondents had low potential, 15 (25%) of the respondents had average potential, 21 (35%) of the respondents had high potential, and 23 (38.3%) of the respondents had very high potential.

Table 5-11: Challenges will face the implementation of lean construction in Sudan

	Frequency	Percent %
Difficulties in understanding the concept of lean construction	21	35
Uncertainty of the positive results can be achieved due to applying lean construction	9	15
Upper-level management will resist changing the current situation	21	35
The project stakeholders will resist to adopt the concept of lean construction	9	15
Total	**60**	**100**

Table 5-11 above presents the results of the respondents' opinions about the major challenge will face the implementation of lean construction in Sudan. Their responds were as follow: 21 (35%) of the respondents saw that difficulties in understanding the concept of lean construction will be the major obstacle for the implementation, 9 (15%) of the respondents suggested that uncertainty of the results can be obtained from the implementation will be the challenge, 21 (35%) went with the choice that top-level management will resist to change the situation, and 9 (15%) saw that the project stakeholder will resist to adopt the concept.

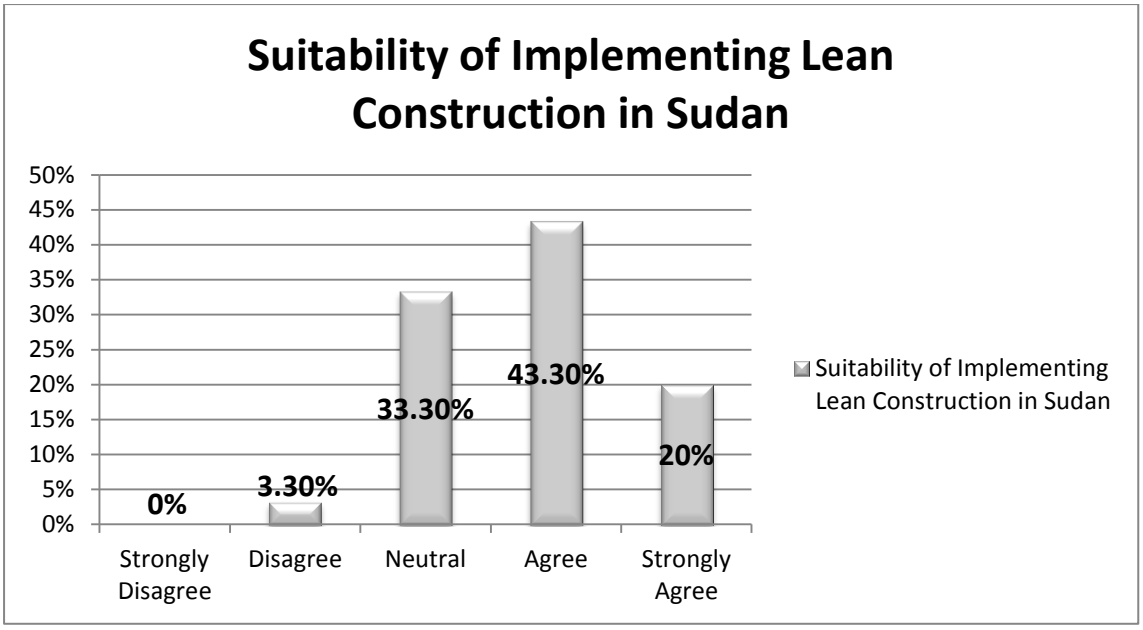

Figure 5-10: Suitability of Lean Construction to Sudan

The above bar chart presents the responds of the question: Do you agree that lean construction suitable to be implemented in Sudan? The responds were 2 (3.3%) were disagree, 20 (33.3%) were neutral, 26 (43.3%) were agree, and 12 (20%) were strongly agree.

