Lean Construction as an innovative approach for minimising risks in Mega-Construction projects in the Kingdom of Saudi Arabia

by

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I declare that while registered as a candidate for the research degree, I have not been a registered candidate or enrolled student for another award of the University or other academic or professional institution.

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ABSTRACT

The past two decades have witnessed a rapid increase in construction projects within developing countries in the Middle Eastern Gulf region. This coincides with the governments' announcements regarding substantially increased spending on the improvement of infrastructure. Despite this increase, construction companies still face many challenges, including completing projects on time and within budgets, thus promoting a negative image of the industry in that region. The negative impact of the aforementioned challenges has been confirmed through (1) data collected from documents concerning completed construction projects in which the researcher has been professionally involved; (2) the researcher's experience in the field of construction project management in the Middle East and risk management in particular; and (3) extensive study of the literature in this domain. This has identified a set of the most common problems associated with construction projects in one of the Gulf Area countries - the Kingdom of Saudi Arabia (KSA) - and has led to them being categorised into three individual risk types, namely Construction Waste; Delayed Schedule; and Project Over Budget. Following a detailed identification and assessment of commonly implemented strategies and a study of the Lean Construction method as the "new" strategy introduced recently to the field, it is proposed that the Lean Construction method could lead to better results in solving these problems.

To that end, the objectives of this study are (1) to develop a Lean Construction framework; and (2) to create a Lean Construction Assessment Tool. To achieve these objectives, the research work (a) investigates the linkages between Lean and risk management; (b) reviews the concept of Lean and its application to the construction industry in Saudi Arabia (c) analyses the barriers and success factors; and (d) identifies the benefits of Lean Construction within construction organisations in Saudi Arabia.

To that end, the adopted research methodology involves both quantitative and qualitative mechanisms. The implementation plan is fourfold, namely (1) undertaking a comprehensive literature review of the construction domain; (2) implementing a survey instrument among KSA construction professionals concerning the Lean Construction method to identify the barriers to, and the successful aspects of, the Lean concept; (3) developing a framework and assessment tool through content analysis in order to provide

a better understanding of the implementation process and the drivers of the Lean Construction method in the construction field; and (4) validating the proposed developed framework of Lean Construction and assessment tool through interviews and an online survey with experts within the construction industry.

Among the main findings of this research is the lack of future strategic plans for the construction industry in terms of managing waste and risks in general and specially to KSA. The developed framework of the Lean implementation process highlights the necessity to understand the implementation of Lean Construction within construction organisations as well as the drivers for implementing Lean. It is hoped that the outcomes of this research study will have theoretical and practical significance for successful Lean implementation in construction organisations in KSA. Furthermore, it is intended to provide construction professionals with significant insights to help focus their efforts on value-adding work processes, resulting in better time management and money-saving strategies.

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LIST OF ABBREVATIONS

3R	Reduce, Reuse and Recycle
AACE	American Association of Cost Engineering
ACAPS	Assessment Capacities Project
ADB	Asian Development Bank
AECOM	Architecture, Engineering, Construction, Operations and Management
BIM	Building Information Modeling
C&D	Construction and Demolition
CDW	Construction and Demolition Waste
CEO	Chief Executive Officer
CI	Continuous Improvement
CIFE	Centre for Integrated Facilities Engineering
CIOB	Chartered Institute of Building
CLES	Centre for Local Economic Strategies
CLIP	Construction Lean Improvement Programme
CNC	Computer Numerical Control
CPM	Critical Path Method
DBB	Design-Bid-Build
DBIA	Design-Build Institute of America
DCN	Design Change Notice
EFQM	European Foundation for Quality Management
ERM	Enterprise Risk Management
ERP	Enterprise Resource Planning
EVA	Earned Value Analysis
FAHWA	Federal Highway Administration
GBP	Great Britain Pound
GCC	Gulf Cooperation Council
HALMAT	Highways Agency Lean Maturity Assessment Toolkit
HR	Human Resource
IATG	International Ammunition Technical Guideline
ICE	Institution of Civil Engineers
IFC	Issued For Construction
IGES	Institute for Global Environmental Strategies
IGLC	International Group for Lean Construction
IPD	Integrated Project Delivery
JIT	Just-In-Time
JV	Joint Venture
KIVP	Knowledge Innovation Visible Planning
KPI	Key Performance Indicator
KSA	Kingdom of Saudi Arabia
LC	Lean Construction
LCAT	Lean Construction Assessment Tool
LCC	Life Cycle Cost
LCFIRM	Lean Construction Framework Integrated with Risk Management
LCI	Lean Construction Institute
LERC	Lean Enterprise Research Centre
LESAT	Lean Enterprise Self-Assessment Tool
LIMA	Lean Implementation Assessment

LP	Lean Production
LPS	Last Planner System
MCPs	Mega-Construction Projects
MEP	Mechanical, Electrical, and Plumbing
MIT	Massachusetts Institute of Technology
MS Project	Microsoft Project
NIST	National Institute of Standards and Technology
NTP	Notice To Proceed
NYSDOT	New York State Department of Transportation
OSPMI	Office of Statewide Project Management Improvement
PERT	Program Evaluation and Review Technique
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PMO	Project Management Office
PMOG	Project Management Online Guide
PMSs	Performance Measurement Systems
PPC	Percent Plan Completed
QFD	Quality Function Deployment
QRA	Quantitative Risk Assessment
RAMP	Risk Analysis and Management for Projects
RIC	Ras Al-Khair Industrial City
SR	Saudi Riyal
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TFV	Transformation-Flow-Value
TIA	Time Impact Analysis
TPS	Toyota Production System
TQM	Total Quality Management
UNEP	United Nations Environment Programme
USSABC	U.S. Saudi Arabian Business Council
UWEP	United Nations Environment Programme
VE	Value Engineering
WSDOT	Washington State Department of Transportation
WWP	Weekly Work Planning

INTRODUCTION

CHAPTER ONE: BACKGROUND OF THE STUDY

The focus of this research is the study of 1) the main issues in the construction industry in the KSA that negatively affect projects, from the perspective of key contractors in the field; and 2) the analysis and evaluation of the current methods and techniques contractors commonly use to eliminate or mitigate those issues in order to find an efficient solution. These are the foundation for the development of an efficient and accurate framework and assessment tool for Lean construction in the Kingdom of Saudi Arabia (KSA).

It has been observed by the researcher in connection with various completed projects that contractors in the Middle East concentrate their interest on problems directly affecting the project's cost, despite the fact that other issues surrounding the project affect cost, including material waste, as well as project delays. Moreover, contractors do not count risk as an issue to be addressed in the planning stage; instead it is handled upon occurrence through the application of corrective actions instead of the instigation of proactive actions (Al-Kharashi & Skitmore, 2009). Based on the researcher's professional work experience of completed projects and the literature reviewed, the following section outlines the main factors that negatively affect construction projects in KSA. These factors are categorised into three main types of risk: waste, project delay and project over budget.

First, it has been observed through years of experience in the construction industry that contractors apply traditional methods for construction projects management and evaluate the performance of workers in KSA only when they see that their profit may be affected. In general, contractors do not participate in the design phase, but are more commonly involved in the construction phase; contractors adopt Value Engineering techniques to achieve waste reduction through selecting the best construction method (Alalshikh & Male, 2010). Thus, Value Engineering (VE) is one of the main methods applied to manage construction waste. According to Elayache (2010), "VE is a thorough problem-solving technique, combining several disciplines, that is, primarily concerned with increasing the value of the steps required to attain the goal of any product, process, service, or organisation" (Elayache, 2010).

Second, the construction industry in the Middle East faces the problem of project delay (Al-Kharashi & Skitmore, 2009). It has been reported that 70% of all construction projects in the public sector in Middle Eastern countries are not delivered on time (Albogamy et al., 2013). At an early stage of the project, the contractor is usually requested by the consultant to submit a baseline schedule for a specific time-frame and present a bi-weekly report during the construction phase so as to guarantee that the project is on track (Albogamy et al., 2013). The big question, thus, is how contractors deal with the submitted schedule, since this will have a direct bearing on the issue of project delay. The problem of schedule delay in construction projects becomes evident on investigation.

Thirdly, the construction industry in KSA specifically, and in the region generally, faces another major problem of projects being over budget (Albogamy et al., 2013). The budget may be significantly impacted by numerous problems; therefore, the early management of associated issues may help in the control of the project's budget. Creating a reasonable cost baseline for the associated project is one of the traditional methods used to control the budget. Another way is assigning a cost control engineer to monitor and report project costs using Earned Value Analysis (EVA) (AACE International, 2008). EVA is a technique for project performance evaluation developed from industrial engineering to highlight the need for eventual corrective actions through the provision of early indications of project performance (Subramani et al., 2014). However, construction projects in KSA have not so far applied any of the commonly known risk management techniques (Alrashed et al., 2014).

The Middle Eastern environment is highly resistant to change, yet the increased number of Mega-projects necessitates the search for more successful project management techniques. Judging from the reviewed literature, the application of Lean principles in other industries has indeed resulted in a more efficient and successful project delivery. Applying Lean principles in the construction industry, a process known as "Lean Construction", should also improve risk minimisation in Mega-Construction projects in developing countries, particularly in KSA.

1.1 PROBLEM STATEMENT

Using the researcher's experience in some of the Mega-Construction projects in KSA, data derived from completed construction projects was collected, studied and analysed. This has allowed for the examination of the drivers and barriers that contractors believe to be hindering their projects' accomplishment. They confirmed that delivering Mega-projects on time and on budget remains a major challenge in the region.

The research may face many problems, including:

1. Questioning, in developing countries like KSA, may be misunderstood as a means of monitoring workers for purposes of fiscal assessment. This may create some tension, as many workers do not like to be observed while performing high-reward activities, which in return might affect their willingness to participate; and
2. While action research is a comprehensive research method, it is focussed on the specific studied project, and therefore results cannot be generalised.

1.2 RESEARCH AIMS, OBJECTIVES, AND RESEARCH QUESTIONS

Aim:

The research aim is to develop an innovative framework and assessment tool that facilitates the use of Lean Construction, a method that is considered new to the field, as a more efficient method of minimising the risks of Mega-Construction projects in the Kingdom of Saudi Arabia.

Objectives:

From the findings of the literature review, the action research and empirical data collection from the survey method, the direct objectives of this research are:

Objective 1: To develop an innovative framework for the application of Lean principles in the construction industry (Lean Construction).

Research Questions: What are the most prominent problems facing the construction industry in the Middle East in general and the Kingdom of Saudi Arabia (KSA) in particular? What are the current practices within the construction domain for resolving these problems? What is the current state of knowledge of contractors and professionals regarding Lean concepts? What are the Lean principles that are most suitable for the construction industry?

Supporting statement: 1) The investigation of the latest research developments in the area of Lean principles, Lean Construction, Risk management, Construction project delays, Cost control, and Construction project budget estimating can provide a better understanding of the domain problems investigated within the scope of this research; 2) the development and administration of a survey instrument can provide insight into the current practices adopted by contractors within this region as well as the level of awareness of these professionals of Lean concepts; and 3) the assessment of completed projects can provide the grounds for the development of the aforementioned framework.

Objective 2: To develop an assessment tool to measure the maturity level of Lean Construction within construction organisations in KSA.

Research Questions: What are the critical success factors for implementation of Lean assessment tools in the construction industry? Which assessment tool and methodology best captures the evaluation of the maturity level of Lean Construction within construction companies?

Supporting statement: Before the implementation of the Lean Construction method in construction companies, Lean assessment has to be conducted to measure the maturity level. The Lean assessment tool is one of the critical success factors for effective implementation of Lean Construction.

Objective 3: To show the extent to which this approach can minimise the risks involved in Mega-Construction projects in developing countries and in KSA in particular.

Research Questions: How can current practices be improved by Lean Construction? What are the appropriate mechanisms for implementing these practices in an ongoing construction project? What are the risk parameters and how are they minimised through Lean construction?

Supporting statement: The integration of the developed framework into an ongoing Mega-Construction project will provide validation and assessment of the research as well as quantify the magnitude of its effect on minimising associated risks.

1.3 THE SCOPE OF THIS RESEARCH

The scope of this study is the implementation of Lean Construction within construction organisations in KSA and its integration with risk management. This research is focused on Mega-projects in order to address the requirements of Middle Eastern developing countries, especially KSA, for improving their economic situation. This study focuses on the contractors' perspective only and the justification for this is that most contractors that engage in procurement arrangements in Saudi Arabia are engaged in large projects. In addition, the contractor is the main party of the project stakeholders because the contractor's position is the main centre point of communication between others. Based on the researcher's experience, if the associated issues with contractors have been solved it will positively affect other parties but will not work the other way around.

The limitations of this study are: a) the nature of the participants, half of whom were not previously aware of Lean; b) use of single action research; c) issues with generalisability; d) models, although applied, were not validated through application but via interviews. In addition, the scope of the research work excludes factors related to quality, as this adds a different dimension of complexity that is beyond its scope. The addition of such an extra layer to the work would require the collection of data that is not readily available or currently being collected by projects within KSA. However, the issue of quality is implicitly included within the study, as it is one of the reasons for project delays and/or budget overrun. The implementation of the new method will directly improve quality: Lean construction projects are easier to manage, safer, completed sooner, cost less and produce better quality.

There are various types of construction waste, but the researcher is referring to specific types of waste in this study, such as Construction materials, Overproduction, Waiting, Transportation, Processing, Inventory, Movement, and Defective products.

There are several studies on the topic of Lean in relation to manufacturing and Lean implementation in construction projects. Nevertheless, few studies have been carried out into the integration of Lean Construction and risk management. As a result of this, it was challenging to develop an optimum framework and assessment tool for Lean Construction techniques combined with risk management, which is the main target of the research.

1.4 RESEARCH RATIONALE

The rationale for this research is to provide a framework for Lean Construction techniques and an assessment tool to measure the level of awareness of Lean Construction within construction organisations in KSA. Having been offered the opportunity of working in the construction industry, the researcher believes that the most significant problem that most construction projects suffer from is waste, which is difficult to manage if it is not controlled at the early stages of the project (especially the design phase).

The author submitted a thesis on "Applying risk management to solid waste handling in demolition activities for building projects in Egypt to attain sustainability" in 2012. The choice of this subject was based on the fact that waste was considered to be a huge problem, and this became even clearer at the conclusion of the thesis. Therefore, it has been decided to address the issue of waste management by considering an alternative method or technique to tackle the problem. After investigation and analysis, Lean Construction was chosen as an appropriate method. The main objectives of Lean Construction are: increasing project value, eliminating waste and reducing associated risks.

1.5 RESEARCH METHODOLOGY

In the construction industry, issues, actions and processes arise every day, and practical strategies are required for facing them. As discussed earlier, the research aims to develop an innovative framework that facilitates the use of Lean Construction, a method that is considered new to the field, as a more efficient method of minimising the risks of Mega-construction projects in the Kingdom of Saudi Arabia. In addition, an assessment tool is proposed to measure the awareness level of Lean Construction within construction organisations.

The questionnaire survey (01) conducted as part of the study (refer to Chapter 9) was based on KSA construction organisations with experience or expressed interest in Lean Construction and risk management. In addition, a discussion on how to apply Lean Construction techniques practically to Mega-projects in KSA is presented by choosing an ongoing Mega-construction project in KSA as an action research.

Furthermore, various personnel ranging from managerial to site worker staff within three different organisations, in addition to academic staff from three different universities in KSA, were interviewed in order to verify the results of the survey. By using structured interview questions, two interviews and a questionnaire survey (02) (refer to Chapter 11 and 14) were conducted in order to validate the output of the research, through obtaining experts' views. It should also be noted that the results presented are based on the opinion of respondents in organisations that have had experience of Lean Construction.

This section presents the research methodology adopted to achieve the objectives of the study. To that end, the research work under the scope of this study is organised in 4 stages (Fig. 1.1), namely 1) A Comprehensive Literature Review; 2) Existing Situation in KSA; 3) Framework Development and Validation; and 4) Assessment Tool Development and Validation.

A specific, ongoing Mega-Construction project in KSA was selected and during the researcher's participation in the project, it was used as an action research in order to investigate the matter deeply and consider the implementation of Lean Construction techniques. This research shows the extent to which applying Lean Construction techniques will improve the success of project delivery as opposed to other traditional methods that have been used before and those being presented throughout this research. A survey has been carried out to construct a preliminary point of view of the extent to which the application of Lean Construction techniques would add value to construction companies. It also aims at investigating the extent of awareness of the Toyota Production System's philosophy and the implementation of the associated management systems among construction workers. The results of the survey are used in the analysis of Lean Construction methods and as the basis for a more successful Lean implementation in KSA.

1.5.1 A COMPREHENSIVE LITERATURE REVIEW

The first stage involves a comprehensive literature review, which serves as a solid departure for critical analysis and identification of the following:

1. The current state of the market and the most prominent problems facing Mega-projects in the Middle East and specifically KSA;
2. The new and emerging research and practical endeavours to mitigate and resolve these problems; and

3. The latest developments in Lean Construction, finding out the best practice in its implementation, its limitations, the barriers to its application and the benefits of using Lean Construction in the construction industry.

1.5.2 EXISTING SITUATION IN THE KSA

The purpose of this sub-task is to understand the current level of involvement of Lean construction practices within the construction industry in KSA. It aims at identifying:

1. The current practices within the KSA construction industry that adopt Lean construction methods;
2. Susceptibility of the industry to change;
3. The best techniques (qualitative, quantitative, mixed) to be adopted for the current task;
4. Variables that promote and/or hinder the integration of Lean construction concepts into the industry;
5. Attitude of key participants in Mega-construction projects in the KSA towards the criticality of the established variables.

1.5.3 FRAMEWORK DEVELOPMENT AND VALIDATION

The purpose of this task is to develop a framework for waste management and risk mitigation for Mega-Construction projects in KSA through the integration of Lean Construction. In addition, it is concerned with the validation of the developed framework. The research work relating to this task is organised in the following seven sub-tasks:

1. Understand the different types of Lean Concept implementation in other industries and decide on the appropriate one for the current task;
2. Determine the appropriate implementation steps and expected transformation method;
3. Determine the variables that need to be considered and devise means of handling them;
4. Develop and compare the outputs of a variety of implementation models to decide on the best one to be adopted by this sub-task;
5. Select a Mega-Construction project in the KSA for implementation and validation.

6. Perform personal interviews and an online survey with key personnel, including clients, consultants, construction professionals and academic staff;
7. Adjust the developed framework based on the feedback from the aforementioned interviews;

1.5.4 ASSESSMENT TOOL DEVELOPMENT AND VALIDATION

This sub-task aims to develop an assessment tool for measuring the level of maturity of the Lean approach to quantify its appropriateness and effectiveness. In addition, this subtask is concerned with the validation of the proposed assessment tool. The research work under this task is organised in the following five sub-tasks:

1. Study the previous developed assessment tools and develop a new assessment tool that can achieve the research objective and that will be applied with the KSA construction industry;
2. Determine the appropriate assessment steps and expected transformation between assessment tool and developed framework;
3. Perform personal interviews and an online survey with key personnel, including clients, consultants, construction professionals and academic staff;
4. Adjust the proposed assessment tool based on the feedback from the aforementioned interviews;
5. Conduct an actual assessment in relation to the organisation managing the selected ongoing Mega-Construction project in KSA in order to identify the level of maturity of the Lean approach and to review and validate the process of selecting the Lean Construction Assessment Tool.

Task 1: Conduct a comprehensive Literature Review

1. Investigate the current state of the market and the most prominent problems facing Mega-projects in the Middle East and specifically KSA;
2. Identify the new and emerging research and practical endeavours to mitigate and resolve these problems; and
3. Highlight the latest developments of Lean Construction and find out the best practice of its implementation, limitations, barriers to application and the benefits of using Lean Construction in the construction industry.

Product 1:

Comprehensive Literature Review.

[Chapter 2,3,4,5,6 and 7]

Task 2: Understand the Existing Situation in KSA

1. Identify the current practices, if any, within the KSA construction industries that adopt Lean Construction methods;
2. Understand the susceptibility of the industry to change;
3. Clarify the best techniques (qualitative, quantitative, mixed) to be employed for the current task;
4. Define the variables that promote and/or hinder the integration of Lean Construction concepts into the industry;
5. Investigate the attitude of key participants in Mega-Construction projects in KSA towards criticality of the established variables.

Product 2:

A comprehensive understanding of the key features and parameters is needed for the development of the framework and assessment tool.

[Chapter 8 and 9]

Task 3: Framework Development and Validation

1. Understand the different ways in which Lean concepts have been implemented in other industries and decide on the appropriate one for the current task;
2. Determine the appropriate implementation steps and expected transformation method;
3. Determine the variables that need to be considered and devise means of handling item;
4. Develop and compare the outputs of a variety of implementation models to decide on the best one to be adopted by this sub-task;
5. Determine the proper tool to assess the maturity level of Lean within construction organisations;
6. Select a Mega-Construction project in KSA for implementation and validation.

Product 3:

Develop and validate a framework for waste management and risk mitigation for Mega-Construction projects in KSA through the integration of Lean Construction.

[Chapter 10,11 and 12]

Task 4: Assessment Tool Development and Validation

1. Perform personal interviews and online survey with key personnel including clients, consultants, and construction professionals; and
2. Adjust the developed framework and assessment tool based on the feedback from the aforementioned interviews.

Product 4:

Develop and validate an assessment tool for measuring the level of maturity of the Lean approach within construction organisation in KSA.

[Chapter 13,14 and 15]

Figure 1.1: Structure of the thesis

1.6 SUMMARY OF INTRODUCTION

In Chapter One the researcher presented the structure of the thesis and provided the aims, objectives, research questions, and hypothesis of this study. The thesis structure is comprised of four tasks: 1) A comprehensive literature review; 2) the existing situation in the KSA; 3) framework development and validation; and 4) assessment tool development and validation in order to achieve the aim and objectives of this research. The scope of the research work excludes factors related to poor quality, as this adds a different dimension of complexity that is beyond its scope. However, the implementation of the new method will directly improve quality: "Lean construction projects are easier to manage, safer, completed sooner, and cost less and are of better quality" (Aziz & Hafez, 2013).

TASK 1: A COMPREHENSIVE LITERATURE REVIEW

Task One (Chapters 2-7): A comprehensive literature review

In this section, the researcher reviews the literature related to Lean Construction's history, application, tools, benefits and barriers. All theoretical aspects/knowledge supporting this study are addressed in order to build a foundation to achieve the research aims and objectives. The diagram below (Figure T.1) shows the activities involved in Task One.

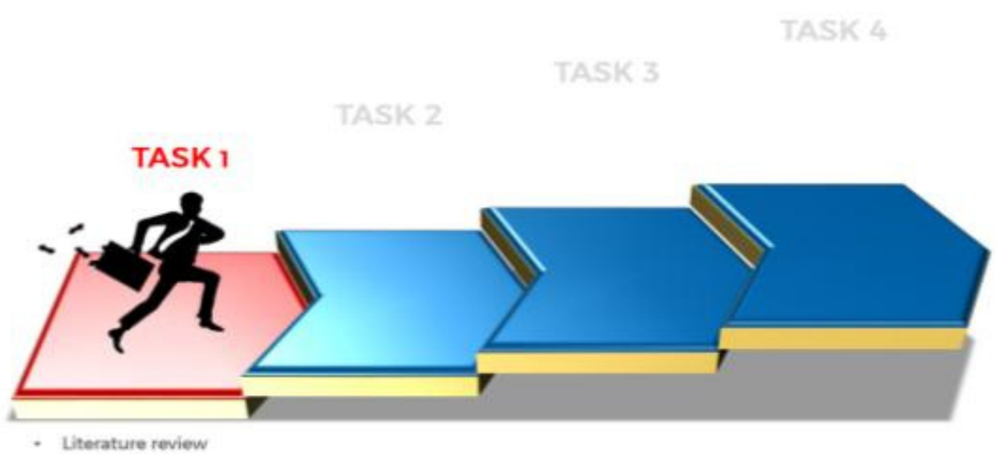

Figure T.1: Activities involved in Task One

CHAPTER TWO: CONSTRUCTION ISSUES AND IMPLEMENTATION METHODS

Several major issues may be experienced in the construction field. From the researcher's experience, most construction projects in KSA suffer from three major issues, namely waste management, project delay and project over budget. The researcher focuses on these three issues to provide an in-depth study and to come up with a solution that may eliminate or minimise such issues. This chapter is an overview of those issues and the common methods used to deal with them.