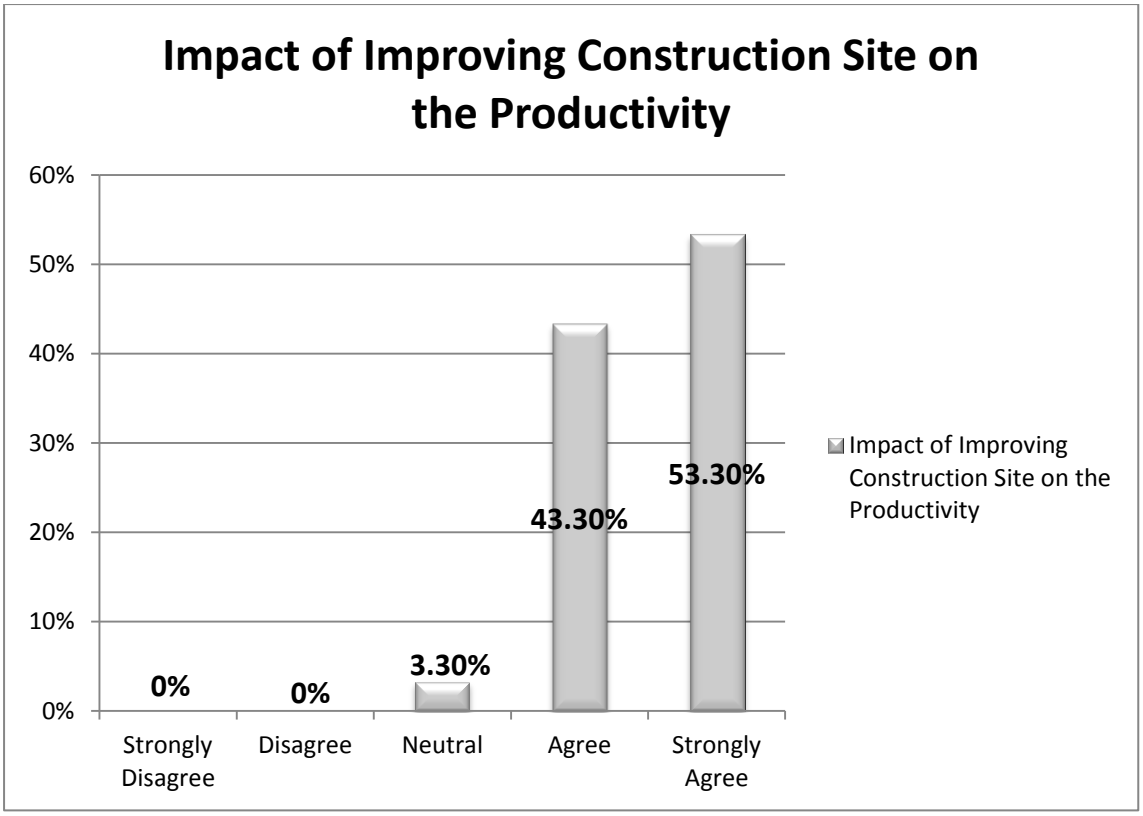

Figure 5-11: Impact of Improving Construction Site on the Productivity

The above bar chart presents the responds of the question : Do you thing that improving work condition in construction site makes improve in productivity? The answers were as follow: 2 (3.3%) were neutral, 26 (43.3%) were agree, and 32 (53.3%) were strongly agree.