2.1 CONSTRUCTION WASTE

The construction industry in general is faced with the problem of generated construction waste, which directly influences the project budget (AbdelHamid, 2007). Kozlovská and Spišáková (2013, p.687) state that construction and demolition waste (CDW) produced 33% of the total waste stream in the European Union in 2010(Kozlovská & Spišáková, 2013). Koskela (1992) states that construction waste is generated by delays, rework, lack of safety, needless transportation journeys, long-distance travel and inappropriate management of the programme or equipment (Koskela, 1992). Thus, construction waste is one of the main challenges facing construction companies, as well as the lack of awareness of the types of waste, not only "material" ones.

In an attempt to mitigate these drawbacks, contractors employ Value Engineering (VE) as one of the main methods to reduce waste. Al-Yousefi (2010) states that VE is a well-known and approved method, which has an impressive history in the field of value improvement, through the customisation of Quality and optimisation of Life Cycle Cost (LCC). A wide range of companies and establishments have applied VE to achieve their goals, since it is known to be an organised and effective process. VE has achieved success because it is able to identify the latest opportunities available for the reduction of unnecessary costs while assuring quality, reliability, performance and other critical factors aimed at meeting or exceeding customers' expectations. Applying VE allows contractors to minimise generated waste at the early stages of a project as a proactive strategy. According to the literature concerning this domain, Middle East contractors do not show any interest in applying the methods possible for reusing produced waste; on the contrary, they are concerned with its reduction in order to maximise the project's value (Al-Yousefi, 2010).

Most KSA contractors, in particular, do not apply VE during the whole project life cycle because of the adopted delivery method (type of contract), which is a Design-Bid-Build (DBB) contract (Al-Dubaisi, 2000). "This is the traditional delivery method where an owner contracts with the designer/engineer to develop a project design and bid package, and then the selected contractor contracts directly with the owner for the construction phase of the project." (Kahn, 2015). Architecture, Engineering, Consulting, Operations, and Maintenance (AECOM) (2013) states that the DBB contract is most commonly used in the Middle East, especially in the Gulf Area, but the VE method does not comply with it because the contractor does not have any input during the design phase(Architecture, Engineering, Construction, Operations and Management (AECOM), 2013). Hence, VE is not applied properly; contractors apply it only during the construction phase, leading the consultant to issue a Design Change Notice (DCN) (Al-Kharashi & Skitmore, 2009).

The proper application of VE is influenced by the type of delivery method, which affects the control of the generated construction material waste (Al-Yousefi, 2010). In 2010, the Design-Build Institute of America (DBIA) claimed that in the standard design-bid-build (DBB) scenario, the study of VE could be applied during the delivery phase of the project, starting from the planning stage until the completion of the design phase. VE studies generally concentrate on major project components, since they indicate the best value (Design-Build Institute of America (DBIA), 2010). Value Engineering should be enhanced and applied at an early stage of the project, to increase the efficiency of managing waste.

VE is an effective technique for reducing costs, increasing productivity and improving quality which may be successfully introduced at any point in the life-cycle of products, systems, or procedures. VE was developed by General Electric Corp. during World War II and is widely used in industry and government, particularly in areas such as defense, transportation, construction and healthcare. It can be used in several applications, through either hardware or software; development, production and manufacturing; specifications, standards, contract requirements and other acquisition program documentation; and facilities design and construction. VE is defined as "an analysis of the functions of a program, project, system, product, item of equipment, building, facility, service or supply of an executive agency, performed by qualified agency or contractor personnel, directed at improving performance, reliability, quality, safety and life cycle costs." (Atabay & Galipogullari, 2013).

Construction companies can significantly keep their costs at the lowest level, price their offer lower and get a better chance of getting jobs if the resources of the country are used. (Kazanc, 2000). But the low offer price is not the only factor for a specific company to get the job. The project must have a high “value”. Value is differentiated into different meanings for the producing company, owner, user or the designer. Companies in the building industry would try to finish the construction with the lowest cost to obtain high profit while owners aim to get the biggest income from the building. The user wants to be able to perform his works easily, while the designer gives more importance to his creation’s aesthetics or functions. Purpose, time, quality and cost of every activity that will be realized during the construction process must be determined or estimated beforehand since the owner or user wants to know which feature they will have after the building is completed and at what cost they will have it. The construction process has many components, such as concept, design and drawing details of the project, construction etc., based on the estimated costs (first investment + usage cost) by providing features such as quality, durability, usefulness, continuity, feasibility, compliance, image and management convenience, increases (Atabay & Galipogullari, 2013). Suitable precautions are taken by predetermination of problematic areas via various project planning and scheduling techniques. But none of these methods includes an examination in terms of the “value”. After a building is completed or during the construction stage, comparing the building value with the costs that occur during its construction is not considered. Although many buildings were built with high costs, the desired functions were not provided. There is absolutely no direct proportion between a building’s costs and the provided benefits. In value engineering rationalist evaluation techniques are used considering the target features, and unnecessary costs are determined to be eliminated from the project, so that a building’s value is increased and resources (money, material and workforce) are not wasted (Atabay & Galipogullari, 2013).

Engineers Australia (2012) claim that waste is anything that does not add value as far as the customer is concerned. Value-added work enhances the form or function of the structure or process; for example, the customer is pleased to pay for bolting a valve or pouring concrete. Any other kind of work/activity is considered non-value-added work or waste, such as waiting for inspection, movement around the site, rework of welds; these activities are carried out without actually adding value to the building or structure (Engineers Australia, 2012).

During World War I, Ford recognised the need to control raw materials in order to reduce waste, and so he fabricated his own car parts because of shortages and price increases. First, Ford attempted to cover breakages of components on the assembly line through accumulating large amounts of stock, but he then realised the waste of money involved in this. Therefore, he decided to include inventories in production (Boscà, 2012). Smith and Hawkins (2004) state that Ford mainly aimed at building cheap automobiles, and that is why he was determined to eliminate waste in all areas of production, since waste of money, material, and time increased the cost per unit of each automobile (Smith & Hawkins, 2004).

According to Ohno (1988), waste is any manufacturing activity that consumes resources and does not add value from the customer's perspective (Boscà, 2012, p.9). Generally, waste should be managed. "However, in some steps of the manufacturing process, waste is a necessary part that adds value to the company and cannot be removed, for instance financial controls." (Melton, 2005). Waste management contributes to the improvement of operating efficiency on a large margin. Efficiency in the control of waste should also be improved at each step of the production process and over the entire plant (Melton, 2005). Seven types of waste are specified by Lean Production theorists (Ohno, 1988 and Melton, 2005 cited in Boscà (2012, p.9)):

Overproduction: One of the most severe types of waste is one that generates yet another type. An example of this is overproduction. It is when elements such as paper, reports and phone calls are generated for no particular customer and consequently turn into inventory, all of low use and almost no value. Such waste occurs when production is based on the full extent of the line rather than only on the customer's requirements, when required and with the quality required.

Waiting: Forgotten material, mishaps in planning and unstable lines result in wasted time during or between processes. The waiting that people, equipment and the product itself have to go through until the process is reformed hinder the value added to the customer.

Transportation: Whenever the materials of a product are in unnecessary movement, whether between supplier or storage and a process, between processes or within one process, they are not being processed. This is considered to be a stage that hinders the addition of value to the customer.

Processing: This is a type of waste that is relatively clear and simply removable. It occurs when a product goes through needless steps that consequently add zero value to it, leaving the customer disinclined to pay for it.

Inventory: This refers to the gathering and build-up of materials or products during any stage of the operation. Other than its obvious drawback of it costing money, it also conceals problems in the process, a fact that will further induce lack of action by demotivated employees to make advancements with their work.

Movement: Excessive movement of any type that is not vital for accomplishing an activity in a competent way is categorised as waste movement. Another example is human movements that are inessential and result in fatigue, at which point support of the processing of the product would not be attainable.

Defective products: These are deficient parts that are produced during the process which necessitate extra work or re-work.

2.2 PROJECT DELAY

Being behind schedule is not mainly attributed to the project management method adopted, but to its application mechanism, as well as the unrealistic time schedules prepared. In order to avoid delays, the construction team should follow the approved baseline and should not report an incorrect status of the project. Moreover, the construction team should prepare a realistic constructability plan that is to be reflected in the project schedule (Al-Kharashi & Skitmore, 2009).

The Association for the Advancement of Cost Engineering (AACE) International (2008) states that the input data required for the creation of a master schedule includes works carried out as per the contract, identification of external effects and milestones, as well as authorisations needed to launch works or access roads. The following phase is based on the definition of detailed activities for each work package and the creation of a master schedule showing interfaces between disciplines, with the unanimous consent of all parties. The resource loading phase is based on the creation of a master resource loaded schedule from the integration of all individual detailed schedules. The resource and cash profiles are then created and analysed in order to start the updating and reporting process (AACE International, 2008).

The bid-winning contractor is asked by the consultant to submit the baseline schedule, identifying the project end date. The contractor then uses planning and scheduling software such as Primavera to create a time schedule, following the typical steps, starting from dividing the project into work activities to marking critical paths (Hildreth & Munoz, 2005). According to the approved baseline schedule, the contractor submits a bi-weekly report to monitor and control the project's progress in order to compare the baseline to the actual performance; and this is how the updated schedule is created. KSA adopted this scheduling method, which is commonly used in the construction industry worldwide. Despite this, contractors in the Middle East claim money in the early project phases through working on a large number of activities at the same time, i.e. they do not follow the work sequence provided in the approved baseline schedule. Therefore, most construction projects in the Middle East are not delivered within the approved time frame (Al-Kharashi & Skitmore, 2009).

The magnitude of the detrimental effect of delays on construction projects has been documented within the literature. A recent study of Mega projects performed by the Ministry of Statistics and Programme Implementation in India has indicated that about 40% of Government projects have experienced a delay of 1 to 252 months (Sumaiyya and Pranay 2014).

The Critical Path method is implemented for this issue, which is an essential technique to construct a project model containing a list of all the required activities to complete the project as well as the time/duration each activity requires until the project delivery (Lu & Li, 2003). The Critical Path method is used to set start times and finish times, float calculations of activities, mark critical path, and develop bar charts.

2.3 PROJECT OVER BUDGET

Delivering large-scale projects on time and on budget remains a major challenge in the Middle East. Baldauf-Cunnington et al. (2014) reported that 78% of participants responding to its survey believe that project over-budgeting was mainly a result of project scope change, unrealistic timeframes, delays and unclear project objectives (Baldauf-Cunnington et al., 2014). In the Middle East, many contractors state that failure to control the approved project budget caused them to lose their project profit. In KSA, contractors attempt to control project cost through using a cost management method including processes such as resource planning, cost estimating, cost budgeting and cost control.

The resource planning process involves the estimation of both the physical resources (manpower, equipment, materials) and the quantities required to perform project activities, as well as the description of the types of resources and the quantities for each element of the work breakdown structure (AACE International, 2008). The cost estimating process produces the cost estimates of required resources, including the identification and consideration of various costing alternatives, such as scope of work, assumptions, and possible range of results, in addition to a cost management plan describing the method of variances management (AACE International, 2008).

The process of cost budgeting, which involves allocation of overall cost, produces the cost estimates of the individual work items for the purposes of establishing a cost baseline in order to measure the project performance after the consideration of the contingency percentage. Cost baseline, the output of the cost budgeting process, is a time-phased budget that will be used to measure and monitor the project cost performance. Cost baseline is developed by summing estimated costs based on period and is usually displayed in the form of an S-curve (Hildreth & Munoz, 2005).

Cost control is the last process; it is concerned with: (1) influencing the factors changing the cost baseline so as to ensure that changes are beneficial; and (2) managing the actual changes when and as they occur. This process monitors cost performance to detect plan deviation, ensures the accurate recording of all appropriate changes in the cost baseline, prevents incorrect, inappropriate, or unauthorised changes from being included in the cost baseline, and informs the authorised party of any changes (Hildreth & Munoz, 2005). During the cost controlling process, the contractor applies the Earned Value Analysis (EVA) developed by project management practitioners, to measure project performance and progress according to a combination of schedules, costs, quality and performance, with a special focus on early warning of trends in any of these areas (Bhosekar & Vyas, 2012).

Bhosekar and Vyas (2012) define the concept of EVA as "a programme management technique that uses “work in progress” to indicate future incidents". Accordingly, cost is the common measure of project cost and performance schedule. It provides the cost measurement in terms of currency, hours, worker-days or any other similar quantity that can be used as a common measure of the values associated with the project. KSA contractors are still failing to control the approved project budget, not due to the inefficiency of the method adopted, but to the manner in which it was applied, despite the use of the above-mentioned cost management processes (Mitra & Tan, 2012).

2.4 APPLICATION OF LEAN THEORY/METHODOLOGY TO CONSTRUCTION ISSUES

One of the most important issues is generated construction waste in terms of material, time and other factors that may affect the project cost. The Reduce, Reuse and Recycle (3R) principles have already been used in construction waste management. However, in the researcher's opinion, it is a corrective action strategy for handling produced waste. A proactive strategy, which eliminates waste rather than managing it, is needed. All developing countries have a common problem: the legal system related to 3R has not been prepared, and institutional structures are not able to support its measures(Asian Development Bank (ADB), Institute for Global Environmental Strategies (IGES), United Nations Environment Programme (UNEP), 2006).

In KSA, most contractors focus on generated material waste only because it directly affects the project cost, but they do not consider or direct any attention to other types of waste, such as time and non-value-addingsteps. All factors that do not add value to the project should be considered. The strategy for the construction waste management should be implemented by applying the VE method; however, it should be enhanced and applied at an early stage of the project. Thus, the delivery method should theoretically be changed to allow VE to work better. Also, new methods that eliminate waste, increase the workers perception of the type of waste and handle the produced waste effectively are needed. Therefore, this research proposes the Lean Construction method for that purpose(Mahamid & Elbadawi, 2014). Finally, the 3R principle is needed for the process of managing the generated material waste (Aadal et al., 2013).

The 3R principles have already been used in construction and demolition (C&D) waste management in urban settings in some Asian countries, including Japan, Hong Kong, India, Sri Lanka, Singapore, and Malaysia. Moreover, these countries have become increasingly aware of C&D waste management (Nitivattananon & Borongan , 2007). During their research on the current situation in Asian countries, Nitivattananon and Borongan (2007) concentrated on technologies, policies and strategies for waste minimisation through the application of the 3R principles. Regional and national policies, laws and regulations controlling 3R principles for C&D waste were negligible in Asia as of 2007. However, some policies do exist and others are still in the process of preparation (Nitivattananon & Borongan , 2007, p. 98).

The key parties in the construction industry, clients, designers, contractors, labourers and suppliers, should promote the 3R principles (Addis, 2006). For example, clients can set the environmental standards and define the conditions of the implementation of any project. As a result, other parties are encouraged to implement the 3R principles, by the following methods (Nitivattananon & Borongan , 2007, p. 100):

1. Designers can decrease the usage of construction resources to minimise site waste by producing an appropriate design;
2. Builders can reduce site waste by using reclaimed materials; and
3. Suppliers can encourage the use of reclaimed materials.

Delay in construction projects is an issue: a significant percentage of projects fall behind schedule, causing damage to all project parties (Aliabadizadeh, 2009).There has been much research conducted on this problem, but it still exists because of conditions in the construction industry. Delay could be caused by main contractors, subcontractors, suppliers, owners or consultants, i.e. almost everyone involved in construction projects.

The problem of being behind schedule results from many issues, such as change in design during the construction phase, due to changes in scope of work and/or low performance from contractors. The researcher has noticed that most contractors work on scattered activities in order to claim money in the early phases of the project, i.e. they do not follow the work sequence provided in the approved baseline schedule (Thomson Reuters, 2014). Consequently, most construction projects in the Middle East fail to finish within the approved time period. As mentioned earlier, the problem of project delay does not occur because of the selected project management method, but because of the manner in which it is applied, as well as the setting of unrealistic time schedules.

During the construction phase, if a project falls behind schedule, the contractor creates a recovery schedule to overcome the delay and usually requests a time extension from the client. Negotiations are then held between both contractor and client to assign delay responsiblities and approve the claimed extension of time. The implemented stategy to request time extension is known as Time Impact Analysis (TIA), which is defined as "a modeled prospective or retrospective Critical Path Method (CPM) schedule delay analysis technique that adds owner-caused and other excusable delay to the planned CPM schedule." (Long et al., 2015).

Even if the contractor gets the required time extension, most clients in KSA do not pay indirect costs to the contractors against the approved extension of time, which affects the project budget, leading the contractor to consider that effect at the end of the project. On the other hand, if the reason for project delay is a result of the poor performance of the contractor, it may lead to project failure or losing a percentage of project profit. The current implemented method is the Critical Path Method (CPM), which is mostly concerned with controlling what is already happening, i.e. "reactive action": the Critical Path Method (CPM) "is a technique for analysing projects by determining the longest sequence of tasks through a project network." (Newbold, 1998). Integrating one of the Lean Construction tools, such as the Last Planner System,with CPM will allow a more reliable way of planning works and provide a smoother workflow, i.e. "proactive action".

Regarding project over budget, it has been noticed that many contractors lose a percentage of their project profit due to their failure to control the approved project budget. Any issue associated with the construction project will affect the project budget. Therefore, in order to control the project budget, the contractor should manage the associated issues effectively. In KSA, contractors mainly use a cost management method to control project costs, which includes processes required to ensure that the project is completed within the approved budget. However, it has been observed that most projects fail to control the approved project budget, not necessarily due to the inefficiency of the method adopted, but to the manner in which it was applied (Baldauf-Cunnington et al., 2014). With the successful settlement of the previous two issues, waste is considerably reduced, resulting in making the project target schedule more attainable; thus, additional costs are kept to a minimum.

In the case of delays in activities or chains along the critical path, attempts are made to reduce costs, as well as the duration of the offending activity; otherwise the sequence of work is changed. If the problem continues to be present, it is usually necessary to substitute cost for schedule so as to find the best sequence required to achieve progress (Howell, 1999, p.4). The waste generated as a result of continuous activities is hidden by the focus on activities and the existence of required resources. "Simply put, current forms of production and project management focus on activities and ignore flow and value considerations."

(Koskela, 1992) and (Koskela & Huovila, On foundations of concurrent engineering, 1997) cited in Howell (1999).

CHAPTER THREE: RISK MANAGEMENT

3.1 INTRODUCTION

Risk is ubiquitous in any area of life: driving a car, crossing streets or playing sports, for example. It can exist in our lives in the form of impediments to established aims. It is the same in business; here, however, it is often related to financial considerations in relation to market volatility and therefore the ability to meet expectations based on risk versus return trade-off (Burtonshaw-Gunn, 2009). In the management of large construction projects, risk is associated more with the projected costs and time scales. A debate on the differences and common features of risk and uncertainty has been raging; where risk actions lead to one of a set of possible specific outcomes of a known probability, uncertainty may lead to a set of consequences of unknown probabilities (Riabacke, 2006). The researcher focuses on risks only in this chapter.

Ehsan et al. (2010, p.16) state that project management applies skills, tools and techniques to carrying out a project while meeting or surpassing the expectations and requirements of stakeholders. Project risk management is a fundamental part of the process, aiming at identifying possible risks and confronting them. It includes activities that focus on magnifying the effects associated with positive events and reducing the effects of negative ones. Risk is generally considered to be a choice rather than something inevitable; uncertain plans can affect the process of achieving the project and business goals. Risk is evident in all processes of the project; the amount of risk is the only thing that varies from one process to another (Ehsan et al., 2010).

Risk has different accepted meanings according to the context. Uncertain outcomes are the common factor in all the definitions, which only differ in the way they express the outcomes; some definitions describe risk as having various effects, while others are neutral (Berg H.-P. , 2010).

Partnerships British Columbia (2006) specify risk management as continuous identification, analysis and addressing of risks. This process aids in avoiding negative effects and identifying emerging opportunities. When a project team is committed to a risk management process, they produce an action plan that, when followed, may aid in alleviating possible risks as well as their possible effects. Project risk allocation can be carried out by: (1) Risk transference (transfer risks to contracting party); (2) Risk retention (public sector retain risks); and (3) Risk sharing (the contracting party and the public sector share the risks) (Partnerships British Columbia, 2006, p. 2).

The Washington State Department of Transportation (WSDOT) (2014, p.12) defines risk as the likelihood of an unknown event and its impacts; a positive impact represents an opportunity, and a negative impact represents a threat. It also describes risk management as the process, culture and structures aimed at managing the project risks effectively, taking into consideration expected opportunities and threats to project goals. Project risk management provides the following benefits: (1) helping in achieving project objectives; (2) addressing uncertainties and proposing possible results; (3) facilitating better decision-making; (4) providing innovative and creative thinking; (5) allowing better control and time management; and (6) providing senior management with a better understanding of project challenges (Washington State Department of Transportation (WSDOT), 2014).

Burtonshaw-Gunn (2009) notes that risk management aims at ensuring rapid identification of business risks, in addition to developing clear processes in terms of assessment, action planning and reporting of risks. Also, the identification of opportunities attracts more attention, which allows those responsible for specific areas to make decisions, ensuring: (1) quick assessment of business opportunities so as to take advantage of such opportunities; (2) lessening or alleviating the threats that the project or any process of the whole company may encounter; and (3) contribution of the decision to sustainable shareholder value (Burtonshaw-Gunn, 2009, p. 7).

The Project Management Institute (PMI) presents risk management as one of the nine knowledge areas. In the construction project management context, risk management is a comprehensive and systematic approach to the identification of, analysis of, and response to, risk for the purpose of fulfilling project objectives. Risk management has many benefits, including identifying and analysing risks, improving the construction project management process, and using resources effectively (Banaitiene & Banaitis, 2012, p. 429).

Construction projects are always unique, but risks occur for a number of different reasons (Oyegoke, 2006 and Pheng & Chuan, 2006). Sterman (1992) and Uher and Loosemore (2004) claim that construction projects are usually complicated and dynamic, with various processes of feedback. The Project Management Institute has shown that participants with various backgrounds and skills naturally have various expectations and interests

(Banaitiene & Banaitis, 2012). Problems and confusion can thus arise even for project managers and contractors who have wide experience (Banaitiene & Banaitis, 2012).

Risk management requires the creating and fostering of a risk management culture, where the team works collectively to manage risks until the project is delivered. Project teams not only work on designing roads, bridges, drainage systems etc., but also develop plans, specifications and estimates for construction contracts. Everyone is responsible for risk management, and that is why there are accountability checkpoints to guarantee the management of project risks (Caltrans, 2012). There should be a clear understanding of the term "risk" in order to manage the project risks effectively (Caltrans, 2012). Risk is defined as the uncertainty that matters; it can negatively or positively influence project objectives (Caltrans, 2012). This uncertainty can be related to a future event that might, or might not, occur, as well as the unknown degree of influence on project objectives. The probability of such occurrences and their unpredictable impact on objectives describe the term "risk" (Caltrans, 2012, p. 4).

Zavadskas, et al. (2010, p.33) state that the construction business involves a very high risk factor because construction projects are unique. The life cycle of such projects has various risks that result from different factors, including the employment of temporary project team members who are gathered from different companies, construction sites, etc. Moreover, the increasing size and complexity of construction, as well as the political, economic and social conditions surrounding the project, add to the risks (Zavadskas et al., 2010).

Boscà (2012, p.44) explains that risk management is currently considered an integral part of successful project management because efficient risk management assists the project manager in reducing all types of project risks, whether identified or unexpected. On the other hand, inefficient risk management contributes to the proliferation of undesired effects associated with scope, time and cost, since risk can greatly and negatively influence project performance (Boscà, 2012, p.44). This leads to task delays, affecting the manager's ability to accomplish the project objectives. This is why the Project Management Institute (PMI) considers risk management to be one of its nine main knowledge areas in the Project Management Body of Knowledge (PMBOK). The success of a project is determined by a range of factors; risk management, however, increases the probability of success (Boscà, 2012).

There are several benefits of risk management to the project and its organisation(Ward & Chapman, 2004). Firstly, it facilitates the identification of favourable complementary action methods; secondly, it increases the probability of the achievement of project targets, and thirdly, it eliminates unexpected events. Moreover, it reduces uncertainty through the provision of more accurate estimates, and, finally, it minimises the effort required for the project management through the understanding of risk control programmes (Ward & Chapman, 2004). The organisation should proactively and consistently be committed to dealing with risk management throughout the project's life cycle in order to carry it out successfully(Ward & Chapman, 2004). The organisation, at all levels, should make a conscious choice to actively identify efficient management over the project's life (Ward & Chapman, 2004).