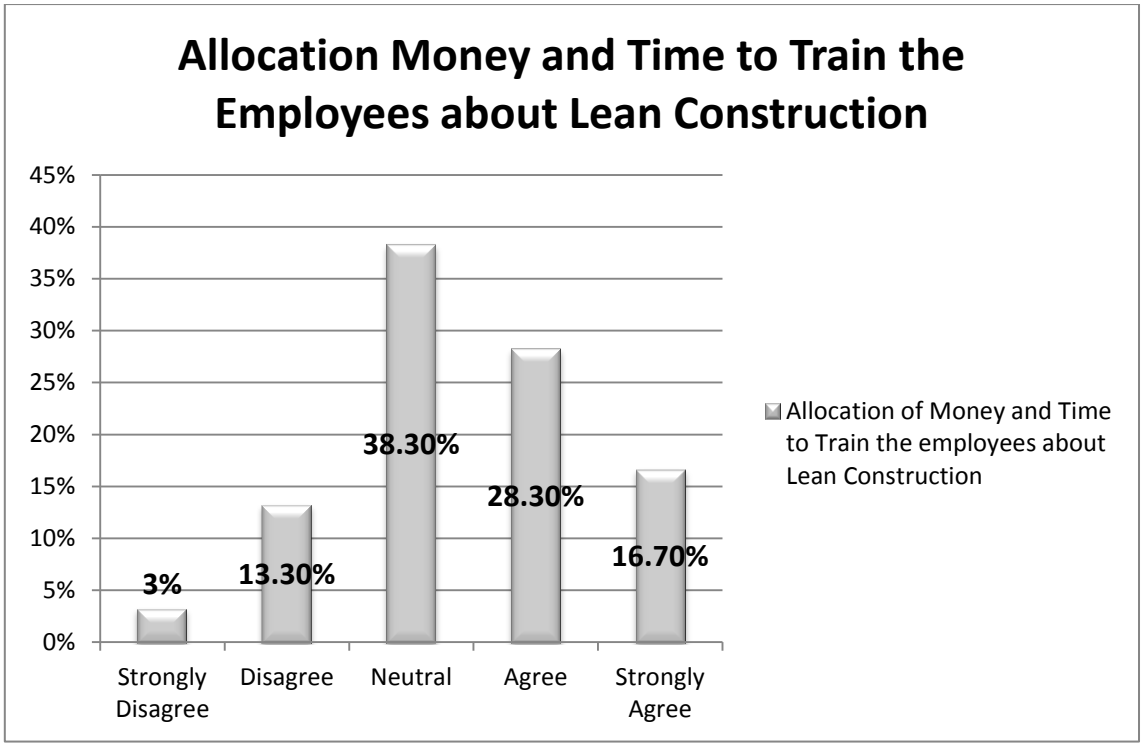

Figure 5-12: Allocation Money and Time to Train the Employees about Lean Construction

The above bar chart presents the results of the responds of the question: Do you think that the firm you work for will allocate time and money for the activities of training to enrich their employees about lean construction? The results as follow: 2 (3.3%) were strongly disagree, 8 (13.3%) were disagree, 23 (38.3%) were neutral, 17 (28.3%) were agree, and 10 (16.7%) were strongly agree.

Table 5-13: To what degree do you have knowledge about lean construction?* education level cross tabulation

		What is your education level				
To what degree do you have knowledge about lean construction		Diploma	Bachelor's Degree	Master's Degree	Doctorate's Degree	Total
	Very Low	10	26	7	1	44
	Low	2	7	5	0	14
	Average	0	2	0	0	2
	Total	12	35	12	1	60

Table 5-13 presents cross tabulation between the question: To what degree do you have knowledge about lean construction? And the question: What is your education level? From the analysis P value was 0.271 which is greater than 0.05, that means statistically not significant. That means there is no relation between the degree of knowing lean construction and the education level.

Table 5-14: To what degree do you have knowledge about lean construction?*Years of experience cross tabulation

		How many years have you deal with construction field				
To what degree do you have knowledge about lean construction		0-5 years	5-10 years	10-15 years	More than 15	Total
	Very Low	27	7	6	4	44
	Low	8	3	2	1	14
	Average	0	0	0	2	2
	Total	27	10	8	7	60

Table 5-14 presents cross tabulation between the question: To what degree do you have knowledge about lean construction? And the question: How many years have you deal with construction projects? From the analysis P value was 0.515 which is greater than 0.05 that means statistically not significant. There is no relation between the two questions.