3.2 RISK MANAGEMENT PROCESSES

Caltrans (2012) claims that project risk management adopts approaches that promote efficiency and effectiveness. However, the details of risk processes differ from one project to another. There are three important elements of risk management: identification, analysis and action (Caltrans, 2012, p. 5). Risk should be identified, described, understood and assessed before it can be properly managed. Risk analysis is a necessary step, but it should be followed by action. Actions should be properly implemented so as to facilitate a complete and useful risk process. The risk process ultimately aims at both risk management and analysis (Caltrans, 2012, p. 5).

The Project Management Institute (PMI) (2008) further states that project risk management includes the processes of management planning, identification and analysis, planning of risk response, and monitoring and control of a project (Boscà, 2012, p.44). Risk project management aims at increasing the probability and consequences of positive events as well as decreasing the probability and consequences of adverse results (Boscà, 2012, p.44). These processes combine with each other and with other knowledge areas as well, although they are different from one another. They can make use of the efforts of one or more individuals, based on the needs of the project. Moreover, each process is carried out once, at least, in the project and in one or more phases of the project (Boscà, 2012, p.44).

Other organisations have also identified the processes needed to deal with risk. Although there are different elements included in the processes, these processes are consistent in the way that the phases are developed throughout the project's life cycle (Ben-David & Raz, 2001). There are four phases included in this activity, the first of which is risk management planning, which identifies the activities required for responding to project risks. Risk identification, the second phase, assists the managers in the process of identifying the potential project risks. Third, risk analysis provides a quantitative and qualitative analysis which evaluates risk probability in addition to risk results. The final phase, risk response, establishes practices and methods necessary for risk reduction and monitoring, as well as the identification of new risks (Ben-David & Raz, 2001).

Risk management processes must be applied in the initial phases of the project in order to provide the opportunity for important modifications. Each project needs to be fully analysed so that the best method can be chosen at each phase. Since project risk management mainly aims at guaranteeing a good basis for decision-making, processes should also be adapted to suit each project(Klemetti, 2006).

The WSDOT Project Management Online Guide (PMOG) outlines the actions involved in risk management as follows (WSDOT, 2014, p.17):

- Risk management planning is the structured process of dealing with how to approach, plan and execute risk management tasks throughout the project's life cycle. It aims at increasing opportunities and reducing or eliminating the outcome of negative risk events;

- Identifying risk events involves the project team making a risk assessment, defining and recording types of risks that will affect the project objectives;

- Qualitative risk analysis is the process of evaluating the probability and impact of the identified risks and establishing a prioritised list of those risks either to immediately resolve them or analyse them later. The project team will evaluate each identified risk by determining the likelihood of its occurrence and its influence on the project goals, seeking the expertise of those in the relevant fields;

- Quantitative risk analysis is the statistical method of identifying the probability of risks and their impact on the time and cost of the project, and is based on a concurrent assessment of the identified and quantified risk impacts;

- Risk response planning involves proposing options and actions to increase opportunities and reduce threats to the project's goals. It involves assigning responsibility for each risk response to a specific party in the project team, who, together with the project manager, will determine the best strategy for each risk response and the methods of its implementation; and

- Risk monitoring and control is the process that continues throughout the project's life cycle. It involves identifying and monitoring the assumed risks and identifying new risks. In addition, it ensures that the execution plans are effective in reducing the project risks.

Risk planning, identification, analysis, response and monitoring are included in the risk management process, which uses tools and techniques to help the project manager in increasing the probability and consequences of positive risks and decreasing the probability and impact of negative events (Office of Statewide Project Management Improvement (OSPMI), 2007). Performing project risk management at an early stage of the project, with continual monitoring throughout the project, is more effective than at later stages (OSPMI, 2007, p.2).

3.3 RISK ASSESSMENT AND RESPONSE

The New York State Department of Transportation (NYSDOT) (2008) states that risk assessment is the quantification of the risk events documented in the preceding identification stage. This process has two main steps: the first deals with determining risk frequency; risks are continuously classified, starting from being very unlikely to very probable. The second step evaluates the impact of risk, in the case of its occurrence. Risk produces different effects on the project; these effects usually appear in direct project outcomes in terms of altered schedules or cost increases (New York State Department of Transportation (NYSDOT), 2008). Some risks influence the project by affecting the public, the public's perception, the environment, or safety and health.

Risk assessment is a technique that aims at identifying and estimating project risks incurred by personnel and property. Traditional construction risk assessment is equivalent to probabilistic analysis. Such approaches require events to be mutually exclusive, exhaustive and conditionally independent. However, there are many variables affecting construction, and causality, dependence and correlations are difficult to estimate. Therefore, the assessment of construction risk impact and uncertainty depends on subjective methods, relying on historical information, as well as the experiences of individuals and companies (Sathishkumar et al., 2015).

3.3.1 QUALITATIVE RISK ASSESSMENT

The International Ammunition Technical Guideline (IATG) (2012) states that qualitative risk assessments are the most widely used approach in relation to risk analysis; they are descriptive, rather than using measurable or calculable data(International Ammunition Technical Guideline (IATG), 2015). Probability data is not required, and only the estimated potential loss is assessed. Qualitative Risk Analysis determines the impact and likelihood of the identified risks and prioritises them for further analysis or direct mitigation.The first step in the risk assessment process requires assessment of the probability and consequences of the risks identified through interview questions (Burtonshaw-Gunn, 2009). Tables 3.1 and 3.2 below show the probability and severity of risks that the researcher will take into consideration during risk assessment.

In addition, Berg describes risk as the uncertainty that could result from future events and outcomes. It describes the probability and effect of an event, in addition to the possibility of realising an organisation's targets. The phrase "the probability and effect of an event" implies that, as a minimum, a certain amount of quantitative or qualitative analysis is needed for reaching the decisions related to major risks or threats to the realisation of an organisation's targets. There are two necessary calculations for each risk: its likelihood or probability; and the extent of its impact or consequences (Berg H.-P. , 2010, p. 79).

Table 3.1: Probability of risks

Description	Explanation	Probability
Highly likely	Almost certain to happen	Very high
Likely	More than 50-50 chance	High
Fairly likely	50-50 chance or less	Medium
Unlikely	Low likelihood but could happen	Low
Very unlikely	Not expected to happen	Very low

Table 3.2: Magnitude of risk impact

Description	Explanation	Impact
Disastrous	The impact is totally unacceptable	Very high
Severe	Serious impact	High
Substantial	Considerable effect on time and/or cost	Medium
Moderate	Medium effect on time and/or cost	Low
Marginal	Minor effect on time and/or cost	Very low

3.3.2 QUANTITATIVE RISK ASSESSMENT

Quantitative risk assessment (QRA) is the process of risk investigation and reduction, (International Ammunition Technical Guideline (IATG), 2015). In addition, California Department of Transportation (Caltrans) (2012) defines quantitative risk analysis as a process that numerically estimates the probability of fulfilling the project cost and time objectives. It is also based on a simultaneous evaluation of the impacts of all identified and quantified risks.

3.3.3 RISK RESPONSE PLANNING

This involves taking action to protect construction project objectives in KSA and to assign responsibilities for each risk to the person best placed to deal with it. The risk response strategies outlined by Hillson (1999) suggest ways of applying them to Mega-Construction projects: (1) Avoid: seeking to remove uncertainty; (2) Transfer: seeking to transfer risk to a third party; (3) Mitigate: seeking to cut down the size of the risk; and (4) Accept: taking action to make the risk acceptable.

3.4 RISK ANALYSIS AND MANAGEMENT FOR PROJECTS (RAMP)

3.4.1 INTRODUCTION

This section introduces and tackles Risk Analysis and Management for Projects (RAMP), which is used for the purpose of managing the risks posed by Mega-Construction projects in KSA. RAMP is defined as a well-established framework for the analysis and management of the risks incurred in projects. It aims at enhancing the financial returns offered to sponsors, investors and lenders, as well as improving the effects of projects on the wider community (Jensen, 2014).

Businesses' need to manage their projects amidst a turbulent environment is increasing; RAMP's systematic approach is applied where there is unexpected and continuous change to ensure the effective identification, analysis and control of risks, as well as the early identification of newly emerging risks in order to minimise them as they occur. There are many benefits in applying RAMP, including (Jensen, 2014):

- Elimination of wasted work, due to the repetitive nature of the process;
- Consideration of opportunities as well as threats;
- Enhancement of the credibility of the project's business case;
- Consistency of approaches to Enterprise Risk Management (ERM) in the project sponsor's organisation;
- Greater confidence of decision makers to proceed with projects; and
- Recording and communication of "lessons learned".

RAMP methodology includes four main activities, namely, (1) process launch, (2) risk review, (3) risk management and (4) process closedown. These main activities are further broken down by lower level processes. Risk Analysis and Management for Projects (RAMP) is a process that deals with the analysis and response to risks that can affect the achievement of project (investment opportunity) objectives. RAMP is the result of the cooperative efforts of the Institution of Civil Engineers (ICE), the Faculty of Actuaries and the Institute of Actuaries. RAMP covers the whole project lifecycle, starting from inception until disposal (Bu-Qammaz, 2007).

3.4.2 THE RAMP PROCESS

The RAMP process consists of four activities that are carried out at different stages of the investment lifecycle. The following indicates both the activities and the stages at which they are supposed to be conducted in (Bu-Qammaz, 2007):

- Process Launch is conducted early in the investment life cycle;
- Risk Review is conducted before key decisions or intervals;
- Risk Management is continually conducted between risk reviews; and
- Process Close-Down is conducted either at the end of the investment lifecycle or on premature termination.

Also, each activity contains a number of phases which consequently have various steps. The number of times for performing each activity depends on their purpose; i.e. the two activities related to the establishment and closing of the project are performed once; however, several risk reviews should be periodically conducted at critical phases during the project lifecycle. Also, risk management activities are continuously performed during risk reviews and as per the analyses, strategies and plans of previous risk review (Bu-Qammaz, 2007).

3.5 INTEGRATED RISK MANAGEMENT

Berg (2010, p.81) defines integrated risk management as the continuous, proactive and systematic process of risk understanding, management and communication from an organisation-wide perspective. It aims at reaching strategic decisions in order to achieve an organisation's overall corporate objectives. It requires continuous assessment of an organisation's potential risks at every level and aggregation of the results at the corporate level to facilitate priority setting and improved decision-making (Berg, 2010, p.81). Integrated risk management should be embedded in the organisation's corporate strategy and shape the organisation's risk management culture. Organisation risk identification, assessment and management assert the importance of the whole, the sum of the risks and the interdependence of the parts (Berg, 2010, p.81).

In addition, Berg (2010) claims that integrated risk management not only focuses on the minimisation or mitigation of risks, but also supports activities that foster innovation, so as to achieve the greatest returns with acceptable results, costs and risks. From a decision-making perspective, integrated risk management typically involves the establishment of hierarchical limit systems and risk management committees to help determine the setting and allocation of limits. Integrated risk management strives for the optimal balance at the corporate level. However, companies have various considerations according to the extent to which important risk management decisions are centralised (Basel Committee on Banking Supervision, 2003).

3.6 APPLICATION OF LEAN THEORY/METHODOLOGY TO RISK MANAGEMENT

Construction risk management is essential for achieving objectives of time, cost, quality, safety and environmental sustainability (Zou et al., 2006, p.1). Schatteman et al. (2008, p.885) state that construction projects are complex and dynamic environments filled with risks. Risk management should be used to define all possible associated issues, list them in a risk register and find suitable strategies to eliminate or manage each risk. The principles and methodologies of risk management will help the decision makers of all departments in taking proactive decisions and managing the generated waste in an effective way(Schatteman et al., 2008).

From the researcher's experience in KSA, the main issue facing construction companies is risk management. Moreover, according to McLeod (2008), the main issues facing construction and engineering companies are sustainability and risk management. In developing countries, contractors do not consider risk an issue; they handle it by using corrective actions upon occurrence, instead of being proactive. Risk management methodologies will help identify possible problems, allowing the contractor to take proactive decisions and manage the associated issues effectively (eliminate or mitigate).

One of the main purposes of this research is to demonstrate how Lean Construction principles can be used to minimise risks of Mega-Construction projects in developing countries. The research embodies the monitoring and review of risk for Lean Construction implementation. The answer to this question is to be provided at the end of the study. The author applies the risk register tool for the identification of possible issues that are related to construction projects in KSA. A risk register is defined as a document that is prepared at the beginning of the project parallel to the planning phase, outlining possible risks that may rise during the project life cycle, as well as other risks related to construction works (The Chartered Institute of Building (CIOB), 2002).

CHAPTER FOUR: THE LEAN APPROACH IN DIFFERENT INDUSTRIES

In this chapter the author discusses the implementation of the Lean approach in the manufacturing and construction industries, and introduces the fundamentals of Lean Thinking, including concepts of waste elimination. In addition, the author provides a clear overview of Lean as a management model and identifies the key characteristics and aspects of the term.

4.1 LEAN MANUFACTURING

4.1.1 INTRODUCTION

Lean originated in Japan in the 1940s within the Toyota company; Toyota based its production system on the desire to create a continuous production flow that did not rely on long production runs to be efficient, as well as the recognition that a small fraction of the total time and effort involved in achieving a product added value for the end customer (Melton, 2005, p. 662). 'Lean Thinking' was first popularised in the 1990s best seller, The Machine That Changed the World: The Story of Lean,by Womack et al., 1990. This book recounts the movement of automobile manufacturing starting from craft production to mass production and finally to Lean Production (Poppendieck, 2002). It describes how Henry Ford enabled low-skilled workers and specialised machines to produce cheap cars for the masses through standardising automobile parts and assembly techniques(Poppendieck, 2002).

According to Womack and Jones (2003), Lean is defined as a way of creating new work instead of dispensing with jobs for the sake of efficiency. Also, they define Lean as a thought process and a philosophy, rather than a tool, applied to the elimination of the non-value-added tasks implicated in any business, whether manufacturing, service or any other activity with a supplier and a customer relation (Womack & Jones, 2003).

Anything that adds to a product's time and cost with no added value to the customer is considered a Lean manufacturing waste. Value-added activities fulfil the customer’s needs, while non-value-added activities do not, and that is why customers are not willing to pay for them (Georgescu , 2011).

Lean Production comprises many principles, including teamwork, communication, efficient use of resources and continuous improvement (Kaizen). It can be said that Toyota pioneered the idea of applying these principles to situations outside of manufacturing environments, such as services or any other activity with a supplier and a customer relation that has the goal of eliminating non-value-added tasks (Womack et al., 1990 cited in Ahrens, 2006, p.19). Marchwinski and Shook (2004) define Lean Production as an organising and managing system for product development, operations, suppliers, and customer relations that requires less human effort, less space, less capital, less material and less time to make more products with fewer defects to fulfil customer desires, compared to the previous system of mass production (Marchwinski & Shook, 2004).

Pettersen (2009) claims that there is no consensus on the definition of Lean Production among the various authors examined. Moreover, many authors have different opinions regarding the characteristics that should be linked to the concept. From this, it can be seen that the term Lean Production does not have a clear definition in the reviewed literature. On the theoretical level, this can cause some confusion; however, it is more problematic on the practical level, i.e. when organisations apply the concept. Pettersen (2009) illustrates the importance of acknowledging the different variations and raising awareness of input during the implementation process. He emphasises that the organisations should not accept random variants of Lean, but rather make active choices and adapt the concept to suit the organisation's needs. This adaptation process enables the organisation to increase the odds of achieving a predictable and successful implementation (Pettersen, 2009).

4.1.2 APPLICATION OF LEAN MANUFACTURING

As per Kilpatrick (2003, p.3), regarding operational improvements, the studies on forty of the clients of the National Institute of Standards and Technology(NIST) Manufacturing Extension Partnership were recently surveyed regarding their application of Lean Manufacturing. Typical improvements were reported as follows (Kilpatrick, 2003):

- Reduction in Lead Time (Cycle Time) by 90%;
- Increase in productivity by 50%;
- Reduction in Work-In-Process Inventory by 80%;
- Improvement in quality by 80%; and

- Reduction in space utilisation by 75%.

The same study has shown a small number of improvements in administrative functions. Kilpatrick (2003), claims that the same number of office staff were able to handle larger numbers of orders with less paperwork and order processing errors. Customer service functions and processing steps were streamlined in order to allow the company to focus their efforts on customers' needs and not to place customers on hold. The implementation of job standards and pre-employment profiling ensures the hiring of only 'above-average' performers, bringing benefits to the organisation if everyone performs as well as the top 20%.

Most of the companies that apply Lean do not make optimum use of the improvements. However, highly successful companies will learn the benefits of these improvements and convert them into increased market share (Aziz & Hafez, 2013). One specific example involves a mid-Western manufacturer of a common health care product, the third largest company of approximately forty U.S. competitors, which took the initiative in applying Lean manufacturing principles. The company's average lead time before the project was fifteen days, the same as that of other similar companies. However, at the end of the project it was four days, with no products shipped in more than seven days. The company started an advertising campaign for the purposes of capitalising the improvements, aiming to deliver the product to customers in ten days, otherwise it would be free. This led to an immediate increase in sales volume of 20%. The company began another marketing campaign after carrying out the improvements required to meet the new demand; for only a 10% premium, they would ship within seven days. Again, sales volume increased (though by only 5%) because new customers wanted the product within seven days, but more than 30% of existing customers also paid the premium, even though they were already receiving the product in less than seven days. By the end of the project, revenues had increased by almost 40%, with no increase in labour or overhead costs. Also, the company was able to invoice customers eleven days sooner than before, greatly improving cash flow (Kilpatrick, 2003).

4.1.3 TOYOTA PRODUCTION SYSTEM (TPS)

This section compiles and organises information about value streams and Lean Production in relation to the Toyota Production System that will aid the reader in understanding the specifics of the study. After Japan had lost World War II, Toyota's president aimed to reach American productivity and quality levels within three years by developing the Toyota Production System (TPS) (Ahrens, 2006). Waste elimination forms the basis of this system, and it is founded on two pillars: Just-In-Time (JIT) and autonomation (Jidoka), or automation with a human touch (see figure 4.1) (Ahrens, 2006, p. 16).

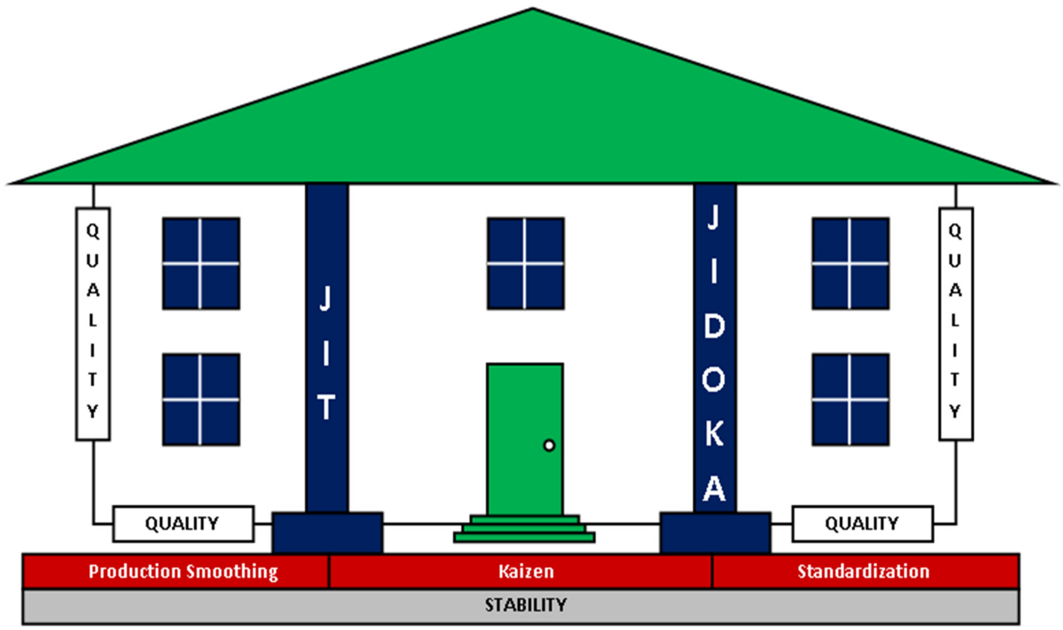

Figure 4.1: The Toyota Production System according to Ohno (Sears and Shook, 2004 cited in Ahrens, 2006, p.16)

In Just-In-Time production, a later process goes to an earlier process in the operation flow and withdraws only the number of parts needed, when necessary. Autonomation refers to automating a process to include inspection. Human attention is necessary only to detect defects (Ohno, 1988).

Ohno's (1988) definition of Just-In-Time is when the right parts needed in assembly reach the assembly line at the time they are needed and only in the amount needed during a flow process. The Just-In-Time approach aims at creating a flow of productionwith zero work-in-progress (inventory). During the application of Just-In-Time, Toyota staff found that conventional operations management methods did not work well: this problem appears early in the process, resulting in a defective product later in the process. Later process steps were not taken into consideration during the production of parts, leading to huge and wasteful inventories (Shingo, 1989).

Autonomation is the second pillar; it was invented when Toyoda Sakichi, the company founder, created an auto-activated weaving machine at the end of the 19th century, which stopped instantly if one of the warp or weft threads broke (Miltenburg, 2001).

Convis (2001), an American Toyota Motor Manufacturing president, describes the TPS as an integrated and interdependent system involving many elements under the headings ofTools, Philosophy and Management (see figure 4.2). He asserts that Ohno's theories were misunderstood, because a lot of managers attempted to apply an individual element such as JIT or Jidoka instead of the entire approach. Engineers are misguided in thinking that if the tools are implemented separately they have captured the essence of TPS. In his opinion, Ohno's theory does not directly specify that the key to successful TPS implementation is the total commitment of everyone in the organisation to make it work (Convis, 2001).

Examples of the Lean toolkit include 5S (five terms beginning with the letter 'S' utilised to create a workplace suitable for visual control and Lean Production), Kaizen (a process function to plan and support concentrated bursts of breakthrough activities), Value Stream Mapping (Winch and Carr, 2000 defined this as a process mapping tool, and it is well known as a management tool for considering how value is provided for customers (cited in Arleroth and Kristensson, 2011, p.26)), and Policy Deployment (a visual management tool that allows management to select the most important objectives and to translate these into specific projects that are deployed down to the implementation level) (Lean Enterprise Research Centre (LERC), 2007).

A comparison of Convis' and Ohno's models makes it clear that TPS is not simply a set of tools and concepts that can be carried out by command and control. Rather, it is a fully integrated management and manufacturing philosophy and approach (Ahrens, 2006, p.18).

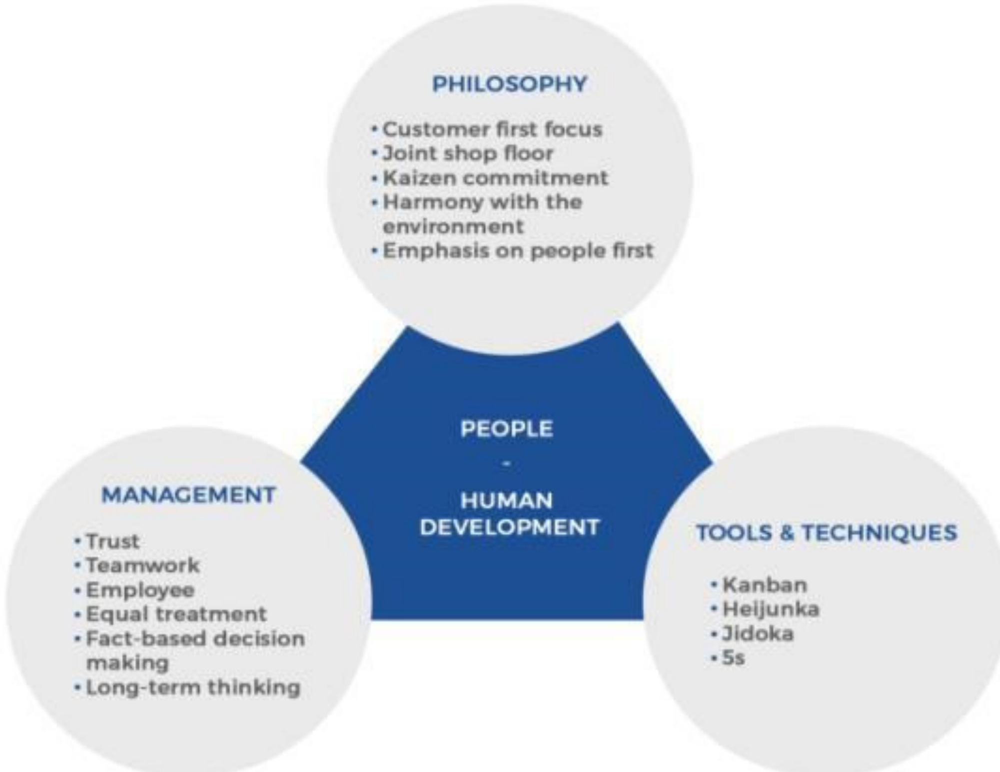

Figure 4.2: The Toyota Production System (TPS) according to Convis (Convis, 2001, cited in Ahrens, 2006, p.18)

As a result of Ohno’s (1988) and Womack/Jones’ (2003) search for methods to achieve lead time reduction through eliminating waste, the terms "Lean" and "Toyota Production System" are considered synonymous. This search does not describe detailed tools for waste reduction in indirect fields including marketing, sales, research and development or others. It is worth mentioning that although Shingo (1989) made it clear that TPS mainly focuses on factory and office improvements, applying Lean tools to the rest of the value chain, such as engineering, is not explained or clarified in Ohno's TPS. This is one of the reasons why most of the companies' continuous improvements focus on the shop area (Ahrens, 2006, p.19).