Table 5-15: To what degree do you have knowledge about lean construction?*Potential of use lean construction cross tabulation

		To what degree do you have potential to work in a lean construction site				
To what degree do you have knowledge about lean construction		Low	Average	High	Very High	Total
	Very Low	1	11	15	17	44
	Low	0	2	6	6	14
	Average	0	2	0	0	2
	Total	1	15	21	23	60

Table 5-15 presents cross tabulation between the question: To what degree do you have knowledge about lean construction? And the question: To what degree do you have potential to work in a construction site uses lean construction principles and tools? From the analysis P value was 0.349 which is greater than 0.05 that means statistically not significant. There is no relation between the two questions.

5-3: Results Interpretation:

The study concluded that the majority of the engineers who work in construction projects in Sudan are civil engineers that represent 77% of the total engineers, and the architects are 13% of the total engineers. The study ended that more than 58% of the engineers who work in construction projects hold bachelor's degree. Junior engineers (with experience less than 5 years) represent 58% of the total engineers that work in construction projects in Sudan. From the survey more than 61% of the firms work in construction projects in Sudan are private firms.

From the results of this study the evaluation of workflow in construction projects, 61.7% of the respondents see that the workflow should be improved and that indicates there is necessary to improve the workflow of the construction projects in Sudan. The most factors affect the workflow process in Sudan are the delays both in financing the project and in material delivery. A study was conducted in Ghana by Ayarkwa et al. (2015)concluded that the delays in materials delivery, inefficient use of quality standards, and lack of long term relationship with suppliers are the factors that affect the workflow in Ghanaian construction sites.

The study concluded that more than 73% of the engineers in construction projects in Sudan have no knowledge about lean construction, and about 23% have just little knowledge about lean construction, and that is an indication of the necessity of boosting the engineers' awareness about lean construction. A study was conducted in Egypt by Swefie (2013) found that 55% of the respondents are not aware about lean construction, 45% of the respondents have little aware about it. Another study was conducted by Enshassi & Abu Zaiter (2014) in Palestine found that 65% of the respondents have no knowledge about lean construction. That indicates that lean

construction is not known in the most of the nearby countries, not only in Sudan.

More than 73% of the respondents have high potential to work in a lean construction site. Swefie (2013) found that 70% of the respondents in Egypt have high potential of using lean construction. The study also ended that the main two reasons behind non-application of lean construction in Sudan so far are the ignorance of the concept, and the unavailability of researches in Sudan about lean construction. That indicates that the implementation can be easy if the engineers have enough idea about the concept.

The study found that the main two challenges can face the implementation of lean construction are the resistance of upper-level management to change the current situation, and the difficulties in understanding the concept of lean construction. This results are completely agree with a study was conducted in Malaysia found that the main two factors will restrict the implementation of lean construction are the lack of attentiveness and commitment from the top management, and the difficulties in understanding lean construction's concept (Abdullah et al. 2015). Enshassi & Abu Zaiter (2014) found that the challenges of implementing lean construction in Palestine are lack of budget for training, and weakness in the learning environment in construction projects. Another study conducted in India concluded that commitment of top management and site management, as well as the culture and systems of the organization will be main forces for the success of lean construction in India (Ingle &Waghmare 2015).

The study found that more than 43% of the respondents are agree that lean construction is suitable to implement in Sudan, and 20% of the respondents are strongly agree. Enshassi & Abu Zaiter (2014) found that 70%

of the respondents agree that lean construction is possible and suitable to implement in Palestine.

The study also found that more than 96% of the respondents agree that the clean and organized construction site make enhancement in the productivity, this result means that implementation of lean construction will be in a positive impact on the Sudan's construction projects. The study also concluded that more than 38% of the respondents are neutral whether the firms their work for will allocate money and time to train their employees about lean construction or not. That means a number of the respondents cannot expect the decision of their organizations, and that indicates of the lack of relation between the employees and their management.