The Lean survey conducted by Ahrens (2006) investigates the critical success factors for sustainable Lean implementation. According to the survey, Porsche applied the Lean principles of the Toyota Production System (TPS) and succeeded in increasing their operating profit from €122 million in1994 to €933 million in 2004 (Ahrens, 2006, p.2).

They defined a set of targets including: 1) shedding light on the Lean Production concept; 2) analysing the tools and concepts necessary to become a Lean operating organisation, and evaluating how and for which functions these tools can be used; and 3) investigating the importance of the Lean philosophy and management behaviour as well as related implementation issues (Ahrens, 2006, p.2).

4.1.4 PROCESS IMPROVEMENT METHODS

Total Quality Management

Over the years, different management theories have emerged. Two management approaches to optimisation are Total Quality Management (TQM) and Lean Production (LP), but there are no unique ideas or views of either of them. The TQM approach is a management manufacturing strategy (Anvari et al., 2012) aiming at fostering awareness of the quality of all parts of the organisation's processes. It is considered an integrated management philosophy consisting of a set of practices that shifts the wide focus of an organisation, starting from top management to workers at all levels, to quality. TQM mainly aims at controlling the company's resources through the development of a business strategy in order to achieve world-class quality at reasonable costs (Small et al., 2011).

According to Ross (1993), TQM is an integrated management philosophy applied to maintain continuous improvement, fulfil customer requirements, avoid rework, facilitate long-range thinking, increase employee involvement and teamwork, and implement process redesign, competitive benchmarking, team-based problem solving, constant measurement of results, and closer relationships with suppliers (Ross, 1993).

There are two particular differences between Lean and TQM: first, Lean targets the improvment of entire value streams, while other improvement methods focus on individual processes. Secondly, most process improvement methods target the improvement of the productivity or efficiency of major value-adding processes, whereas Lean targets the reduction or elimination of non-value-adding activities (waste) as well as adding value (Anvari et al., 2012).

Judging from the aforementioned literature review in this section, Lean and TQM do not have many similarities. The reason behind this is that, according to more recent Lean approaches, Lean is a system, philosophy and way of thinking rather than a box of tools. Nevertheless, there are various tools and techniques for implementing Lean principles in an industry, including TQM (Shah & Ward, 2007 and Vinodh & Joy, 2012).

Lean Six Sigma

Motorola developed Six Sigma, a process improvement methodology, in the 1980's for the purposes of reducing defects in its processes. It aims at achieving a performance level where the defect rate equals 3.4 defects per million opportunities; this is a virtually defect-free environment (Bevan et al., 2005). Six Sigma has attracted many comments, mostly negative, including (Hines et al., 2004):

- Non-consideration of system interaction, leading to uncoordinated projects;
- Independent improvement of processes;
- Lack of consideration of human factors;
- Lack of significant infrastructure investment;
- Over-detailed and complicated for some tasks;
- It is the new flavour of the month;
- The absolute goal of Six Sigma (3.4 defects per million opportunities) is not always an appropriate goal and may not be thoroughly achieved; and
- It targets quality only.

Figures4.3 and 4.4 below show the roots of Lean and Six Sigma and the similarities betweenthem.

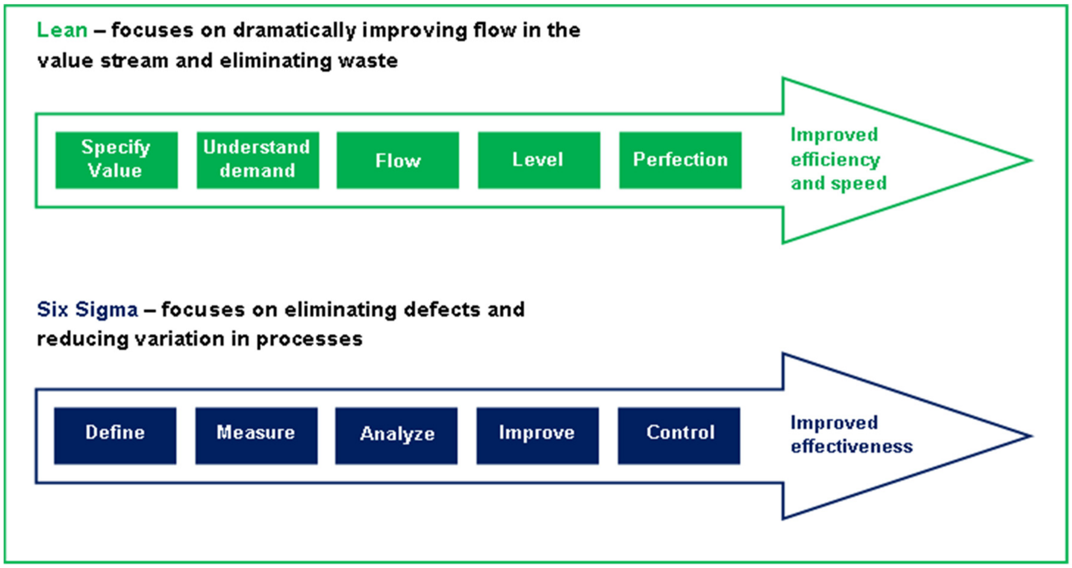

Figure 4.3: Integrating the two improvement approaches (Institute, 1993).

Figure 4.4: History of Lean and Six Sigma (Bevan et al., 2005)

Lean and Six Sigma methodologies are based on process improvement; both were developed in manufacturing environments and have proved their effectiveness. There are numerous and dramatic success stories concerning both (Bevan et al., 2005). When combined, they can solve problems and create rapid transformational improvement at lower cost. This could probably increase productivity, improve quality, reduce costs, improve speed, and help to exceed customer expectations (Bevan et al., 2005).

4.2 LEAN CONSTRUCTION

In this section the researcher discusses Lean Construction principles and tools and the benefits of adopting the Lean Thinking approach in the construction industry by reviewing and analysing the previous literature on Lean Construction. It is particularly important to define waste and its types in this section because it is the main issue that most construction projects suffer from.

Before reviewing the literature of Lean Construction, the researcher listened to the panel discussion held between Glenn Ballard, Lauri Koskela, Luis Alarcón, and Sven Bertelsen. He also attended the 22nd annual conference of the International Group of Lean Construction (IGLC) (2014) in Oslo, where the participants replied to two main questions: how did they learn about Lean Construction, and what is its meaning? The participants introduced different experiences and perspectives and offered many interpretations of Lean Construction depending on the audience and the industry. In summary, they claimed that Lean Construction is about waste elimination. They put forward a simple meaning of Lean; it has three main elements: management philosophy, tools and people.

4.2.1 INTRODUCTION

The definition of Lean Construction in Constructing Excellence (2006) is “a philosophy based on the Lean manufacturing principles. It mainly focuses on the management and improvement of the construction process in order to profitably deliver what the customer needs. Lean Construction, as a philosophy, can be pursued through a number of different approaches.” (Constructing Excellence, 2006).

As a standard of perfection, Lean Construction applies Ohno’s production system design criteria, but the question here is how the Toyota system, Lean Production, is applied to construction. Lean Construction is considered an adaptation and implementation of the

Japanese manufacturing principles within the construction process, and as such Lean Construction assumes that construction is a special kind of production (Bertelsen, 2004).

Ohno recommended that companies should "Apply high production pressure on each activity because cost and duration reduction is the basis of improvement." The following are the reasons why managing under Lean Construction is different from the typical contemporary approach (Howell, 1999, p.4):

- Lean has a clear set of objectives for the delivery process;
- Lean is aimed at maximising performance for the customer at the project level;
- Lean designs concurrently product and process; and
- Lean applies production control throughout the life of the project.

"By contrast, the current form of construction production management is derived from the same activity-centred approach applied in mass production and project management. It targets optimising the project activity by activity, on the grounds that customer value has been identified in design. Production management is carried out throughout a project in many steps, including: first breaking the project into pieces, i.e. design and construction, then putting those pieces in a logical sequence, estimating the time and resources required to complete each activity and therefore the project." (Howell, 1999, p.4). All the activity's 'pieces' are further decomposed until they are contracted out or assigned to a task leader, foreman or squad boss (Howell, 1999, p.4). Control is carried out through monitoring each contract or activity in terms of its schedule and budget projections.

Arleroth and Kristensson (2011, p.31, 32) define Lean Construction as applying the principles of Lean Manufacturing in the construction industry. Many construction companies claim that they have been applying Lean for a long time, e.g. using JIT delivery, even before the term Lean or Lean Construction was known. Others also associate Lean more with partnering than with the principles of Lean manufacturing (Green & May, 2005). Koskela (1992) maintains that construction and manufacturing both focus on processes and value (cited in Arleroth and Kristensson, 2011, p.31, 32). His work has become the foundation of Lean Construction. Jørgensen and Emmitt (2008) also identify a few elements common to Lean manufacturing and Lean Construction (cited in Arleroth and Kristensson, 2011, p.31, 32): 1) focus on waste elimination and reduction; 2) focus on the end customer in order to determine what value is and what waste is; 3) pull approach from a customer perspective; this is about understanding the customer's request, i.e. to produce only what the customer wants when the customer wants it; and 4) focus on processes and flows of processes.

4.2.2 UNDERSTANDING THE CONSTRUCTION INDUSTRY

The construction industry has a well-established relationship with economic development. The significant contribution of the construction industry to national economic development has been tackled in many studies (Myers, 2013).

Construction greatly contributes to the economic growth of any country and is essential for the prosperity of all nations. Over the past two decades, construction activities have rapidly and dramatically increased across the developing countries in the Middle East Gulf region, coinciding with the substantial spending announcements the governments have made for the improvement of infrastructure (Samba Financial Group, 2012). Construction companies still face many challenges, which are intensified by the increase in construction activities, including completing projects on time and within budgets. Delays have given a negative impression of the industry in the region.

The Kingdom of Saudi Arabia (KSA) is the largest country contributing to the field of construction in the Middle East, both by the value of contracts awarded in general and in terms of future projects in the pipeline industry in particular (Ventures Middle East, 2011). KSA is currently implementing more than 1,300 Mega-projects that are worth over $732 billion in the sectors of oil, gas, construction, transport, power and water(Deloitte GCC Powers of Construction, 2013). This high value underlines the need to use advanced techniques to minimise the projects' cost and maximise their value through risk control in order to avoid project failure, which may consequently lead to severe negative impacts on economic growth in the Gulf area.

Baldauf-Cunnington et al. (2014) conducted an industry survey in the Middle East, which shows that the Middle East construction industry still has some way to go before it can have confidence in its ability to manage risks. Middle Eastern construction companies are influenced by many factors that could either lead to project failure or negatively affect their performance; these factors include material waste, time loss, poor quality, reworking and unexpected risk (Baldauf-Cunnington et al., 2014). The situation is exacerbated when each project party attempts to evade their responsibility for project failure. From the researcher's work experience in KSA and the data collected from previous construction projects, it is clear that, with the main goal of any construction company being to increase profit, it always seeks to propose alternatives that may reduce a project's cost.

The construction industry has justifiably refused to apply many ideas taken from manufacturing, due to the belief that construction is different. Manufacturers produce parts that go into projects; however, "the design and construction of unique and complex projects in highly uncertain environments under great time and schedule pressure is fundamentally different from making tin cans." (Howell, 1999).

4.2.3 THE LEAN CONCEPT

The International Group for Lean Construction (IGLC) has significantly contributed to the formulation of a theoretical foundation for Lean Construction through abstracting the core concepts of Lean Production and applying them to the management of construction processes (Salem et al., 2005, p.2).

Pettersen's paper (2009) shows that there is no consensus on the definition of Lean Production among the authors examined. Moreover, the authors have different opinions regarding the characteristics that should be linked to the concept. It can be said that the term Lean Production does not have a clear definition in the reviewed literature. On the theoretical level, this can cause some confusion; however, it is more problematic on the practical level, i.e. when organisations apply the concept. Pettersen's paper illustrates the importance of acknowledging the different variations and raising awareness of input during the implementation process. It emphasises that organisations should not accept random variants of Lean, but rather make active choices and adapt the concept to suit the organisation's needs. This adaptation process enables the organisation to increase the odds of achieving a predictable and successful implementation (Pettersen, 2009).

4.2.4 LEAN PRINCIPLES AND LEAN THINKING

Various authors discuss many principles which the researcher is attempting to illustrate in order to provide the reader with detailed information and background on other researchers' studies. The researcher concentrates on Womack &Jones' Lean principles and the 5 guiding principles deriving from his studies of other authors.

Key terms and definitions of Lean Principles

Before discussing the principles of Lean, it is necessary to define some key terms. Womack and Jones (1996) state: "There are five principles of Lean Thinking: precise specification of value by specific product, identification of the value stream for each product, making value flow without interruptions, enabling the customer to pull value from the producer, and pursuing perfection." (Hines, 2009). Womack and Jones (1996) define each of these principles in more detail as follows (cited in Hines, 2009, p.1):

Value: The definition of **value** derives its significance from its explanation as a product that fulfils the definer's needs – the customer's - at a certain price at a certain time. Value is thus a sensitive starting point for Lean thinking.

Value stream: the group of defined steps that are needed to take a product (good, service or a combination of the two) from the very early stages of 1) Problem solving: from concept to detailed design to engineering to product launch, then 2) Information management: order-taking to detailed scheduling to delivery, through to the end stages of 3) Physical transformation: raw materials to finished product at the customer's end.

Flow: After the value of a product is accurately defined and its value stream "route" is laid out by the Lean Industry, thus eliminating all associated waste, there comes the task of making sure that the succeeding stages of creating value - as part of the Lean thinking process - run smoothly.

Pull: A good or service should never be produced at the upstream level unless it is requested by the customer at the downstream level.

Perfection: In the context of Lean, perfection is truly not far-fetched at all. Once value is accurately determined, value stream established, value-creating steps are made to stream fluently and the dynamic of having customers' pull value is made to flow, perfection is attainable.

Lean Principles according to Womack and Jones

According to Womack and Jones (1996), the Lean flow principle means the continuous accomplishment of tasks along the value stream in order to convert the product from being a design, an order and a raw material into being launched and delivered into the hands of the customer without any stoppages, scrap or backflows (Weigel, 2000, p.3). Five principles of "Lean Thinking" (Womack and Jones, 1996, cited in Lean Enterprise Research Centre (LERC), 2007) were proposed as a framework for organisations to apply Lean Thinking.

Womack and Jones' five principles are (cited in LERC, 2007):

1. Specification of value from the customer's perspective;
2. Identification of all steps across the whole value stream;
3. Performance of actions that create value flow;
4. Preparation of what is pulled by the customer just-in-time; and
5. Striving for perfection through continuous removal of successive layers of waste.

The Lean Principles relating to the production process itself, as originally defined by Womack & Jones (Constructing Excellence, 2004) are: (1) waste elimination; (2) precise specification of value according to the ultimate customer; (3) clear identification of the process, delivering what the customer values (the value stream) and eliminating all non-value-adding steps; (4) facilitating the continuous and uninterrupted flow of the remaining value-adding steps by managing the interfaces between different steps; (5) not making anything until a customer needs it; and (6) then making it quickly, and pursuing perfection by continuous improvement.

Five guiding principles and aspects of Lean Construction

The 5 guiding principles (Figure 4.5) stated by Engineers Australia as relating to overall company strategy (Engineers Australia, 2012, p.4) are:

Figure 4.5: The Five Guiding Principles (Engineers Australia, 2012, p.4)

Challenge the Status Quo: The first principle underlines the fact that if something is done in a certain way; it does not mean that it should continue in this way. We should not surrender to the status quo and we should challenge our ideas and processes so as to improve them.

Go & See: If we want to improve our process we must check it ourselves; if there is a problem or an opportunity, you should go to the actual worksite to check it. Problems are not solved behind a desk, and inspiration will not strike while you are doing your emails.

Continuous Improvement: There are always opportunities for improvement; we need to create systems and behaviours in the organisation in order to encourage, facilitate, and recognise Continuous Improvement. Leaders should encourage simple, quick and inexpensive ideas for improvement, allow their teams to trial these and build the results into the process using Lean tools and techniques.

Respect the Individual: We should respect the role each individual plays in the organisation, as well as the knowledge they have. If they are doing a job day in and day out they will have more knowledge of that job than anyone else; therefore leaders need to make use of this knowledge and stimulate the creativity of their workforce.

Teamwork: Team members should be proud, because working in a team helps in understanding and improving their strengths and weaknesses. “Teamwork should encourage communication; everyone should feel themselves to be a part of the work and be able to share ideas. We need to remove the fear of asking dumb questions and work together for a solution”.

Eriksson (2010) discusses the different aspects of Lean Construction, which he divides into six core elements (see Figure 4.6). These elements are waste reduction, process focus in production planning and control, end customer focus, continuous improvements, cooperative relationships and systems perspective (cited in Arleroth and Kristensson, 2011, p.32).

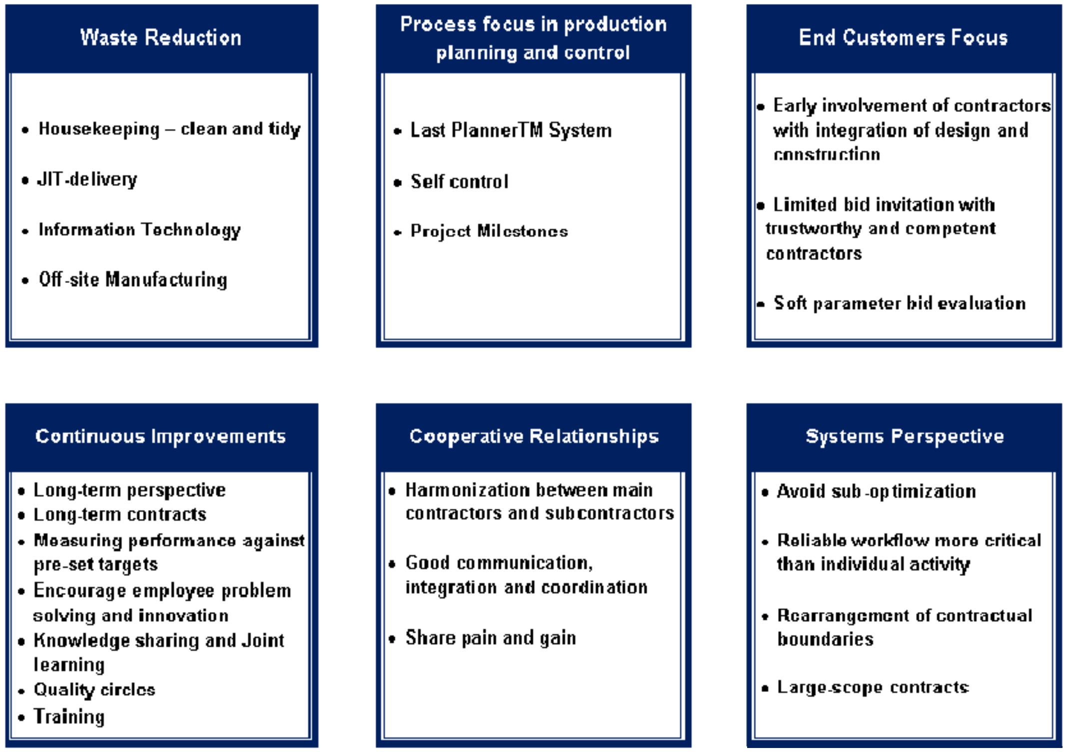

Figure 4.6: The Six Core Elements of Lean Construction (Eriksson, 2010, cited in Arleroth and Kristensson, 2011, p.32)

Application of Lean principles

Any small fraction of the time and effort exerted in the production or the delivery of a product or a service increases the value added for the end customer. Hence, it is very important to define the value of a product or service from the end customer's perspective in order to eliminate waste step by step (Lean Enterprise Research Centre (LERC, 2007). Kovacheva (2010, p.11) points out that these five principles of Lean specified by Womack and Jones (1996) are necessary in order to achieve successful implementation (Kovacheva, 2010). Application of these five steps is required on every organisational level and demands a complete transformation of the current business system. However, the real challenge lies in the initial step, which is based on the precise definition of the value to the customer. It is also important to ensure the value flow across the organisation as well as through the departments of each company; otherwise it could result in a faulty product or service being produced, with great waste for the organisation. The second step is the identification of the entire value stream and elimination of waste(Kovacheva, 2010, p. 11).

Womack and Jones (1996) state that the Lean Thinking definition of the value stream is the set of all the specific activities necessary for the design, order and provision of a specific product, from concept to launch and order to delivery into the hands of the customer (Weigel, 2000, p.3). The product process should be described at each step in order to create the value stream. The value stream involves three types of activities; one adds value and the other two are "muda" (the Japanese word for waste) (Womack and Jones, 1996 cited in Weigel, 2000, p.3): 1) Value-Added: those activities that unambiguously create value; 2) Type One Muda: activities that create no value but seem to be unavoidable with current technologies or production assets; and 3) Type Two Muda: activities that create no value and are immediately avoidable.

The Lean Enterprise Research Centre (2007) demonstrates that 5% of activities of the production operations create value, while 35% are necessary non-value-adding activities and 60% add no value at all. Hence, the greatest source of improvement in corporate performance and customer service is by eliminating non-value-adding activities (waste). Some goods or services depend on organisation only; waste removal then should be performed throughout the entire non-value-adding value stream, i.e. all the activities involved in delivering the product or the service. Inter-firm waste elimination, as well as value stream management, requires new relationships. Processes are reorganised so that the product or design flows through all the value-adding steps without interruption, instead of the workload being managed through successive departments. The Lean techniques toolbox is used to remove the flow obstacles successively. Synchronisation of firm activities is performed by pulling the product or design from the upstream steps to fulfil the end customer's needs (LERC, 2007).

Performance improvements and value creation could be achieved through eliminating wasted time and effort. The first step of pull and flow creation is the radical reorganisation of the individual steps of the process, but the gains become truly significant as the whole series of steps link together. This makes the waste easier to eradicate, until the theoretical end point of perfection is reached, where all actions and assets add value for the end customer. In this way, Lean Thinking represents a path of sustained performance improvement and not a one-off programme (LERC, 2007).

4.2.5 LEAN CONSTRUCTION TOOLS AND TECHNIQUES

Lean is not simply a set of tools and concepts which can be implemented by command and control. Rather, it is a fully integrated management and manufacturing philosophy and approach in which the human dimension is the single most important element for success(Ahrens, 2006). The Lean Enterprise Research Centre (2007) defined the tools and techniques required to support the Lean philosophy and to enable organisations to apply the ideas and perform change. These originated from several schools of thought and others were originated by the Toyota Production System, while many tools have been developed by research organisations such as LERC. Hence there is an extensive toolkit to help the Lean practitioner.

Last Planner

The Last Planner System (LPS), which was developed by Ballard and Howell in the 1980s, is a production control system for project management. It substitutes for or replaces both a typical management system based on activities and a defined schedule produced by a project manager (Engineers Australia, 2012, p.19). The LPS develops a predictable workflow and rapid learning in design, programming and construction projects and by doing so provides maximum value to the owner through eliminating waste caused by unpredictable workflow. LPS has helped contractors in the reduction of project delivery time and at the same time allowed specialty contractors to improve utilisation of their resources (Engineers Australia, 2012, p.19). The most completely developed Lean Construction tool is the Last Planner system of production control, introduced in 1992, which emphasises the relationship between scheduling and production control (Ballard, 2000).