5-4: Conclusion:

The introduction and implementation of lean principles has had a great effect on the construction industry on the global scale (developing and developed countries) by enhancing workflow and the performance of people in construction which has been mentioned in the literature review of this study. After the results discussion and interpretation were conducted, the study concluded the following:

- The main two factors affect workflow in construction sites are the delays in financing the project and material delivery.
- Workflow in construction sites in Sudan should be improved.
- Lean construction concepts are unfamiliar among the engineers who work in Sudan's construction industry.
- The majority of respondents expressed their admiration for working in a lean construction site.
- The reason behind non-application of lean construction in Sudan is the ignorance of lean construction concepts and unavailability of researches in this field.
- The major barrier will face the implementation of lean construction is the resistance of the top management to adopt this concept and make steps toward applying lean construction and change the current situation.

5-5: Recommendations:

- Ensuring that the top management actively adopts the culture of training and developing their staff about new managerial tools and techniques such as lean construction.

- Make steps toward enhancing workflow of Sudanese construction projects through deep study of the factors affect the workflow negatively to overcome all stoppages causes.
- Hiring lean construction experts to play the role of directors to help actors who involved in the project establish strong awareness to implement.
- It is very essential to hold seminars in the universities and institutes, because knowledge of new topics often comes from universities, and other academic organizations.
- It is very essential to encourage the councils of engineers and the associations to hold lectures and training courses to enrich the engineers about lean construction.
- It is important to train the organizations and make sure that everybody thoroughly understands lean construction well to ease the implementation of the concept.

5-6: Future Researches:

- Further research could take what is known about lean construction so far and continue to evaluate its potential in the construction industry.
- Develop a framework to achieve real results from the application of the concept of lean construction.
- Implementing a lean construction tool by generation of a model and assess its impact on the project performance.
- A comparative study can be undertaken between private sector and public sector to show the degree of awareness and the potential of applying lean construction.
- A study could be undertaken by concentration on consultants and show their idea and awareness about lean construction, because of their basic role in applying any new management concept.

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Appendices

Appendix I: Questionnaire- English Version

Appendix II: Questionnaire- Arabic Version

Sudan University of Science and Technology

Master of Science in Civil Engineering

(Construction Engineering)

Part 1: General Information:

Please choose the appropriate choice by putting (√)

(1)What is your specialty?

□ Civil Engineer □ Architect □ Other……..

(2)What is your education level?

□Diploma □ Bachelor's Degree □ Master's Degree □Doctorate's Degree

(3)How many years have you dealing with construction projects?

□0-5 □ 5-10 □10-15 □More than 15

(4)What is the sector type you work for?

□Public Sector □Private Sector □Multi

(5) What your firm's role in the project?

□Contractor □Consultant □Client/ Client Representative

Part II: Factors Affecting Construction Process Flow:

(1)What your evaluation to the flow of work in the construction site you work in?

□Weak □Good □ Very Good □ Excellent

(2)To what degree do you think that the flow of work in your construction site should be improved?

□Strongly Disagree □Disagree □Neutral □Agree □Strongly Agree

(3) To what degree do you think that the following factors can make negative impact to the flow of construction process?

Factors	Disagree	Agree	Strongly Agree
1.Delays in financing the project by the owner			
2.Change orders/specifications by the owner during construction			
3. Improper construction methods			
4. Mistakes in design documents			
5.Unqualified labors			
6. unorganized workplace			
7. Delays in material delivery			
8. Inadequate details of drawings			
9. Improper cost estimation			
10. Inefficient communication with the higher management			

(4) In the construction site you work in are there any procedures followed to prevent stoppages in work?

☐Strongly Disagree □Disagree □Neutral □Agree □Strongly Agree

Part III: Extent of Respondents' Awareness of Lean

Lean construction is an adaptation of lean production techniques which has been developed in Toyota motor company. Lean construction is to manage and improve the construction process to deliver what the customer needs perfectly.

Lean construction is a continuous process that applies through design, planning, and construction. It is an integrated process in which clients , designers, contractors, suppliers, etc. must be committed to working together . The aim of lean construction is to improve communication, eliminating waste and errors, and improving the work site environment.

(1) To what degree do you have knowledge about lean construction?

□Very Low □Low □Average □High □Very High

(2)What do you think the reason behind of non-application of lean construction in Sudan?

□Unavailable researches in lean construction in Sudan

□Resistant to change

□Upper-level management satisfied with Status Que

□Ignorance of the concept

(3)To what degree do you have potential to work in a construction site uses lean construction principles and tools?

□Very Low □Low □Average □High □Very High

(4) In your opinion what the major challenge will face implementation lean construction?

□Difficulties in understanding the concept of lean construction

□Uncertainty of the positive results can be obtained from the implementation

□Upper-level management will resist changing the current situation

□The project stakeholders resist to adopt new managerial techniques

(5)To what degree do you think that lean construction suitable to be implemented in Sudan?

□Strongly Disagree □Disagree □Neutral □Agree □Strongly Agree

(6)Do you agree that improving work condition in construction site makes improving in the productivity?

□Strongly Disagree □ Disagree □Neutral □Agree □Strongly Agree

(7)Do you think that the firm you work for can allocate time and money for the activities of training to enrich employees about lean construction?

□Strongly Disagree □Disagree □Neutral □Agree □Strongly Agree

Thanks for your corporation

جامعة السودان للعلوم و التكنلــوجيا

- هذا الاستبيان بغرض الحصول على درجة الماجستير في الهندسة المدنية (هندسة التشييد) – كل المعلومات لغرض الدراسة فقط.

-عنوان الرسالة: Applying Lean Construction to Construction Industry in Sudan

- أرجــو التكـــــرم بالإجابة على أسئلة هذا الإستبيان.

الجزء الأول: معلومـــات عامـــة:

من فضلك ضع علامة (√) أمام الإختيار المناسب:

(1)مـــاهو مجال تخصصك؟

☐مهندس مدني ☐مهندس معماري ☐آخر.....

(2)ما هو مستواك التعليمي؟

☐دبلــوم ☐بكـالريوس ☐ماجستــير ☐دكتـــوراة

(3)كـــم عدد سنوات خبرتك في مجال مشروعات التشييد؟

☐0-5 أعوام ☐5-10أعوام ☐10-15عام ☐أكثر من 15 عام

(4)ماهو القطاع الذي تعمل بـــه؟

☐قطاع حكومي ☐قطاع خاص ☐آخــر.....

(5) ما هو دور الجهة التي تعمل بها في المشروع؟

☐مـقـــاول ☐إستشـــــاري ☐مـــالك / ممثل للمـــالك

الجزء الثاني: العوامل المؤثرة على سريان عملية التشييد(عدم حدوث توقفات خلال عملية التشييد)

(1)ماهو تقييمك لسريان عملية التشييد في الموقع الذي تعمل به؟

☐ضعيف ☐جيـــد ☐جيــد جـداً ☐مـمتاز

(2)إلى أي درجة تعتقد أن سريان عملية التشييد تحتاج إلى تطوير في الموقع الذي تعمل به؟

☐لا أوافق بشدة ☐لا أوافق ☐محايد ☐أوافق ☐أوافق بشدة

(3)إلى أي مـــدى تعتقد أن كل عامل من العوامل التالية يمكن ان يؤثر سلباً على سريان عملية التشييد؟

العـــوامل	لا أوافق	أوافق	أوافق بشدة
1.التأخيرات في سداد الدفعيات			
2.تغيير المواصفات أثناء عملية التشييد			
3.إستخدام تقنيات قديمة في عملية التشييد			
4.الأخطـــاء في التصميم			
5.الرسومات غيرالمكتملة اوغير الصحيحة			
6. موقع التشييد غير المنظـــم			
7.التأخير في توريد المواد للموقع			
8. العمالـــة غير المؤهلـــة			
9.التقدير غير الصحيح في تكلفة المشروع			
10.ضعف الاتصال بين الاطراف المختلفة في المشروع			