Ballard (2000) indicates that Last Planner System (LPS) is a technique that provides workflow and responds to construction project variables. The Last Planner is the person or group responsible for operational planning, i.e. a product design structure which facilitates improved work flow and production unit control, i.e. the achievement of individual assignments at the operational level (Salem et al., 2005, p.3). This will achieve "Should Can Will", which is the key term in Weekly Work Planning (WWP) (Ballard, 2000). “Should” refers to the work that is required to be done as per schedule requirements. “Can” refers to the work which can actually be accomplished within various field constraints. “Will” indicates the work commitment which will be made after all the constraints are taken into account (Salem et al., 2005, p.3). WWP requires commitments between team members to complete their activities as scheduled and is the basis for the increased predictability and reliability of work flow on a project using LPS (Engineers Australia, 2012).

LPS encourages the project participants' commitment (trades, crews, contractors, etc.) through a number of planned conversations, as in Figure 4.7. These conversations take place as a result of the team's understanding of, and agreement to, the requirements of the Master Schedule, in addition to their teamwork for the purpose of preparing the Phase Pull Plan (which is made by a project team to show the required activities to finish a work phase and identify the best logic to complete those activities), and their application of this Pull Plan so as to identify constraints in order to efficiently carry out their work (Engineers Australia, 2012, p.19).

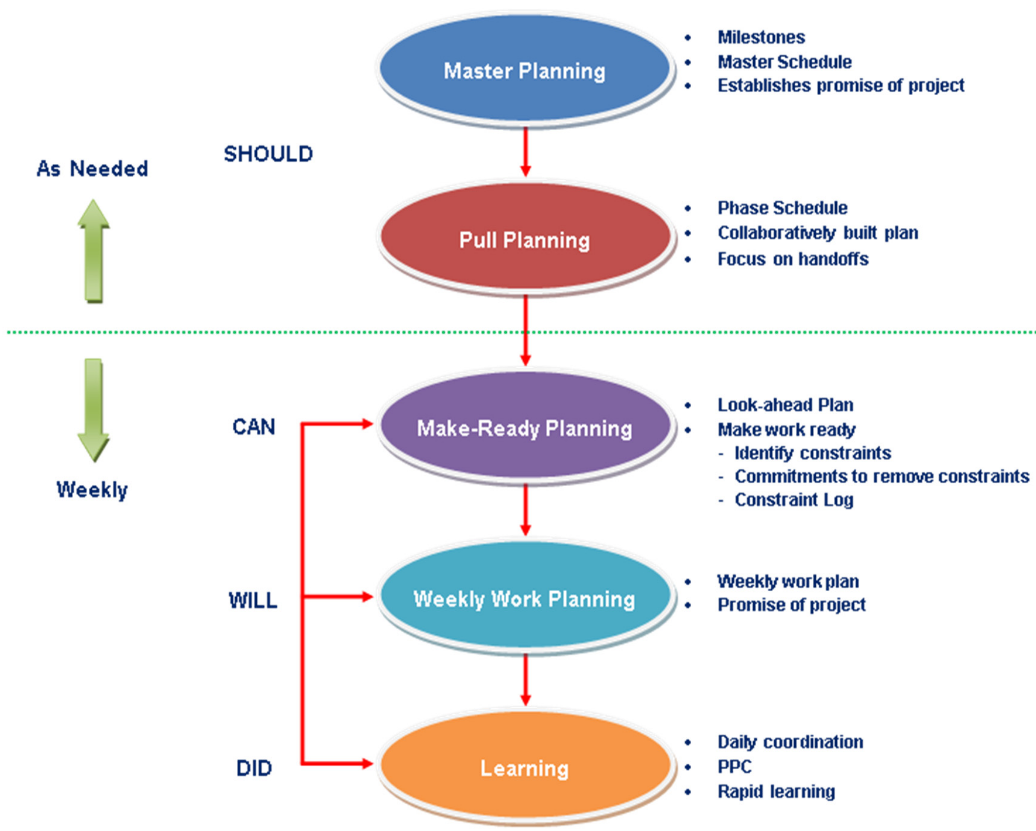

Figure 4.7: Last Planner System (Macomber and Barberio, 2007, cited in Engineers Australia, 2012)

A Phase Pull Plan is defined by an “end” target or event – pouring slab on grade, ready to erect steel, or (in the case of a design phase) target cost agreed upon, permit package issued, etc. The team works backwards (pulls) from the end date to the start of the phase to identify the activities necessary to reach the “end” target. A typical schedule prepared by a planner or project manager in a home office is ineffective, especially if the team members are not committed to it or believe it is inaccurate or impossible to achieve (Engineers Australia, 2012). The team pays special attention to the “handoffs” – what is necessary to be completed in one activity before the next one can begin. The actual time or duration of a phase is based on the master schedule or the team’s best estimate – phases can be measured in hours for a shut-down, weeks for a typical construction activity, or months if the team is developing an overall project plan (Engineers Australia, 2012).

Make-Ready Planning and the Weekly Work Planning require team members' commitment to finish their activities as scheduled and are considered the basis for the increased predictability and reliability of the project’s workflow using LPS. Some building works are usually delayed because work planning does not take all the specific project variables into consideration, as they are based on projects with a high degree of uncertainty. Examples of some variables that are not usually taken into account are: availability of inventory from suppliers, uncertainty of designs and requirements, problems of manpower availability, administrative problems and wrong estimates of performance (Boscà, 2012).

The planning process should focus mainly on managing what can be done; the better we can do our tasks, the better will be the real possibility of progress. “This progress can be influenced if the amount of activities that can be done is low”. In order to avoid this, planners should increase their efforts to remove the obstacles affecting the initiation or continuation of tasks. Hence, the amount that can be achieved will be increased, as well as the options for progress. It is extremely important that management focuses on the root problem, because nothing positive will be obtained from rushing the executors of the activities if they do not receive the necessary resources on time (Boscà, 2012).

Therefore, construction needs to be planned by people holding different positions in the organisation and during different times of the project’s life cycle. LPS provides specific criteria of assignment in order to protect the productive units from uncertainty and variability. The process of applying the system is carried out as follows (Boscà, 2012):

- Reviewing the general plan of work (master scheduling);
- Developing the scheduling phase in the case of complex and extensive projects i.e. identification of the phase that is going to be developed next and devising the plan;
- Developing the intermediate scheduling for an approximate period of one to three months; carrying out constraints analysis in order to avoid any bottlenecks which may be involved in the master scheduling;
- Preparing the weekly scheduling in cooperation with decision-makers or planners: managers, foremen, subcontractors, wholesalers, etc. as part of the inventory of ready activities achieved in the intermediate planning phase; and
- Meeting last planners to verify fulfilment of the weekly scheduling, identifying causes of non-fulfilment, and devising the plan for the next week.

The Last Planner system plays the important role of replacing optimistic planning with realistic planning through the appraisal of workers' performance based on their ability to reliably achieve their targets. The goals of Last Planner are to pull activities by reverse phase scheduling through team planning and to optimise resources in the long term. This is similar to the Kanban system (a production control system for just-in-time production which is of two types: one is called 'conveyance Kanban', which is carried when going from one process to the preceding process. The other one is called 'production Kanban' and is used to order production of the portion withdrawn by the subsequent process (Sugimori et al., 1977)) and production levelling tools in Lean manufacturing (Salem et al., 2005, p.3).

Increased Visualisation

"The Increased Visualisation Lean tool is about the effective communication of key information to the workforce through posting various signs and labels around the construction site. Workers can better remember elements such as workflow, performance targets and specific required actions if they visualise them (Moser & Dos Santos, 2003). This includes notices about safety, schedule and quality. This tool is similar to the Lean manufacturing tool, Visual Controls, which is a continuous improvement activity that relates to process control." (Salem et al., 2005).

Daily Huddle Meetings (Tool-box Meetings)

"Two-way communication is a key to the daily group meeting process, guaranteeing/facilitating the participation of employees. Employee satisfaction (job meaningfulness, self-esteem, sense of growth), as well as problem-solving, will increase with awareness of the project, along with the training provided by other tools." (Salem et al., 2005). The improvement cycle includes conducting a brief daily start-up meeting where team members quickly describe/outline the status of their work since the last meeting, especially in the case of the existence of an issue preventing completion of the work (Schwaber, 1995). "This tool is similar to the manufacturing concept of employee involvement, which ensures a rapid response to problems through empowerment of workers, and continuous open communication through the tool box meetings" (Salem et al., 2005).

The 5S Process

Lean Construction considers the project to be a group of activities providing value to the customer (Dos Santos et al. 1998). The 5S process (sometimes referred to as the Visual Work Place) is about "a place for everything and everything in its place". It has five levels of housekeeping, which aid the elimination of wasteful resources: Seiri (Sort) indicates the separation of needed tools/parts and the removal of unneeded materials (trash); Seiton (Straighten or set in order) is the neat arrangement of tools and materials for ease of use (stacks/bundles); Seiso (Shine) means cleaning up; Seiketsu (Standardise) means continuing to apply the first 3Ss; Shitsuke (Sustain) indicates the creation of the habit of adhering to the rules. This process is similar to the 5S housekeeping system from Lean manufacturing. The material layout is applied to accelerate 5S implementation on the construction site (Salem et al., 2005). Spoore (2003) refers to the 5S as a system based on an area of control and improvement. Implementation of 5S has many benefits, including improved safety, productivity, quality, and improvement of set-up-times, creation of space, reduced lead times and cycle times, increased machine uptime, improved morale, teamwork, and continuous improvement (Salem et al., 2005).

4.2.6 RECOMMENDATIONS FROM PREVIOUS RESEARCH APPLIED TO LEAN CONSTRUCTION

According to Arleroth and Kristensson (2011), construction companies should be familiar with the possibility of savings and increased efficiency in their operations. They should undertake company-wide initiatives to introduce the Lean perspective: sending a few managers or crews to Lean seminars is not enough. There should be a philosophy and working method that is eventually applied in the entire company, otherwise the traditional working method will continue and workers at sites will continue to perform second-rate work rather than concentrating on the planning and efficient execution of their tasks. The Lean perspective should influence company suppliers and subcontractors. Companies should begin by ceasing to focus solely on price and starting to focus on the total cost of different alternatives and working with different suppliers/subcontractors (Arleroth and Kristensson, 2011, p.76).

Moreover, the construction industry should realise the possibilities presented by logistics. Despite the positive effects of having logistics managers at construction sites having been demonstrated by studies such as those dealing with potential monetary savings, it is unusual to find them. This is mostly true, unless the project is one of the largest and most prestigious construction projects for the company. Therefore it is recommended that construction companies consider the hiring of logistics managers for smaller projects as well, not only for the largest ones (Arleroth and Kristensson, 2011, p.76).

Another recommendation is to begin working closely with subcontractors and suppliers in order to redefine and refine processes, which could be achieved by working repeatedly with the same supplier. Repeated work between groups will eventually and continuously improve their teamwork. Construction workers and firms should have better dialogue and team work in order to avoid situations such as tearing down walls because pipes have not yet been installed (Arleroth and Kristensson, 2011, p.76).

It is highly recommended that all construction workers exert extra effort in order to keep track of tools and materials: structure the tool shed, clean up the inventory and sustain a clean and tidy workplace so as to reduce the time spent on unnecessary tasks and small talk with colleagues. In addition, management should study the possibility of paying extra money for delivering material to the construction workers in order to avoid further transportation of materials. The return on this investment would probably be much greater than the money spent from the beginning, since the probability of adhering to the time schedule would increase and perhaps a reduction of lead time might be achieved (Arleroth and Kristensson, 2011, p.76).

4.2.7 LEAN IMPLEMENTATION BARRIER

This section examines and discusses how the implementation of Lean could bring value to the organisation processes and contribute to the achievement of operational excellence, and identifies the challenges and obstacles that could face the organisation. Researchers consider the construction industry to be a slowly progressing industry with numerous problems. Over the past 60 years, the industry has produced several reports aimed at reviewing its performance and suggesting means of improvement (Sarhan & Fox, 2013).

Nevertheless, construction has rejected the borrowing of ideas from manufacturing, believing that construction is different, since construction projects are one-off, project-based and more complex, and face many uncertainties and obstacles (Salem et al., 2006). Moreover, according to this view, construction has unique features which distinguish it from manufacturing. Egan (1998) rejected this idea, maintaining that the construction industry employs many repeated processes (Sarhan and Fox, 2013, p.4). The report of the Construction Task Force to the UK Deputy Prime Minister, John Prescott (1998), on the scope for improving the quality and efficiency of UK construction, indicates the two options facing the construction industry as follows: "to ignore all this in the belief that construction is so unique that there are no lessons to be learned; or seek improvement through re-engineering construction, learning as much as possible from those who have done it elsewhere." (Egan, 1998). Likewise, Koskela (2000) believes that rejection of ideas from manufacturing in the belief that construction is different is just temporary; it may slow down diffusion but will not impede it (Sarhan and Fox, 2013, p.4).

Bertelsen (2004) introduced three alternative strategies for dealing with the challenges facing construction: 1) reduction of complexity to a level where the manufacturing principles can be used as they are; or 2) the development of new management methods for the management and control of construction as a complex system; or 3) the improvement of the product or the process as proposed in Denmark (Bertelsen, 2004, p.50). The product strategy practically means the transfer of more and more parts of the construction work into off-site fabrication, thereby making the site work assembly-only, aiming at developing the onsite construction process in its own right (Bertelsen, 2004, p.50).

Implementation of Lean Construction tools in the United States is limited by the lack of investment in construction industry research (Salem et al., 2005, p.2). Banik (1999) demonstrated the reluctance of the construction industry to invest in research and the improvement of productivity (Salem et al., 2005, p.2). Lean Construction is currently in its early stages of development: the Last Planner tool has been tested and refined only over the last decade. On the other hand, tools such as Visualisation, daily huddle meetings and 5S have not been extensively tested, while concrete procedures for their implementation are still being developed (Salem et al., 2005, p.2).

Identification of the barriers to implementing the LC approach required the development of studies in different countries worldwide. Some of these studies focused on investigating barriers that prevent the diffusion and implementation of LC (Sarhan and Fox, 2013, p.4). Others focused on identifying barriers existing during the execution of LC practices (Sarhan and Fox, 2013, p.4). These barriers could, if not properly managed, influence the application of LC and hinder project performance. If organisations do not understand the factors influencing the successful implementation of LC, they will not know what improvement efforts are needed, where they should be focused and which efforts could produce optimum results (Leong & Tilley, 2008).For this reason, an extensive literature review was conducted by different authors, in different countries, to understand the possible barriers hindering the successful implementation of LC. This literature review classified these barriers into ten different categories: 1) Fragmentation & subcontracting; 2) Procurement & contracts; 3) Lack of adequate Lean awareness & understanding; 4) Culture & human attitudinal issues; 5) Time & commercial pressure; 6) Financial issues; 7) Lack of top management commitment; 8) Design/Construction dichotomy; 9) Educational issues; and 10) Lack of the use of process-based traditional Performance Measurement Systems (PMSs) (Sarhan and Fox, 2013, p.4, 11).

The overall diffusion of Lean Construction within the construction industry is still limited, and its applications are incomplete. The characteristics of the construction industry that are used by Lean Construction opponents as arguments against application are: the one-of-a-kind nature of projects, and onsite production. This leads them to consider the construction industry to be different from manufacturing (Slootman, 2007). Matthews et al. (2000) claim that: “Despite the fact that these characteristics may hinder the efficient attainment of flows as in manufacturing, the general principles of flow design and improvement of construction are still valid and construction flows can still be improved to reduce waste and increase construction value.” (Matthews et al., 2000).

Matthews et al. (2000) have conducted a study on the use of Lean principles in construction which indicates that: “an increasing number of construction organisations have applied quality assurance and total quality management (TQM), first in construction material and component manufacturing and later in design and construction, but this has often been driven by commercial imperative rather than as a business philosophy.” (Matthews et al., 2000).

4.2.8 APPLYING LEAN THINKING TO THE CONSTRUCTION INDUSTRY

Koskela (1992) has the honour of being the first to consider the application of Lean Production in construction. Koskela (1992) originated the transformation-flow-value generation production model, known as the TFV theory of production, which, when applied to construction, could result in the improvement of performance (Sarhan and Fox, 2013). Traditional construction thinking mainly focused on conversion activities regardless of the flow. Koskela (1992) introduced a production review in construction implementing flow processes along with the conversion activities that are crucial to eliminate waste (Sarhan and Fox, 2013). The researcher cites three real examples from different construction companies implementing Lean Thinking (Constructing Excellence, 2004):

First, the Neenan Company, specialising in designing and building, and one of the most successful and fastest growing construction firms in Colorado, attempted to understand Lean Thinking principles and searched for applications to its business, through ‘Study Action Teams’ of employees who were tasked with reconsidering the work method. Neenan achieved a reduction in project times and costs of up to 30%, through developments such as (Egan, 1998):

1 Improvement of worksite flow through defining production units and using tools such as visual control of processes;

2 Hiring design teams to work exclusively on one design from beginning to end and devising a tool known as ‘Schematic Design in a Day’ to speed up the design process;

3 Innovation of design and assembly, for example through the use of pre-fabricated brick infill panels manufactured off-site, and pre-assembled atrium roofs lifted into place; and

4 Supporting sub-contractors' development of tools for improving processes.

Second, using the same number of employees, Pacific Contracting of San Francisco, which originally specialised in cladding and roofing, increased their annual income significantly by 20% in 18 months (Egan, 1998). The aforementioned contractor improved the design and procurement processes that facilitated onsite construction and investment in their projects' front end, reducing both construction costs and durations (Egan, 1998). There are two major problems facing the achievement of flow in the construction process: inefficient supply of materials preventing the smooth flow of site operations and incomplete design information from the prime contractor, leading to a great amount of work redesign (Egan, 1998).

"In order to confront these problems, Pacific Contracting related the efficient use of technology to tools used to improve construction planning. They applied a computerised 3D design system enabling a better and faster redesign and providing better construction information. This system offered many benefits, including isometric drawings of components and interfaces, fit co-ordination, planning of construction methods, motivation of work crews through visualisation, first run tests of construction sequences and virtual walkthroughs of the product. They also applied a process planning tool (Last Planner), developed by Glen Ballard of the Lean Construction Institute, to improve the worksite flow through removing obstacles such as lack of materials or labour." (Egan, 1998).

Third, the Construction Lean Improvement Programme (CLIP) was devised in 2003 for the purpose of supporting the UK construction industry in its drive, inspired by the Egan report "Rethinking Construction", to improve its financial performance, provide a better product and service to its customers, and cope with a skills shortage. "CLIP operates across the whole construction supply chain, from processors of raw materials to clients". It provides the knowledge and practical skills needed to make change happen and to bring about real business benefits (Constructing Excellence, 2004). CLIP has created a number of programmes, adapted to meet the needs of construction but based on a successful Common Approach used across UK industry, allowing companies to make real and measurable improvements to Quality, Cost and Delivery performance, and to improve partnerships with customers and suppliers (Constructing Excellence, 2004).

The hands-on approach of CLIP Engineers led to practical programmes being applied in the workplace, from site to boardroom. These engineers interact with the company's staff to help them to visualise the benefits and achieve sustainable change. These programmes are devised according to the needs of the organisations CLIP works for. Typical products include (Constructing Excellence, 2004): 1) benchmarking and recommendations of product and process; 2) strategy development programme; leadership, planning tools, policy deployment; 3) master class for process improvement; 4) supply chain and supplier development programme; 5) communications, teamwork and team-leader training; 6) Lean assessment; and 7) company and project team roll-out programmes. The results of seven pilot projects based on real construction projects around the UK have demonstrated productivity improvements of up to 50% in key processes.

4.3 APPLICATION OF LEAN THEORY/METHODOLOGYTO CONSTRUCTION ISSUES'

Boscà (2012) demonstrates that complex projects are no longer managed through traditional methods. The more complex and uncertain the projects become, the more the interaction between the activities and the resources grow in ways that are not envisaged by these methods (Boscà, 2012). Lean project management could be considered a substitute approach for dealing with complexity and uncertainty, as well as being the most recent approach adopted by Lean methodology. The latest studies in this regard indicate that traditional methods are suitable for simple projects, whereas Lean methods are suitable for complex projects (Boscà, 2012).

The researcher has found that the best way to illustrate Lean Thinking is to study the Lean Construction practice trips that were carried out by the Lean Construction Institute (LCI). The aim of one of the short study trips, undertaken in the United States in February 1998, was to find out if Lean Thinking principles were applied in any construction companies in the US (Garnett et al., 1998). LCI helped in creating the opportunity to participate in the annual company conference led by the Neenan Company.

Four company case studies were completed as a result of this trip. The University of California at Berkeley and Stanford University were also visited. Garnett et al. (1998) found that the growing community of academics and practitioners in the US are trying to develop Lean Construction in cooperation with the two leading contracting companies, Neenan & Pacific.

The results shown to date include:

- Reduction of office construction times by 25 % within 18 months;

- Reduction of schematic design from 11 weeks to 2 weeks;
- Increase in turnover of 15-20 % (Pacific Contracting);
- Increase in productivity;
- Satisfied clients looking to place repeat orders; and
- Reduction of project costs.

All companies cooperated, and a number of suppliers were very keen to undertake Lean work and fully cooperate. Contracting companies have adopted an experimental approach based upon an understanding of Lean principles and the identification of an appropriate area to trial and first run studies to assess their potential, where full-scale trials are then implemented. Innovations include prefabrication, daily work monitoring, and single piece flow on site, as well as integrated engineering, procurement construction processes and 3D design. Senior management supports and promotes the learning culture as well as the single-minded desire to improve (Garnett et al., 1998). The study proved that there are a number of different applications of Lean principles, with a set of interesting initial results (Garnett et al., 1998). In spite of the lack of a strategic approach, discussions with individual companies generated the need to rethink their business strategy, for the purposes of supporting further development.

Construction contractors are still searching for methods to eliminate waste and increase profit due to the constant decline in profit margins as well as the increasingly intense competition in construction projects (Mastroianni & Abdelhamid, 2003). Among the many approaches for the purpose of construction efficiency and effectiveness improvement, Lean Construction principles can minimise, if not eliminate, non-value-adding work. The construction research community has been analysing the possibility of applying the principles of Lean Production to construction since the early 1990s (Salem et al., 2005, p.1).

Lean principles can be fully and effectively applied in construction by focusing on the whole process of improvement. This requires all parties to be committed and involved, and to overcome obstacles arising from traditional contractual arrangements (Constructing Excellence, 2004). Lean Construction is the result of applying a new form of production management to construction. There are a number of objectives for Lean Construction regarding the delivery process, aimed at maximising performance for the customer at the project level, concurrent design of product and process, and the application of production control throughout the life of the product from design to delivery. Significant research remains to be done to help complete the application to construction of Lean Thinking (Howell, 1999, p.9).

Howell (1999) refers to the similarities between Lean Construction and current practices in the construction industry, as they both pursue better fulfilment of customer needs while reducing waste in every resource. On the other hand, the difference between current practices and Lean Construction is that the latter is based on production management principles as well as producing better results in complex, uncertain, and quick projects (Salem et al., 2005, p.2).

CHAPTER FIVE: BUILDING INFORMATION MODELING (BIM)

5.1 INTRODUCTION

In this chapter, the researcher will focus on one of the virtual design and construction tools used to achieve integration management, namely Building Information Modeling (BIM).

The term 'Building Information Modeling' and the abbreviation BIM have only become common since 2002; however, the concepts and ideas are much older. In the 80s and 90s, 'building product modeling' or 'product modeling of buildings' were more commonly used terms for the technology known currently as BIM (Eastman, 1999), supporting interoperability and communication throughout the life-cycle of a building. BIM is not a simple technology, as it requires a thorough understanding of a number of abstract modelling concepts (Van Nederveen et al., 2010). BIM is not just software; BIM is a process as well (Hardin, 2009).

The glossary of the BIM Handbook defines BIM as "a verb or adjective phrase to describe tools, processes, and technologies that are facilitated by digital, machine-readable documentation about a building, its performance, its planning, its construction and later its operation." BIM activity results in a 'building information model', i.e. software tools that have the ability to assemble virtual models of buildings using machine-readable parametric objects that exhibit behaviour commensurate with the need to design, analyse and test a building design (Sacks et al., 2010). BIM provides a more integrated design and construction process leading to better quality buildings at lower cost and reduced project duration. In this regard, BIM is supposed to lay the foundation for some of the results that Lean Construction is expected to deliver (Sacks et al., 2010).