(4)هل يتم إتباع أي إجراءات في الموقع لتلافي حدوث توقفات في سير عملية التشييد؟

☐لا أوافق بشدة ☐لا أوافق ☐محايد ☐أوافق ☐أوافق بشدة

الجزء الثالث: مدى المعرفة بالتشييد الرشيق(Lean Construction):

التشييد الرشيق (Lean Construction) هو عبارة عن اقتباس لمفاهيم التصنيع(الانتاج) الرشيق (Lean Production)، و الذي تم اقتباسه في الاساس من النظام المطبق في شركة تايوتا اليابانية للسيارات. التشييد الرشيق(Lean Construction) يطبق لإدارة و تطوير مراحل عملية التشييد لإنهاء المشروع بصورة مثالية و الوصول للرضا التام للعميل.

التشييد الرشيق(Lean Construction) عبارة عن عملية مستمرة تتطبق في كافة مراحل عملية التشييد بدأ من التصميم، التشييد الرشيق(Lean Construction) عبارة عن عملية مستمرة تتطبق في كافة مراحل عملية التشييد بدأ من التصميم، التخطيط ،توريد المواد، ادارة الموقع و طريقة التنفيذ. و هو ايضاً عبارة عن عمليات متداخلة تلزم كافة المشاركين في المشروع (المالك، المصمم، المورد، المهندس.....الخ) للعمل بصورة مترابطة مع بعض . يهدف التشييد الرشيق بصورة عامة لتحسين موقع العمل، زيادة الانتاجية، و التخلص من كل انواع الهدر في الموارد، الوقت و الجهد.

(1) ما هو مدى معرفتك بالتشييد الرشيق و تقنياتـــه؟

☐ضعيف جداً ☐ضعيف ☐ جيد ☐جيد جداً ☐ممتاز

(2) برأيك ما هو السبب في عدم تطبيق التشييد الرشيق(Lean Construction)في السودان حتى الآن؟

☐عدم وجود بحوث في هذا المجال في السودان ☐عـــــدم الرغبة في التغيير

☐رضـــا الادراة العليا بالوضع الراهن ☐عدم المعرفة بالتشييد الرشيق

(3)إلى أي درجة لديك رغبـــة في العمل في موقع يطبق أدوات و مفاهيم التشييد الرشيق(Lean Construction)؟

☐منخفض جداً ☐منخفض ☐متوسط ☐عالي ☐عالي جداً

(4) برأيك ما العقبة الرئيسية التي يمكن أن تواجه تطبيق التشييد الرشيق في السودان؟

☐ صعوبات في فهم و استيعاب مفاهيم التشييد الرشيق

☐عدم رغبة الإدارة العليا في تغيير الوضع الراهن

☐عدم الثقة في النتائج التي يمكن أن تتحقق نتيجة للتطبيق

☐عدم حماس المهندسين و العاملين في المشروع في بذل جهد لتعلم أدوات التشييد الرشيق

(5) إلى أي درجة تعتقد أن التشييد الرشيق (Lean Construction)ملائم للتطبيق في السودان؟

☐لا أوافق بشدة ☐لا اوافق ☐محايد ☐اوافق ☐اوافق بشدة

(6) هل تعتقد بأن تحسين موقع التشييد يساهم في زيادة الإنتاجية؟

☐لا أوافق بشدة ☐لا أوافق ☐محايد ☐أوافق ☐أوافق بشدة

(7)هل تعتقد أن المؤسسة التي تعمل بها يمكن أن تخصص وقت و مال لتعليم العاملين بها مفاهيم التشييد الرشيق؟

☐لا أوافق بشدة ☐لا أوافق ☐محايد ☐أوافق ☐أوافق بشدة

شكـــراً لحســـن تعـــاونكم