BIM is the process of computer-generated model development and usage adopted in order to simulate the planning, design, construction, and operation of a facility (Azhar et al., 2008, p.1). It is a new approach to "Virtual Building Construction" based on parametric CAD technology. It is used as a building design and documentation methodology for the purposes of significantly enhancing the building design practice and easing the construction process for everyone involved (Woo, 2006).

For the successful implementation of BIM, detailed and comprehensive planning must be performed; the planning should comprise complete and sufficient information that can be interpreted directly by computer applications to support all lifecycle processes

(Abbasnejad & Moud, 2013). It comprises information about the building itself, as well as its components, and properties such as function, shape, material and processes for the building life cycle (Van Nederveen et al., 2010). Azhar et al. (2008) give figures based on 32 major projects using BIM from Stanford University Center for Integrated Facilities Engineering (CIFE). BIM indicates benefits such as (Collier & Fischer, 1995):

- Up to 40% elimination of unbudgeted change;
- Cost estimation accuracy within 3%;
- Up to 80% reduction in time taken to generate a cost estimate;
- Savings of up to 10% of the contract value through clash detection. Infocomm International(2011) defined clash detection as "a process of finding the building system conflicts and issues by collaborating in 3D. Sometimes referred to as interference checking"; and
- Up to 7% reduction in project time.

5.2 4D SIMULATION

The researcher focuses on one of the product challenges of BIM that of 4D simulation of the construction schedule, which will help in implementing Lean Construction techniques. In his view, based on his experience, the first and foremost process that should be addressed is that of planning and scheduling during the project life cycle, since it is a critical task for construction management, as well as being a fundamental and challenging activity in the management and execution of the construction project. "Four-dimensional (4D) models link three-dimensional geometrical models with construction schedule data. The visual link between the schedule and construction site conditions is capable of facilitating decision making during both the planning and construction stages." (Chau et al. 2004, p.598). The four main processes in the 4D model are (1) Prepare 3D model; (2) Prepare project plan; (3) Prepare 4D simulation; and (4) Prepare cost estimation.

For Mega-projects, many contractors and sub-contractors are involved, which will lead to the preparation of many time schedules for each project. During the development of a master plan for the project, the planning engineers and project managers may find a conflict between those time schedules. Hence, it is necessary to identify time-based clashes before starting the project. Nowadays, construction industries need highly accurate planning and scheduling of the project process to achieve the overall optimisation of time, cost and resources. Engineers still use the older systems, such as Microsoft (MS) Project and

Primavera, for scheduling, and AutoCAD for drawings; in addition, they use traditional planning techniques for scheduling and monitoring progress such as bar charts, CPM, PERT etc. The usage of older systems and traditional techniques only is very problematical and time-consuming, especially in the decision-making process (Naik et al, 2011).

"For most construction projects, the client's requirements are still represented in terms of paper-based working drawings, while the contractor has an important task to formulate a project schedule for the different construction activities on the basis of these working drawings. In this process, planners have to take into consideration practical construction sequence, proper workspace logistics, and feasible resource allocation, which includes labour, material, equipment, and the use of site space." (Chau et al. 2004).

The 4D models give more explicit explanations of construction operations, keeping the client informed about the construction process, and offering a major benefit to the customers, who feel more a part of the process, appreciate the work's complexity, and feel that the contractor is taking an active role to accomplish their goals. 4D models provide a new form of communication that everyone in the construction process can share and use. Their use provides the clients with a better understanding of the construction phase through involving them in construction planning. Also, the 4D model presents both the detailed process of the construction phase as well as the detailed information that can provide more complete answers to clients' questions. For instance, the clients can observe all the processes of construction, such as installation of doors, painting of walls, landscaping, etc. Moreover, animation of the schedule gives the client a better idea of the sequential nature of construction activities. Project managers can also easily see a delay in critical activities and the impact of delays, and can take better decisions to deal with these delays (Collier and Fischer, 1995).

The 3D and 4D technologies offer significant benefits to project teams in the processes of developing coordinated and constructible designs and construction sequences. Specifically, 3D and 4D models enable project teams to identify design conflicts, design errors, sequencing constraints, access issues, fabrication details, and procurement constraints affecting the project delivery process. Moreover, the use of these tools helps project teams to minimise risk and attract quality team members to construction projects. It has been found that these technologies have a dramatic impact on project execution, including (Staub-French & Khanzode, 2007): the elimination of field interferences; less reworking; increased productivity; fewer requests for information; fewer changed orders; less cost growth; and a decrease in time from start of construction to facility turnover.

Hardin (2009, p.4) notes that BIM is not just software but rather a process. He also expresses the belief that many organisations practise BIM once they have purchased a licence for a particular piece of BIM software. Many organisations do not realise that BIM not only means using three-dimensional modelling software, but also implementing a new way of thinking. Fundamentally, BIM is a new way of not doing the same old thing. According to Graham et al. (2011), in the case study of Heathrow Terminal (T5), a 4-D construction planning is defined as a work planning process that adds time as a fourth dimension to programmes with CAD data (2-D or 3-D), creating a real-time graphical simulation of planned works, and the key benefits include: 1) clear visual communication of construction sequence to all; 2) early and ongoing co-ordination between contractors and stakeholders; 3) easy comparison of various programme phasing options; 4) immediate comparison: automatic link between graphics and programmes; 5) usefulness as a tool for reporting progress on site;6) ability to be used at a macro- or micro-planning level; and 7) overall time savings, due to increased logistics efficiency (Hardin, 2009).

In general, BIM technology enables project managers to easily coordinate and supervise the construction process from the conceptual development stage through construction, confirming that the project is delivered on time and within budget. BIM eliminates industry fragmentation and provides a seamless flow during the phases of planning, design, construction, and operation and maintenance (Meadati, 2009). Moreover, BIM implementation offers benefits in all the phases of the project's life, and it gives any-time access to digital data to the owners, clients, engineers, architects, contractors, facility managers, maintenance and operations engineers, safety and security personnel and many others involved in the building life cycle (Meadati, 2009). The overall objectives of 4D simulation regarding construction schedule are (Meadati, 2009):

1. To allow going over construction schedules and 'what-if' scenarios during the project's life cycle and giving opportunities for modifying without cost;
2. To allow architects to analyse site space configuration and minimise clashes between activities and work group;
3. To simulate realistically the construction progress based on activity work-rate approach through the utilisation of interactive 4D CAD visualisation; and

4. To enable architects, planners, and clients to open lines of communication and work together to create a successful plan and add value to the project.

Tulke and Hanff (2007, p.80) have detailed the process of 4D simulation. They argue that a time schedule specifies the tasks required to design and erect a building, the duration of these tasks and the relationships between the tasks. The duration of a task is based on calculations of building quantities on the basis of 2D drawings. Generating a 4D simulation includes these steps: 1) creating a three-dimensional model; 2) this is followed by the very time-consuming manual or semi-automatic linking of 3D objects to the tasks in the time schedule; 3) during linking, adjustments of the CAD objects' granularity (the Oxford Dictionary defines granularity as “the scale or level of detail in a set of data”) to the requirements of the time schedule are necessary; due to the complexity of the CAD software, which involves CAD specialists in the 4D simulation process (Tulke & Hanff, 2007).

5.3 SYNERGY BETWEEN BIM AND LEAN CONSTRUCTION

In the industry of construction, Lean Construction and Building Information Modelling (BIM) are vital drivers for transformation (Eastman et al., 2011). According to recent research, there are considerable synergies between the two (Sacks et al., 2010). The synergies start from the design phase and continue until the construction and facilities management phase (Dave et al., 2013). An overview of the top ten synergies between BIM and Lean Construction is included in the 10 points below (Sacks et al., 2010) cited in (Tezel, 2015).

1. Reduce end-product variability

When the evaluation of design alternatives and their functional properties (i.e. thermal, acoustic, wind etc.) is enhanced, variability caused by late changes ordered by the client during the construction stage is reduced. The application of BIM models evaluates design, constructability and space clashes which improve the quality in the field. Also, complex prefabrication of construction components is enabled by the extended integration of BIM with industrial CNC (Computer Numerical Control) systems, leading to reduction in product variability in the field.

2. Reduce production variability

Automated quantity take-offs linked to BIM models are more accurate than manual processes. Additionally, the late change in the design changes the linked quantity files; this ensures the accuracy of quantities. Moreover, any change in a section or plan influences all other sections and plans, maintaining the design consistency. BIM models provide a single, complete-life cycle data repository that reduces variability through the coordination and project-data handover issues during the project life cycle.

3. Reduce production cycle-durations

Collaborative design and reduced cycle times for the design phase are enabled by quick turnaround of structural, thermal, and acoustic performance analyses; of cost estimation; and of evaluation of conformance to client programme. Also, design cycle times are reduced by parallel processing on multiple workstations in a coordinated fashion (without the need for integration and coordination of the different 2D models). Good design enhances the optimisation and accuracy of operational schedules in the field with fewer conflicts, which consequently reduces cycle-times in the construction phase. Moreover, completion of data repository free of soft and hard clashes on a BIM model reduces the extended cycle-times related to information need and constructability issues in the field.

4. Reduce batch sizes towards single-piece flow

Smaller batches for review and production are enabled by automatic drawings, especially shop drawings for fabrication of steel or precast. The information can be provided on demand, to produce the appropriate quantities at the right time.

5. Use pull systems

Components used in the pull system are only replaced if they are consumed or needed by downstream work units. In order to meet downstream customer demands and control the work-in-progress, upstream work units only produce the appropriate amounts. The BIM database allows construction crews to pull construction drawings when needed and this prevents design drawing overloads or push. The integration of BIM quantity take-offs, company Enterprise Resource Planning (ERP) and suppliers' ERP systems allows Just-In-Time basis material and consumable logistics to be supported for the field through appropriate coordination between the construction field and suppliers.

6. Verify and validate value generation

Automated checking against design and building regulations is enabled by virtual prototyping and simulation due to the intelligence built into the BIM model objects, which improves the efficiency of verification and validation of the design. Process information is verified and validated by visualisation of proposed schedules and visualisation of ongoing processes, while product information is verified and validated by clash checking and solving other integration issues.

7. Decide by consensus

The client easily understands all aspects of the design intent and its parameters through a 3D model that includes the requirements of the conceptual development stage. Client and stakeholder engagement and the Last Planner meeting sessions witness the application of BIM visualisation features to improve communication and coordination during the construction phase. At the conceptual design stage, evaluation of multiple design options for participatory decision making is enabled by rapid turnaround to prepare cost estimates and other performance evaluations.

8. Ensure consistency of requirements

The same objects are represented in multiple places in sets of 2D drawings and specifications. Operators must maintain consistency between the multiple representations/information views through design progresses and changes. This problem is entirely solved through BIM by using a single representation of the information that automatically produces all reports. Communication at the design and construction phases is enhanced through sharing models among all participants of a project team even without producing drawings.

9. Standardise work processes

BIM-based animations of production or installation sequences guide workers to perform work in specific contexts and ensure the correct application of standardised procedures. Also, in order to increase site safety standardisation, BIM models can now perform automatic safety checks to eliminate hazards (e.g. barriers around slab holes or safety proximity warnings). BIM models are increasingly used by construction companies to train their workforce in safety and quality issues in the field.

10. Visualise production process

In “4D” and “5D” tools, visualisation of construction processes is enabled by modelling and animation of construction sequences, which identifies conflicts in time and space, resolves constructability issues with their cost impacts and facilitates process optimisation in order to improve efficiency and safety and allow the identification of the bottlenecks. The improved use of wearable/mobile devices in conjunction with cloud databases (i.e. AutoCAD BIM 360) contributes to ubiquitous BIM visualisation. Also, visualisation and process transparency in the construction and maintenance phase is further supported by the integration of Virtual Reality, BIM models and wearable/mobile devices.

BIM contributes directly to Lean goals: clash detection is a sound example of such a contribution. During the process of BIM, models from separate disciplines (architectural, structural and Mechanical, Electrical, and Plumbing (MEP)) are aligned against each other and are checked for any physical or clearance clashes, which are corrected by designers. The virtual application of this activity saves a significant amount of time and money that would otherwise be wasted through rework or delay. On the other hand, traditional 2D CAD technologies would make it impossible to achieve, while even if drawings are overlaid on each other, they do not always make it easier for the user to identify where the clash would be in a 3D space. Also, there is no method to automate clash checking.

Another example relates to visualisation of co-ordinated /synchronised models. From the early conceptual design stage, models from separate disciplines are synchronised and visualised in order to allow both clients, especially end users, to provide their input, and designers to better understand the requirements of the client. This ensures a much better flow down through the various stages of the project, which contributes directly to the Lean Construction principles regarding waste minimisation and value generation. However, it must be understood that stakeholders should be early involved in the project so as to achieve this.

Lean processes and goals are widely supported by BIM: the use of the BIM model during production is an example of it. Lean Construction has major contributions to make, such as collaborative planning, which is popular as a Lean tool among construction projects in the UK. Stakeholders find it difficult to visualise the task at hand and also the sequence of the process, particularly on a complex project where there are complicated services being installed. Collaborative planning deepens the understanding of the planned activities in advance (Dave et al., 2013).

5.4 INTEGRATING LEAN CONSTRUCTION WITH BUILDING INFORMATION MODELING (BIM)

Lean Construction and BIM do not depend on each other (i.e. Lean Construction practices can be adopted without BIM and vice versa) (Eckblad et al. 2007). This is illustrated by the numerous cases of separate adoption of each in design and construction companies within the past decade. However, the researcher considers that construction projects could be improved through the parallel adoption of BIM and Lean Construction, as they are within the Integrated Project Delivery (IPD) approach. The American Institute of Architects' document on IPD expresses the same idea (Eckblad et al., 2007). "Although it is possible to achieve IPD without BIM, this study recommends that BIM is essential for the efficient achievement of the collaboration required for IPD."

IPD is defined as "a project delivery approach that integrates people, systems, business structures, and practices into a process that collaboratively harnesses the talents and insights of all project participants to optimise project results, increase value to the owner, reduce waste, and maximise efficiency through all phases of design, fabrication and construction."(Eckblad et al., 2007).

Khemlani (2009) reports a detailed case study of a project that applied IPD. The Sutter Health Castro Valley Medical Center project, a $320 million hospital building facility, was built based on the project team's earlier experience in the implementation of BIM and Lean on projects such as the Camino Medical Center (Eastman et al. 2008, p. 358). The discipline models are integrated using collaboration software for coordination and the design is tested for code compliance using the Solibri model checker ("a program that performs automated quality assurance of BIM projects", (BIM Equity, 2013)). The team also uses value stream mapping, one of the Lean tools, to monitor and improve the project processes, for the purposes of minimising the cycles of iteration as the design converges. On this project, a unique professional role, defined as "Lean/BIM project integrator", has been created. The positive results reported to date show how the new project management process combines the areas of Lean and BIM to leverage maximum benefit.

CHAPTER SIX: MEGA-PROJECTS

6.1 INTRODUCTION

Most developing countries need Mega-projects to improve their economic stability, especially Middle-East countries. This research will focus on how Mega-projects can help to meet the requirements of developing countries to improve their financial situation. It will also discuss the risks generated in Mega-projects, which are huge and must be considered at early stages of projects, especially the design phase.

Various terms are used to define large projects in the literature, such as complex projects, major projects, giant projects and Mega-projects (Ruuska et al., 2009). Several authors have defined Mega-projects and discussed their characteristics; the various researchers' definitions of Mega-projects have common characteristics, as follows (Oliomogbe & Smith, 2012): (1) time span: more than a decade (often more than one political regime); (2) cost: greater than £100 million; (3) extensive consumption of resources (money, human, equipment etc.); (4) owner: government/public sector, large size, risk and uncertainty, technological creativity/inadequate experience; (5) social, political, economic and environmental influences; (6) multiple owners; (7) complexity; (8) poor performance (cost, quality, performance, etc.); (9) control issues/prioritising issues; (10) indirect benefits to non-users of the project; (11) located in inhabitable places; and (12) career risk.

The Federal Highway Administration (FAHWA) defines Mega-projects as large infrastructure projects that cost more than $1 billion, or projects of a significant cost attracting a high level of public or political interest because of their massive direct and indirect impact on the community, environment, and state budgets (Haidar & Ellis, 2010). However, no exact definition of a Mega-project has been produced up to now.

Also, what distinguishes it from any other large or complex project is not yet understood. Exceeding one billion dollars and entailing cost overruns (Flyvbjerg et al., 2003) are the common features mentioned by practitioners and researchers (Fiori & Kovaka, 2005).

Definitions of Mega-projects should be put forward within the framework of their construction management, i.e. projects with activities, resources, budgets and deadlines. According to Capka (2004), Mega-projects are expensive projects requiring the management of numerous concurrent and complex activities, in addition to the maintenance of busy schedules and limited budgets (Capka, 2004). There are more elaborate definitions describing Mega-projects as complex, meaning that they do not often meet cost estimates, time schedules, or anticipated project outcomes. Other definitions describe Mega-projects as projects involving huge technological creativity with high risk, conflict, uncertainty, and poor cooperation between partners (Van Marrewijk et al., 2008).

In the Saudi construction industry Mega projects require care in the project development process to reduce any possible optimism bias and strategic misrepresentation. Examples of megaprojects include bridges, tunnels, highways, railways, airports, seaports, power plants, dams, wastewater projects, Special Economic Zones (SEZ), oil and natural gas extraction projects, public buildings, information technology systems, aerospace projects, and weapons systems (Husein, 2013).

6.2 THE IMPORTANCE OF MEGA-PROJECTS

Mega-Construction Projects (MCPs) provide a strategic option for achieving objectives of sustainable development in developing countries. These projects are identified by the need for high design knowledge and technical skills, competent human resources and managerial capabilities, as well as high-cost investment. However, developing countries lack many of these requirements, leading to the obstruction of MCP development (Othman, 2013). Developing countries' governments are developing MCPs in order to achieve the social and economic sustainable objectives of approximately 85.4% of the world's population. They manage to do this through the accomplishment of infrastructural, industrial, educational, cultural, transportation, medical, and residential projects fulfilling society's needs and requirements (Othman, 2013).

6.3 THE CHALLENGES PRESENTED BY MEGA-PROJECTS IN CONSTRUCTION INDUSTRIES

Mega-Construction Projects (MCPs) are considered complex, risky and time-consuming operations, funded by governments and carried out by national and international participants with different cultures, backgrounds, political systems, and languages (Shore & Cross, 2005). These projects attract high levels of public and political attention as a result of the substantial costs, as well as the direct and indirect impact on the community, environment, and budgets (Van Marrewijk et al., 2008 and Capka, 2004). Due to the unique nature and characteristics of MCPs, they require high design knowledge and technical skills, competent human resources, professional managerial capabilities and large-scale investment (Flyvbjerg, et al., 2003).

On the other hand, developing countries experience shortages in providing such essential knowledge, skills, capabilities, and funds, which consequently hinder the development of MCPs. Attempting to support the governments of developing countries in the achievement of sustainable development objectives, researchers such as Othman aim at identifying, validating and classifying the obstacles hindering the delivery of MCPs in developing countries (Othman, 2013, p.730).

These projects are extremely complex and difficult, and require the integration of technology, manpower and extremely consistent project management to guarantee the continuous focus and commitment of workers to the project. “Contingencies are an integral and vital part of mega-project management, given the sheer scope, scale, timing and sometimes uncertainty of the projects, and this is where the Joint Venture (JV) partners need to understand the risks and share the same risk appetite and philosophy when managing and responding to these risks.” (Deloitte GCC Powers of Construction, 2013, p.22).

6.4 THE KINGDOM OF SAUDI ARABIA

The Kingdom of Saudi Arabia (KSA) is an Arab state in Western Asia; it consists mainly of the bulk of the Arabian Peninsula. Saudi Arabia has a land area of approximately 2,150,000 km^2 (830,000m^2), and hence it is geographically the second largest state in the Arab world after Algeria. KSA is the only nation to overlook both the Red Sea and the Persian Gulf, and most of its terrain consists of arid, inhospitable desert or barren landforms. Since its foundation in 1932, KSA has been an absolute monarchy, effectively a hereditary dictatorship which is governed on Islamic lines. KSA discovered petroleum in 1938 and it controls the world's second largest oil reserves, and is the world's largest oil producer and exporter. The kingdom is categorised by the World Bank as high-income, with a high Human Development Index (Husein, 2013).

Being the largest exporter of oil in the world, Saudi Arabia has witnessed a constant rise in economic activity, especially the construction sector. Improving the Saudi infrastructure has been a matter of concern to the Saudi Government; statistics show that this concern will remain at the top of the agenda of Saudi decision-making. The Government has shifted its focus to the housing shortage in Saudi Arabia, resulting from increasing population growth (Husein, 2013).

The Saudi construction market plays a significant role in the Middle East; it is currently estimated to be worth >$122 billion per year (in recent times) and this is anticipated to reach >$610 billion in next five years (Alrashed et al., 2014). Although the data on the actual percentage of success rate and vital risk factors in aforementioned projects is still limited, construction projects in the residential sector are in a better state than those in the commercial sector. Consequently, this study can only provide estimates for the risk evaluation of recent Saudi construction projects as well as a new risk evaluation method for current projects: this analysis was based on a new linear decision-making model. Furthermore, this study tackles the risk management applications applied in both international and national construction companies (Alrashed et al., 2014).

In the Gulf region, the Saudi construction sector is considered the largest and fastest growing market. Ongoing construction projects in the Gulf are valued at $1.9 trillion (SR7.1 trillion), with one quarter of the developments in Saudi Arabia alone. Saudi Arabia has a number of positive economic, demographic, and geographic features, which have combined with continued government support to successfully overcome the current economic downturn in comparison to most of its Gulf neighbours. Construction experts state that 34 contracts, each with a value over $500 million (SR1.9 billion), were awarded in the first two quarters of 2009. These contracts represented a combined worth of $50.1 billion (SR187.9 billion), i.e. a decrease in the total value of the 49 contracts awarded compared to the same period in 2008, with a total worth of $63.5 billion (SR238 billion) (The U.S.-Saudi Arabian Business Council (USSABC), 2011).

Furthermore, the Saudi Government is determined to support the growth of the economy. Saudi Government officials have announced that the Kingdom will allocate an estimated $400 billion (SR1.5 trillion) to large infrastructure projects over the next five years. Construction experts estimate that the Saudi Government invested nearly $137 billion (SR513.8 billion) on construction projects in the period between October 2008 and April 2009. The figure is more than twice the estimated value of projects that have been delayed ($62 billion) during this same period (The U.S.-Saudi Arabian Business Council (USSABC), 2011).

6.5 PRESENTATION OF AN ACTION RESEARCH STUDY

The researcher chose a Mega-project in the KSA as an action research study. The project is the “Site Development of the Industrial City of RAS AL-KHAIR” (Fig. 6.1). This project has played an important role in the development of the huge industrial city of Ras Al-Khair, which has had a significant effect on the economy of the country. The contract value is SR750 million, (around $573 million). Considering the Saudi Arabian currency in relation to the budgets of construction projects in the Middle East, which is considered a Mega-project, the researcher chose it to implement the selected method of Lean Construction. The researcher critically analyses the traditional methods of solving construction problems and compares them to the selected technique of Lean Construction in order to achieve the main objective of this research. His conclusions so far are that the Mega-project must be carefully planned and managed, all project parties should be involved in the big picture from an early stage in the project and that lessons must be learned from similar attempts that were applied previously in other countries.

The Scope of Work of the project is to construct and develop approximately 1,427 hectares of industrial land. It is part of the ongoing development of Ras Al-Khair Industrial City (RIC). The main objective is to procure, supply and construct the facility within 30 months from Notice To Proceed (NTP).

The theoretical project execution plan, at an early stage of the project, provided a framework for assisting top management, the architect and the project management team to identify the project's objectives. It also determined the roles and responsibilities of each party, as well as the details and scope of the information to be shared. Value for money and fast delivery of the project are the major objectives that need to be achieved throughout the project's life cycle.

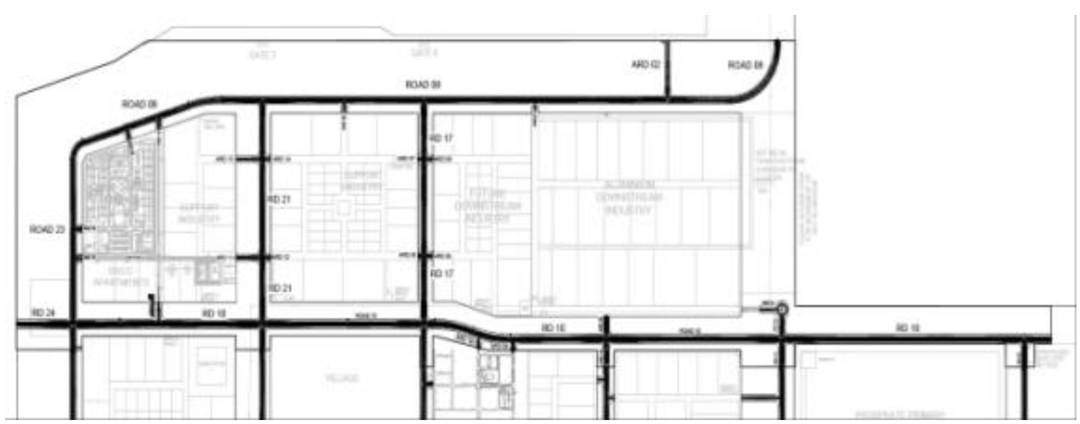

Figure 6.1: The Site Layout of the Site Development Project: 'Selected Mega-project in the KSA' (Royal Commission, 2013)

It is important to examine the traditional methods that are usually implemented in infrastructure projects and compare them to Lean Construction. The KSA Government requested that the project be completed in 30 months, as scheduled. New challenges are likely to appear, and following Lean Construction techniques throughout the project phases will require a high level of awareness from the project team. A final predicted challenge is to ensure and demonstrate that the selected method encourages a positive approach on the part of the contractor.

CHAPTER SEVEN: REVIEW OF DEVELOPED LEAN FRAMEWORKS AND ASSESSMENT TOOLS

Based on the review of literature, some examples of developed frameworks and assessment tools are presented below.

7.1 DEVELOPED LEAN FRAMEWORKS

7.1.1 LEAN IMPLEMENTATION ASSESSMENT (LIMA) FRAMEWORK

A framework for assessing the implementation of Lean Construction within construction organisations was developed by Ogunbiyi (2014) for the purpose of assessing the process of Lean implementation and focusing on areas for improvement (Ogunbiyi, 2014).

According to Ogunbiyi, the LIMA framework could be considered as a self-assessment framework that gives focus to positioning and implementation of the strategy and the measurement method the organisation applies to tangible and intangible benefits of Lean. Ogunbiyi's Lean implementation assessment framework is based on all the perceived components of Lean implementation as well as the expected return thereafter, i.e. the drivers, barriers, success factors and the benefits derived from Lean implementation (Ogunbiyi, 2014). The proposed framework focuses mainly on Lean implementation in sustainable construction for the purpose of enabling construction organisations to evaluate and analyse their implementation of Lean efforts and assess their benefits. The Lean implementation assessment framework is a means and not an end in itself, i.e. it is a reflective guide that promotes the awareness of implementation issues as well as the benefits of implementing Lean (Ogunbiyi, 2014).

The LIMA framework was adopted from The European Foundation for Quality Management (EFQM) model by using the nine criteria of the EFQM. Figure 7.1shows the significant issues considered in the LIMA framework as follows: (1) Policy and strategy deployment; (2) Leadership and direction; (3) People management; (4) Resources; (5) Processes; (6) Drivers for Lean; (7) Success factors; (8) Barriers; and (9) Business results (benefits) and organisational learning (Ogunbiyi, 2014).

The LIMA framework is a roadmap that explains the processes and guidelines applied to the assessment of Lean implementation efforts. Section1sets up the implementation goals through the development of policy and strategy positioning. Section 2 provides the Lean implementation issues which enable the company to assess itself. Section 3 then describes the application and implementation phase which outlines the measures applied to track the benefits of the Lean approach in sustainable construction. The benefits are divided into environmental benefits, economic benefits, and social benefits (Ogunbiyi, 2014).

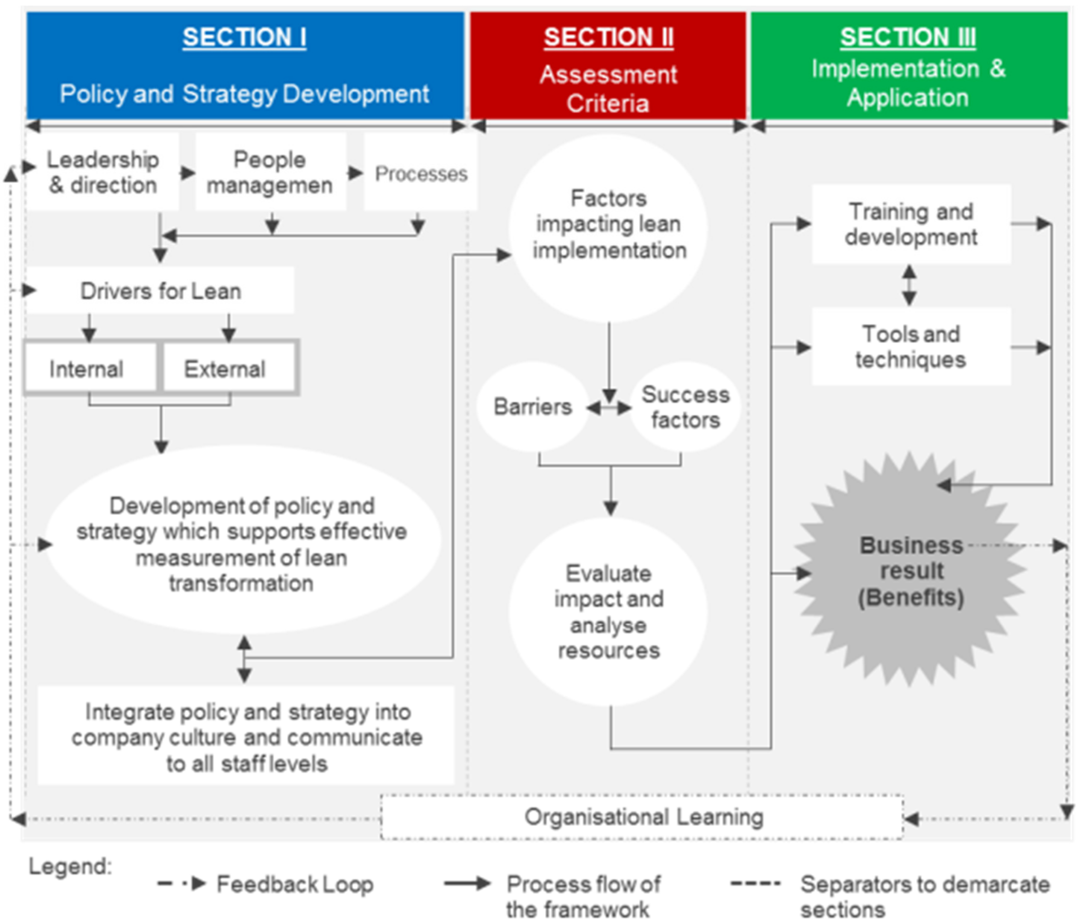

Figure 7.1: LIMA Framework developed by Ogunbiyi (2014)

7.1.2 THE FRAMEWORK FOR LEAN PRODUCT LIFECYCLE MANAGEMENT

Hines et al. (2006) developed the framework for Lean product life cycle management, which is considered a theoretical model containing six distinct stages, starting with the development and understanding of customer needs and the established current product life cycle management status quo. Some of the fundamental steps necessary for effective Lean overall process management are described in the developed framework. During the development of this framework, the adopted approach explained how a single project can be managed more effectively according to both technical and people-based perspectives.

The six steps undertaken in the framework consider customer needs, value stream mapping, the improvement of both end-to-end technical processes and end-to-end people processes, as well as the development of the single project standard and the complete process standard.

Understanding Customer Needs

The first principle of Lean thinking is the basis for understanding of customer needs as defined by Womack and Jones (1996). During any Lean process, the fundamental starting point is to focus on customer needs. However, the definition of customer needs given by Womack and Jones (1996) was described as narrow according to Hines et al.(2006),who extended their definition of the customer voice to include a minimum of two types of customer; the external buyer or end-user of the product; and the internal buyer or end-user of the process under consideration.

Value Stream Mapping

The second step in the developed framework, which is an essential part of Lean thinking, is the mapping of the current state of a process and the development of a future state. According to Hines et al. (2006), the process may include a number of value stream mapping tools; however, the four field mapping tools first described by Dimancescu (1992) are the most appropriate. These mapping tools describe an existing (or planned) project within four fields, namely cross-functional participants or stakeholders; various phases (in this case a request for quotation); a flow chart of the detailed activities within the phases; and the standards by which these processes are performed (Dimancescu, 1992).

Improving end-to-end Technical process

The third step of the developed framework introduces Quality Function Deployment (QFD) as the primary tool for improving the end-to-end technical part of the process (Clausing, 1994). It is worth noting that the execution of the third and the fourth steps of the framework should happen concurrently, as the technical and people aspects need to be applied together in order to lead the project to success (Hines et al., 2006).

Improving End-to-end People Process

The application of Knowledge Innovation Visible Planning (KIVP) is the fourth part of the developed framework. It is a people-centred approach, developed by Japan Management

Association Consultants (Tanaka, 2002), that focuses on the fact that people produce innovative products within the process.

Developing the Single Project Standard

Developing the single project standard is the fifth step in the developed framework. This stage includes the consideration of the attempt to move from a single project theoretical-world environment to one that has repetitive cycles of product development, where future innovations in the project management can be incorporated (Hines et al., 2006).

Developing the Complete Process Standard

The final step of the developed framework is the development of the complete process standard. This stage transforms textbook theories to practical real world solutions. Hines et al. (2006) believes that the majority of texts tend to concentrate on the successful introduction of products to market and neglect the fact that most firms are developing multiple products at one time. The case is worse in the literature on technical product development, because it is dominated by examples from low variety and high innovation industries like the automotive sector.

This framework is considered limited, since it appears to be partial or incomplete and was developed in the product development area. Also, in order to ensure its robustness in the development of competitive advantage, the framework is yet to be tested in a number of different environments.

7.2 PROPOSED ASSESSMENT TOOL

7.2.1 LEAN ENTERPRISE SELF-ASSESSMENT TOOL (LESAT)

The Lean Enterprise Self-Assessment Tool (LESAT) is a tool for the assessment of enterprises in order to provide leadership with the guidance required through a transformation process leading to enterprise excellence (Massachusetts Institute of Technology, 2012). The Lean Advancement Initiative at MIT brought together a team of industry, government, and academic members who developed LESAT. It was originally developed with input from the aerospace industry in both the United States and the United Kingdom, and has substantial applicability to a diverse range of manufacturing industries (Massachusetts Institute of Technology, 2012). The assessment has been used in healthcare and service sectors without modification because of its broad applicability across a wide range of industries (Casey, 2007).

This assessment assists in the identification of performance gaps as well as the prioritisation of points of focus, and the provision of` a future-state vision for the enterprise (Massachusetts Institute of Technology, 2012). As the transformation plan is implemented, ongoing assessment can then measure progress and offer feedback, which can then be used to review and revise the transformation plan over time (Nightingale & Mize, 2002).

The assessment process consists of five key phases, each of equal importance (see Figure 7.2). The sequence of the implementation of phases should be followed, because output of each phase serves as input for the next (Massachusetts Institute of Technology, 2012). For instance, the assessment plan must be developed in line with the objectives identified in the first phase using the available resources; improvement actions cannot be formulated until assessment results have been analysed and evaluated. The assessment process is iterative (Massachusetts Institute of Technology, 2012). After the assessment is performed and the results are analysed, participants may evaluate the effectiveness and efficiency of the assessment process in order to identify needed improvements. The new assessment cycle starts with the review of the implementation of improvements in the assessment process (Massachusetts Institute of Technology, 2012).

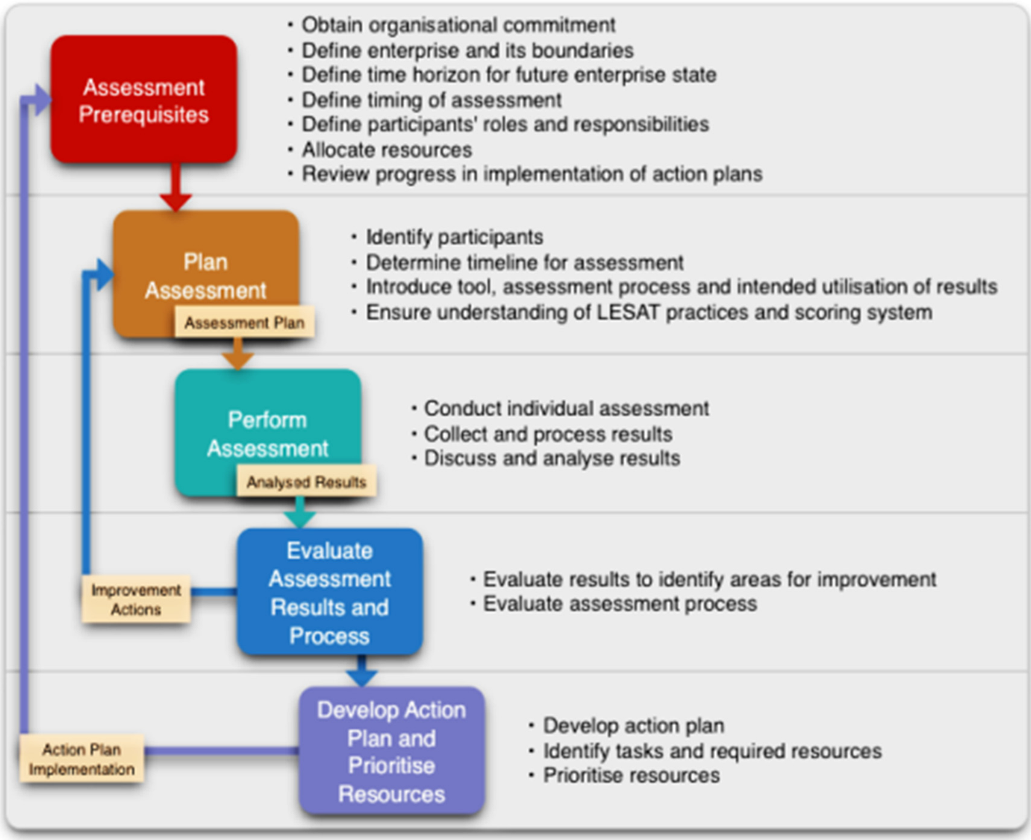

Figure 7.2: LESAT assessment process

7.2.2 THE HIGHWAYS AGENCY LEAN MATURITY ASSESSMENT TOOLKIT (HALMAT)

The assessment tool is purposefully used to provide an organisation with a structured assessment form concerning its position in terms of implementing a Lean culture (Highways England, 2012). This process aims at highlighting the actions required to improve and use this information to help drive the Lean adoption process (Highways England, 2012). This Lean Toolkit assists the implementation of this process. It has two main aims (Highways England, 2012):

1) To enable organisations to assess their Lean awareness, using a series of exam questions.
2) To provide a structured method for the organisation to carry out a moderation of self-assessments and also identify the best practice in which Lean principles can be applied within the supply chain.

7.2.3 LEAN CONSTRUCTION ASSESSMENT FRAMEWORK (ENGINEERING AUSTRALIA, 2012)

Engineering Australia (2012) developed the Lean Construction Assessment Framework, which consists of the 10 recommended practices listed below. It includes the processes used by the project and what the evidence looks like for each recommended practice and at each level (1-Aware, 2-Ad-hoc, 3-Localised, 4-Integrated, and 5-Best In Class). Tables below (7.2 to 7.11) illustrate the activities involved in each practice.

1. Eliminating waste (not just defects) and Continuous Improvement (CI)

The first step in the process is to identify which key areas, tasks, or crews will be targeted to eliminate waste. Eliminating waste means working differently and this takes resources, so it is sensible to do this where you will get the largest return initially. Ideally, everyone on site should understand, look for and work to eliminate waste, so a series of tasks was chosen to work on to grow these skills within our organisation (Engineers Australia, 2012).

Continuous Improvement in all its forms is done with the aim of improving safety, quality, and productivity on site. In addition to the returns from each small Operational Continuous Improvement, LEAN seeks to develop the people themselves. The more someone experiments, the more they will learn and the better they will become at Continuous Improvement. Continuous Improvement is an activity that must be done by the crews, team leaders and superintendents themselves. In this way, they will own the process and start to see opportunities more clearly (Engineers Australia, 2012).

2. Last Planner System

The deployment process steps of the Last Planner System (LPS) are as follows: (1) select project (or portion of), phase, team and leader to implement the Last Planner System; (2) introduce the LPS process to the team; (3) review the Pull Phase Plan and agree on its relevance to and accuracy for the work to be performed; (4) ideally, the team members or their foreman will have participated in the development of the Phase Pull Plan; (5) print out or display the next six weeks of work from the Pull Phase Plan; (6) review the next six weeks of activities to determine whether there are any constraints to accomplishing the tasks shown on it; (7) list these constraints and agree on who is going to remove them and when (Engineers Australia, 2012).

3. Pull Planning

Team members must understand their part or role in the process being Pull Planned. Openness and willingness to discuss their activities is essential to the success of the Pull Plan – their ability to listen and understand other's roles and constraints during the process is critical to a successful Pull Plan. The facilitator or leader of the Pull Plan must be open to comments and requests from all the team members and not stifle discussion, especially about the requirements for handoffs (Engineers Australia, 2012).

4. Target Value Design and Target Costing

The team (owner, management, engineers, designers, etc.) must understand that the Target Cost is a design parameter that must be achieved, much as throughput, quality or safety is. The team will regularly review the current status of the project's progress toward (or away from) the target cost and work to meet the target. Typically, multi-functional teams are established to work on each of the cost "buckets" (Engineers Australia, 2012).

5. Building Information Modelling - BIM (expanded 3D CAD)

BIM provides one of the most important breakthroughs in construction planning, design and execution since the Critical Path Method of planning and scheduling became common. However, the team must learn to use the model, to trust the people constructing it and to regularly "Go & See" what is happening on the model. When a team agrees to use BIM as their primary means of collaboration and design interaction, it is important that all members agree to this and that all members use the model as their design documentation. If one member requires hard-copy 2D drawings for review or checking, many of the advantages of using BIM are lost (Engineers Australia, 2012).

6. Information Centre Meetings

Information Centre Meetings are 10 – 15 minute stand up meetings around a whiteboard to review Key Performance Indicators (KPIs) for the team on a daily basis. Information Centre Meetings form the nerve centres of the project, ensuring each person on site is aware of their role, delivering the site KPIs and enabling problem-solving around concerns as they arise.

These meetings take place at workgroup, contractor and site levels and enable information, targets and results to flow up and down the site organisation. The workgroup Information Centre Meetings happen as the pre-start meetings between the supervisor and workgroup in the crib room, office or at the worksite (Engineers Australia, 2012).

7. Standardised Work

Standardised Work increases productivity, quality and safety by having an agreed best practice for doing a specific work task (Engineers Australia, 2012).:

- It forms the foundation for Continuous Improvement and the involvement of the workforce in Continuous Improvement
- It enables us to balance our processes and ensure no-one is overloaded or underutilised
- It is written by the team themselves to include a detailed description of the work; with key safety, quality and knack points included
- It is valuable for training, with new workers being taken through the Standardised Work Document to ensure that the task is clear and all safety, quality and knack points are covered (knack points are small tricks of the trade that an experienced person will have built up over the years)
- It is a work group-based method of recording the safest, best quality and most efficient way to do a particular job.

8. 5S and Visual Management

5S and Visual Management are part of the foundation of LEAN, enabling operational stability. They increase productivity, quality and morale by having a safe and efficient site. In 5S we think of how to best place everything we need on site. At the macro level this includes site layout, access points, laydown area positioning, work fronts and crib rooms. The micro level may include positioning of grinding tools in a storage container, colour coding welding equipment or sorting a computer filing system in the office. In Visual Management we think of how to make the area in which we work tell us a story by visual means – are all my tools here, do I have enough consumables, are the parts for tomorrow's job in the staging area? These techniques tell us whether we are in control or not, allowing us to manage by exception, by highlighting abnormalities. They are also fundamental to the engagement of all employees, increasing ownership of the work site and morale – very few people want to work in an untidy, disorganised environment (Engineers Australia, 2012).

9. Built-in Quality

One of the pillars of Lean is Built-in Quality, which is used to avoid the waste of rework and the cost of repairs to a job. In a Lean organisation a worker has three responsibilities: (1) do not accept poor quality, (2) do not make poor quality, and (3) do not pass on poor quality (Engineers Australia, 2012).

Quality should be built in at the start of a project and as a result of previous lessons learnt. Once on site, the following should happen to identify causes of quality problems (Engineers Australia, 2012):

- All members of staff will have an initial training on Standardised Work, 5S, Built-in Quality and Error Proofing.
- A tradesperson sees a quality issue; stops work to call the supervisor and then waits for his arrival.
- The two discuss the issue and determine root cause (the 5 Whys may be used). Root causes are much easier to determine when you can see the issue in its raw state, when it has only just happened (easier to see the smoking gun)
- The immediate action is decided upon and the supervisor notes the quality issue.

10. Just-In-Time (JIT)

Just in Time means producing or providing only what is needed, when it is needed, and the amount needed – no more, no less. It is the right part, at the right time, in the right place. Just in Time has become shorthand for the Lean Material Management functions, encompassing Push versus Pull Systems for inventory delivery (Engineers Australia, 2012).

JIT is a Pull System that responds to actual customer demand. In essence, products are “pulled from” the JIT system. JIT only commits the resources needed to meet the customer’s needs. It leads to reduced inventories (and space), higher human productivity, better equipment productivity and utilisation, shorter lead times, fewer errors, and higher morale (Engineers Australia, 2012).

- Part costs: low scrap cost, low inventory cost
- Quality: fast detection and corrections, and higher quality of parts purchased
- Design: fast response to engineering change
- Administrative efficiency: fewer suppliers, minimal expediting and simple communication and receiving
- Productivity: reduced rework, reduced inspection, and reduced parts delay.

Table 7.1: Eliminating waste (not just defects) and Continuous Improvement (CI)

Recommended Practice		LEVEL				
		1 – Aware	2 – Ad-hoc	3 – Localised	4 – Integrated	5 – Best In Class
Eliminating waste *(not just defects)* and Continuous Improvement (CI)	What processes does the project use for eliminating waste?	• Few participants understand waste or know how to identify and eliminate it. • Some awareness of CI.	• Types of waste sometimes taught to team members. Some waste and process walks conducted. • Value determination (who is customer understood • Some connection with CI and improving processes.	• Waste eliminated in significant areas, and stories spread about Lean processes achieved. • New projects address potential waste. Processes in new projects address, uncover, and eliminate waste. • Connects CI with improving internal processes.	• Waste reduction is ongoing part of work. New and current projects can demonstrate waste reduction and elimination in various areas. • Architects, engineers, contractors, and subs vigilant and skilled in reducing and eliminating waste. • Connects CI with all process improvements.	• All participants practise waste elimination and prevention in project activities.
	What does evidence look like?	• Waste not a topic of meetings or reviews. Waste is moved around rather than eliminated. • People are blamed for defects, corrections, high costs, and systemic causes are ignored.	• Waste identified in some areas and among various participants. • Waste sometimes a topic of investigation or discussion in planning and review.	• Each person takes responsibility for eliminating waste. • Lean methods used such as Waste Walks, Value Stream Mapping, 5-Whys and 5S in business processes and work areas.	• Architects, engineers, contractors, and subs vigilant and skilled in reducing and eliminating waste. • Operational and Tactical CI is common	• Savings and efficiencies obvious from ongoing and integrated work to eliminate waste. • Visitors regularly remark on exceptionally clean and orderly sites.

Table 7.2: Last Planner System

Recommended Practice		LEVEL				
		1 – Aware	2 – Ad-hoc	3 – Localised	4 – Integrated	5 – Best In Class
Last Planner System	How does the project use the Last Planner System?	• Some limited knowledge or practice of Last Planner System • No regular education in Last Planner System in place	• Some team members have participated in Pull Planning sessions. • Team is aware of requirements defined in Pull Phase schedule. • Last Planner System is discussed and the concept of Make Work Ready and Weekly Work Planning is understood.	• Make Work Ready Schedules are discussed at meetings. • Team members have identified Constraints on the MWR schedule and look for ways to remove them. • Trade partners and foremen have been asked to prepare Weekly Work Plans • PPC is calculated and discussed.	• Make Work Ready Schedules and Weekly Work Plans are the focus of weekly work planning meetings. • Huddles are held each morning where WWPs and task completion are discussed. • Team has established a goal for PPC	• Team actively plans to improve PPC – their goal is 100% • Team requires new members to learn and participate in LPS. • All team members prepare and submit their WWP in a timely fashion. • Contractors are evaluated based on their LPS performance.
	What does evidence look like?	• Some trade partners may practice Last Planner System, but the traditional "command and control" approach is standard practice on the site. • 21 day rolling schedules are used with little commitment to achieving dates on them.	• Team has Last Planner forms available but do not use them in meetings. • Superintendents do foremen talk about LPS but do not complete forms or make commitments.	• PPC charts are displayed. • Constraint logs are distributed and get results. • Weekly Work Plans are available to all team members. • Someone is assigned to compile an overall project WWP.	• Weekly Work Planning meetings are collaborative. There is a facilitator but no "commander" • Team members debate the best way to accomplish goals. • PPC and variances are discussed. • Management asks about PPC and variances.	• Steadily increasing PPC. • Team and management take steps to learn from and minimise variances. • PPC and variances are part of project evaluation.

Table 7.3: Pull Planning

<table>
<tr><th colspan="2" rowspan="2">Recommended Practice</th><th colspan="5">LEVEL</th></tr>
<tr><th>1 – Aware</th><th>2 – Ad-hoc</th><th>3 – Localised</th><th>4 – Integrated</th><th>5 – Best In Class</th></tr>
<tr><td rowspan="2">Pull Planning</td><td>How is Pull Planning used on the project?</td><td>• Some knowledge or practice of Pull Planning. No regular education on Pull Planning in place.</td><td>• Pull Planning used occasionally, plans are documented and saved for future reference.</td><td>• Pull Planning is used regularly to plan new projects or phases of projects.
• Pull Planning is taught to new architects, engineers, contractors, and subs if they are not practising it.</td><td>• Pull Planning is integrated in designing and building facilities.
• All participants practice Pull Planning in their own organisations.
• Phased scheduling approach to identify major handoffs.</td><td>• Pull Planning is used for planning all activities – not just design and construction.
• All team members including subcontractors require planning and commitments to be based on a Pull Plan session.
• Management requires Pull Planning to be performed prior to making commitments.</td></tr>
<tr><td>What does evidence look like?</td><td>• Some trade partners may practice Pull Planning, but the traditional “Push” approach is the standard practice.</td><td>• Few plans or schedules have been developed in a collaborative fashion.
• Pull Planning is initiated by Lean SME or External Coach when performed.</td><td>• Schedule improvement and production efficiencies from Pull Planning apparent to those participating in specific projects.
• External coaching used to support team leaders</td><td>• Pull Planning integrates with other project schedules and plans.
• Internal coaching done by team leaders.
• Savings and efficiencies from Pull Planning are quantifiable.</td><td>• All trade foremen and project managers conduct Pull Planning without assistance from specialist or coach.
• Cost savings and production efficiencies from Pull Planning are substantial.</td></tr>
</table>

Table 7.4: Target Value Design and Target Costing

Recommended Practice		LEVEL				
		1 – Aware	2 – Ad-hoc	3 – Localised	4 – Integrated	5 – Best In Class
Target Value Design and Target Costing	How is the project using target budget and estimates?	• Target budget set after design completion.	• Target budget developed during design process but set after design completion.	• Target budget developed and set early in design by integrated team. • Cost is a design element considered with others such as throughput, constructability, safety, etc.	• Target budget developed for each element cluster. • Multi-functional teams are responsible for each cluster.	• Target budget cluster supported by enhanced estimate detail. • All team members are aware of progress towards target cost.
	What does evidence look like?	• Value engineering and cost reduction rework cycles the primary process for maintaining budget.	• Design is evaluated for constructability. • Benchmarks are used in setting initial target budgets.	• Target budget is set prior to design and tracked periodically. • Visual controls in place for team to track cost status. • Progress above or below the target cost is discussed at every team meeting.	• Designers, builders, and end users share the responsibility for assessing value and for selecting how the value is produced. • Real time cost updates with design updates. • Budget allocations are moved freely across clusters to meet project target budget.	• A mechanism and visual display is in place to evaluate the design against the budget. • Scheduled ongoing reviews track achievement of targets. • Scope and cost are kept tightly aligned trough frequent estimate updates and reconciliation.

Table 7.5: Building Information Modelling - BIM (expanded 3D CAD)

Recommended Practice		LEVEL				
		1 – Aware	2 – Ad-hoc	3 – Localised	4 – Integrated	5 – Best In Class
Building Information Modelling – BIM (expanded 3D CAD)	How does the project BIM?	• Some 3D modelling	• 3D modelling overdone (unnecessary detail or components). • Drawings on FTP site. • Architect or engineer leads BIM.	• Clash detection. • Modelling done only as it adds value to project. • Architect or engineer hands BIM model off to Construction after Detailed Design.	• Estimating is based on BIM. • Drawings on Integrated Server (Big Room). • Architect hands BIM off to Construction Management after Criteria Design. • BIM is available on site for use by craftsmen.	• Database for as-built use by Facilities. • Construction Management leads BIM use. • Digital prototyping and construction simulation.
	What does evidence look like?	• Most design is still 2D. • Many RFIs and change orders	• Engineers design respective systems. Drawing coordination happens at discrete milestones. • Reduced RFIs and change orders.	• Engineers and field detailers collaborate in real time to produce near as-built documents. • Few RFIs and change orders. • Innovation/VE ideas are modelled for constructability and cost analysis prior to incorporation into design. • Field Techniques to be used are considered in the digital model. • Contractors model constructions details and simulate installations – "digital prototyping". • Weekly clash detection sessions.	• BIM model is used to determine cost options by varying element attributes. • Incidental RFIs from trades not involved in design process. • Design and drawing work is in real time with multiple designers. • BIM used to track weekly digital build. • Less clash detection is needed as some coordination is performed in real time.	• Database of parts and devices is developed in BIM. Operations and maintenance use model rather than manuals. • No RFIs. Change orders are only from owner scope change requests. • Use of BIM to track progress and completion. • BIM actively used by Facility Management as part of their process. • Coordination and clash detection/avoidance performed in real time

Table 7.6: Information Centre Meetings

Recommended Practice		LEVEL				
		1 – Aware	2 – Ad-hoc	3 – Localised	4 – Integrated	5 – Best In Class
Information Centre Meetings	What process metrics and targets does the project use for defining performance?	• Engineers, contractors, and subs measured on adherence to detailed plan designed by small group of architects no longer working on project.	• Some process measures determined, but not distinguished from outcome measures. • Overall project performance against metrics tracked at milestones.	• Process measures identified and approved for conducting Lean design and construction. • Metric performances tracked at Information Centre Meetings.	• Managers and executives more concerned about problem solving, A3s, and alignment with annual goals. • Metric performances tracked real-time at Information Centre Meetings.	• Abundant use of A3s and problem-solving is obvious, documented, and leads savings and efficiencies, replacing systems for elaborate tracking of measures. • Metric performances tracked at set level real-time Information Centre Meetings.
	What does evidence look like?	• Wasteful meeting and work time is spent developing systems for measuring goals rather than processes. • Additional meeting and work time is spent checking adherence to these systems. No time is spent measuring smoother flow, reducing steps, or implementing.	• Measures for achievement of LEAN construction goals are developed, but tracking and review of performance is outside of work site and away from design and construction processes.	• Information Centres established but meetings only in some areas. • Percent Plan Complete (PPC) tracked on weekly basis as part of Last Planner approach. • Visual management used.	• Information Centre Meetings are daily, disciplined gatherings with some problem solving evident. • Target resets based on performance need. • Customer communications (memo, communication plan, presentations, etc.)	• Information Centre Meetings are the main communication forums for the project. • They are held daily and robust problem solving stems from the meetings. • Problem-solving is closed out and tracked to ensure robust solutions are in place.

Table 7.7: Standardised Work

Recommended Practice		LEVEL				
		1 – Aware	2 – Ad-hoc	3 – Localised	4 – Integrated	5 – Best In Class
Standardised Work	What processes does the project use for implementing Standardised Work?	• A few participants understand Standardised Work and how to implement it.	• Standardised Work training is given. • Some supervisors are allowing time for their tradespeople to write Standardised Work, but on an ad hoc basis.	• Many Standardised Work documents are being written. • Standardised Work is used to train new starters. • Standardised Work is starting to be used as a basis for CI by the crews. • Standardised Work includes value-added and non-value-added (necessary and not) timings.	• A strategic plan Standardised Work is set-targeting those tasks with the largest safety, quality or productivity impacts • Each supervisor has a plan for his crew. • All crews are engaged with writing Standardised Work.	• All participants write and use Standardised Work. • Training and knowledge of the relevant Standardised Work is necessary before a task is begun. • Standardised Work is used continually as the basis for CI and Waste Elimination.
	What does evidence look like?	• No evidence of Standardised Work written by the teams themselves. • Some high-level Standard Operating Procedures.	• Some Standard Operating Procedures have input from the tradespeople. • Some Standardised Work being written.	• Standardised Work documents exist and are being used actively for training and CI. • Supervisors and Managers are 'auditing against' – the Standardised Work in place.	• Measures for progress with Standardised Work tasks are visible. • Each crew has Standardised Work and is working on priority new documents.	• Savings and efficiencies obvious from the use of Standardised Work. • All key tasks on site have Standardised Work.

Table 7.8: 5S and Visual Management

Recommended Practice		LEVEL				
		1 – Aware	2 – Ad-hoc	3 – Localised	4 – Integrated	5 – Best In Class
5S and Visual Management	What processes does the project use for implementing 5S and Visual Management?	• Some on site have a basic understanding of 5S and Visual Management. • There are no processes for using or training these tools.	• Some areas have put some thought into their work space. • Some training is going on in 5S and Visual management but it is ad hoc.	• Several areas on site have good 5S – not only has the Sort & Set been done, but Shine is happening regularly, Standards are clearly displayed and Sustainability audits are a routine feature.	• The site layout as a whole has been optimised. • The site as a whole is divided into areas with specific accountability for each designated. • 5S is running for each designated area? • Audit are happening.	• 5S and Visual Management add to the safety, quality and productivity of the site. • Leadership beliefs and behaviours support 5S implementation. • CI opportunities are made clearer by 5S and Visual Management.
	What does evidence look like?	• The site is poorly laid out. • Lay down areas are unclear and parts are often lost/spoiled. • Specific job sites are untidy and jobs take longer as tools/parts cannot be found. • Signage exists but only for HSE.	• Some areas are showing signs of 5S • A basic sort and set has occurred in some places.	• Several areas have good organisation and Visual Management is clear. • Standards are displayed and can be seen to be adhered to.	• A well-organised and safe site is apparent to all. • Layout is optimised from Site to Laydown area 'to job specific' – Omit 'meaning?'	• 5S changes regularly as CI ideas are implemented. • New Standards are put in place as improvements are made. • Ideas for Visual management techniques are constantly improved.

Table 7.9: Built-in Quality

Recommended Practice		LEVEL				
		1 – Aware	2 – Ad-hoc	3 – Localised	4 – Integrated	5 – Best In Class
Built-in Quality	What processes does the project use for implementing Built-in Quality	• Some on site have a basic understanding of Quality • Understanding of Built-in Quality is not widespread.	• Some design takes error-proofing into account but this is ad hoc. • Participants have some knowledge of Built-in Quality and good Supervisors are using Standardised Work and 5S.	• Several areas on site have good work practices – Standardised Work, 5S and boundary samples so workers can tell what the required specification for the job is. • Some receiving inspection is done and parts quarantined if no good.	• All crews have a good understanding of Built-in Quality and are working to minimise rework. • Error-proofing is widely used as a solution. • Receiving inspection is done on all parts according to a quality plan.	• Receiving Inspection does sample testing on robust parts delivered. • Standardised Work and 5S are employed throughout the site. • Design and error-proofing devices enable right-first-time work.
	What does evidence look like?	• Incoming parts are not Quality Assured or checked. • Standards for work are not clear. • Poor quality is seen on site and rework is common. • No system is in place to react to defects.	• Some examples of incoming parts inspection is seen. • Some examples of error-proofing are on site. • Very little root cause problem-solving is done. • Tradespeople alert Supervisors to defects but no robust system is in place to react to this.	• Several areas are using error-proofing and jigs and fixtures to ensure a quality job. • Problem-solving is happening, but usually still in the blame mode. • Some supervisors react quickly to defects and some root cause analysis is present.	• A robust system for stop Call Wait is being implemented and Supervisors are trained in their reactions to problems. • Problem solving is no longer in blame mode but seeks the root cause of the issue and uses design and error proofing to solve it.	• No rework is seen on site. • Parts arrive right first time. • People are clear on how to do their jobs and the quality required. • Stop Call Wait triggers problem-solving which is robust and goes to root cause.

Table 7.10: Just In Time (JIT)

Recommended Practice		LEVEL				
		1 – Aware	2 – Ad-hoc	3 – Localised	4 – Integrated	5 – Best In Class
Just In Time (JIT)	What processes does the project use for implementing Just In Time?	• Some knowledge of JIT exists within Materials Management (MM)	• Different systems hold the information for parts ordering and delivery, but often do not talk to each other.	• Systems are integrated and a Plan for Every Part has been established which is used locally.	• Plan for Every Part systems are in place and output used universally. • Pull systems are in place for frequently used materials supported by a clear drumbeat process for their use in Construction.	• All parts arrive on time to the Plan for Every Part schedule, be it Push or Pull • Work is under way to reduce inventory and batch sizes to reduce laydown area size and increase flexibility.
	What does evidence look like?	• Materials on site are largely unknown and untracked. • Delays often occur due to materials shortages.	• Some laydown areas are organised and clear to see. • MM is aware of materials within these but not others.	• Localised staging areas exist at work faces – usually associated with well-managed laydown areas. • MM are mostly aware of the parts on site and most of their locations.	• Laydown areas are all organised and clear to see. • Staging areas are used for each workface. • A robust process is in place for tracking and progressing shortages including 'problem-solving to root cause and solution'	• Laydown areas are organised, clear to see and reducing in size. • More frequent deliveries of small batch sizes are scheduled and consolidated to reduce transportation costs.

7.3 SUPPORTED PRINCIPLES AND MODELS

7.3.1 FOURTEEN (14) MANAGEMENT PRINCIPLES FROM THE WORLD'S GREATEST MANUFACTURER, BY LIKER (2004)

The Toyota Way has been called "a system designed to provide the tools for people to continually improve their work". Liker (2004), in his book "The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer", provided The 14 principles of The Toyota Way, organised in four sections. The principles are set out and briefly described below:

1. Long-term philosophy (principle 1);
2. The right process will produce the right results (principles 2-8);
3. Add value to the organisation by developing your people (principles 9-11); and
4. Continuously solving root problems drives organisational learning (principles 12-14).

Principle 1. Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals.

- Adopt a philosophical view that supersedes any short-term decision-making. Work, grow, and align the whole organisation towards a common purpose that is bigger than making money. Understand your place in the history of the company and work to bring the company to the next level. Your philosophical mission is the foundation for all the other principles.
- Your starting point is to generate value for the customer, society, and the economy. Assess the company's functions in terms of its ability to achieve this.
- Bear the responsibility. Face the struggle to choose your own fate. Be independent and have faith in your own abilities. Take the consequences of your conduct. Maintain and improve your skills to produce added value.

Principle 2. Create continuous process flow to bring problems to the surface.

- Redesign work processes to achieve high value-added, continuous flow. Eliminate waste of time, for example when a work project is sitting idle or waiting for someone to work on it.
- Guarantee process flow to quickly move material and information, connecting processes and people together to predict problems immediately.
- The key to a true continuous improvement process and to people development is to guarantee the flow of your organisational culture.

Principle 3. Use pull systems to avoid overproduction.

- Fulfil the needs of your downline customers in the production process at the exact time they want, and in the amount they want. The basic principle of Just-In-Time is material replenishment initiated by consumption.
- Cut your work to the minimum in terms of process and warehousing of inventory, stock small amounts of each product and restock based on customer's requirements.
- Be responsive to the day-by-day shifts in customer demand rather than relying on computer schedules and systems to track wasteful inventory.

Principle 4. Level out the workload (heijunka). (Work like the tortoise, not the hare)

- Successful implementation of Lean depends on waste elimination; it represents just one-third of the equation. Do not overburden people and equipment, and avoid unevenness in the production schedule.
- Lighten the workload of all manufacturing and service processes instead of the stop/start approach applied at most companies, which involves working on projects in batches.

Principle 5. Build a culture of stopping to fix problems, to get quality right the first time.

- Your value proposition is led by providing quality for the customer.
- Adopt all available modern quality assurance methods.
- Install your equipment with the capability to detect problems and stop itself. Create a visual system that alerts team or project leaders that a machine or process

needs assistance. Building in quality depends mainly on Jidoka (machines with human intelligence).

- Apply support systems that quickly solve problems and put in place countermeasures.
- Get quality right the first time through adopting the philosophy of stopping or slowing down to enhance productivity in the long run.

Principle 6. Standardised tasks are the foundation for continuous improvement and employee empowerment.

- In order to maintain the predictability, regular timing, and regular output of your processes, use stable, repeatable methods everywhere; this is the foundation for flow and pull.
- Summarise lessons learnt from a process up to a point in time by standardising today's best practices. Allow improvement of the standard through creative and individual expression; then incorporate it into the new standard in order to share the learning with the next person.

Principle 7. Use visual control so no problems are hidden.

- Develop simple visual indicators to enable people to immediately determine whether or not they are in a standard condition.
- Eliminate use of computer screens if they distract workers' attention from the workplace.
- Support flow and pull through designing simple visual systems at the workplace.
- Produce one-paper reports whenever possible, even for your most important financial decisions.

Principle 8. Use only reliable, thoroughly tested technology that serves your people and processes.

- Apply technology to support people instead of replacing them. Adopt a manual process before adding technology to support the process.

- It is often difficult to rely on or standardise new technology, which then endangers flow. It is always better to apply a proven process that works generally instead of new and untested technology.
- Actual tests should be conducted before adopting new technology in business processes, manufacturing systems, or products.
- Technologies that conflict with your culture or that might disrupt stability, reliability, and predictability should be rejected or modified.
- These should not stop you from considering new technologies in work approaches. Thoroughly considered technologies should be quickly implemented if they have been proven in trials and can improve flow in your processes.

Principle 9. Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others.

- Foster leaders from your organisation, rather than buying them in from outside.
- Leaders must be role models of the company's philosophy and way of doing business; their job should not be viewed as simply accomplishing tasks and having good people skills.
- Understanding the daily work in great detail enables good leaders to be the best teachers of your company's philosophy.

Principle 10. Develop exceptional people and teams who follow your company's philosophy.

- Guarantee the company has a strong, stable culture that displays its values and beliefs over a period of many years.
- In order to achieve exceptional results, provide training for exceptional individuals and teams to abide by the corporate philosophy. Exert your best efforts to provide continuous support to the culture.
- In order to improve quality and productivity and enhance flow, use cross-functional teams to solve difficult technical problems. Empowerment occurs when people improve the company using its own tools.
- Company should learn teamwork; exert continuous efforts to teach individuals how to work together so as to achieve common goals.

Principle11. Respect your extended network of partners and suppliers by challenging them and helping them improve.

- Show respect to your partners and suppliers and value them as an extension of your business.
- Value your outside business partners through challenging them to grow and develop. Set challenging targets and assist your partners in achieving them.

Principle12. Go and see for yourself to thoroughly understand the situation (genchi genbutsu).

- Observe and verify data personally to solve problems and improve processes rather than depending on what other people or the computer screen tell you.
- Base your thoughts and words on personally verified data.
- High-level managers and executives should undertake processes personally, in order for them to have more than a superficial understanding of the situation.

Principle 13. Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly (nemawashi).

- Consider alternatives before taking a single direction, then move quickly but cautiously down the path.
- Nemawashi is the process of discussing with affected persons to collect their ideas about the problems and potential solutions in order to get agreement on a path forward. This consensus decision-making process, though time-consuming, helps provide more solutions and prepare for rapid implementation.

Principle 14. Become a learning organisation through relentless reflection (hansei) and continuous improvement (kaizen).

- After establishing a stable process, use continuous improvement tools to determine the root cause of inefficiencies and apply effective countermeasures.
- Make wasted time and resources visible for all through designing processes that require almost no inventory.

- In order to identify all the shortcomings of the project, use hansei (reflection) at key milestones and after you finish a project. Develop countermeasures to avoid repeating mistakes.

- Derive benefits from lessons learnt instead of reinventing the wheel with each new project and each new manager.

7.3.2 THE 4P MODEL OF LEAN

Liker (2004) developed the 4P model of Lean to include the Toyota way or TPS and incorporate the 14 key management principles. The model pyramid includes continuous improvement and learning at the top followed by development of people and partners, process orientation and long-term thinking at the base. Management of the 4P model can be seen as a prerequisite for sustainable improvements (Liker, 2004). Table 7.1 shows the 14 principles classified under each of the 4Ps.

Table 7.11: The 4P model of Lean

4P's	Principles
Philosophy	Adopt a long-term philosophy to be the basis for management decisions, even at the expense of short-term financial goals
Processes	Bring problems to the surface through the creation of continued process flow Avoid over-production through using the pull system Level out the workload Get quality right the first time by creating a culture of stopping to fix problems
People and partners	Grow leaders who completely comprehend the work, live the Lean philosophy, and introduce it to others Develop exceptional staff who abide by the organisation's philosophy Respect partners and suppliers of the organisation by challenging them and helping them improve
Problem solving	Undertake site visits to thoroughly understand the situation Make consensus decisions, study all options to implement decisions rapidly Become a learning organisation through relentless reflection and continuous improvement

SUMMARY OF TASK ONE: COMPREHENSIVE LITERATURE REVIEW

The researcher reviewed the literature that helped and guided him to achieve the aim of this research. This task consists of five chapters (from Chapters Two to Seven). Chapter Two discussed the main issues that construction projects suffer from, such as construction waste, project delay and project over budget and also examined the implemented traditional methods for each issue mentioned by introducing Value Engineering, Critical Path Method (CPM) and Cost Management Method. Chapter Three aimed to integrate risk management with Lean Construction, and therefore this chapter reviewed all risk management processes (planning, identification, qualitative and quantitative analysis, response planning and monitoring and controlling processes). The introduction of the Risk Analysis and Management for Projects (RAMP), as well as its benefits and processes, have been summarised for the purpose of managing the associated risks in Mega-Construction projects in KSA. In addition, the possible benefits of the integration of Lean Construction and Risk Management have been discussed.

Chapter Four studied the literature of the main topic of this research, which is Lean. It has been divided into three sections (Lean Manufacturing, Lean Construction and implementation of practical theories in construction issues). The history of Lean Manufacturing has been addressed; the theory and application of Toyota Production System (TPS) and process improvement methods have been considered and studied. The second section of Chapter Four covered the concept, principles, tools and techniques of the Lean Construction method. Lean Thinking has been discussed as well in order to review the history of Lean. At the same time, Lean implementation barriers have been critically analysed to find ways of overcoming them through the developed framework. The last section studied the implementation of practical theories in construction issues. It also demonstrates that complex Mega-projects would be managed by Lean Construction better than by other traditional methods.

Chapters Five and Six considered Building Information Modeling (BIM) in relation to Mega-projects. The BIM chapter reviewed 4D simulation and the benefits of the integration between Lean Construction and Lean. Moreover, it discussed the synergy between BIM and Lean Construction. Chapter Six studied the importance of Mega-projects and the challenges presented by Mega-projects in construction industries. The location of the Kingdom of Saudi Arabia and its markets has also been discussed. Lastly, the presentation of an action research study has been listed and the scope of work studied. In addition, the ways in which the researcher used the action research to achieve the aim and objectives of this study have been described.

Chapter Seven has summarised the review of different Lean frameworks, assessment tools and supported management principles. Continuous improvement requires the creation of innovative new thoughts, and new thoughts come from reviewing and learning what other authors have discovered and finding new ideas that can achieve more improvement. These previous frameworks and assessment tools (Chapter 7), in addition to the reviewed literature (Chapters Two to Six), will be a step forward for the researcher to develop a framework to achieve the research aims and objectives.

TASK 2: UNDERSTANDING THE EXISTING SITUATION IN KSA (SURVEY 01)

Task Two (Chapters 8 and 9): Understanding the existing situation in KSA (survey)

It was essential to investigate and understand the situation in the country where the researcher chose to implement the new method, Lean Construction, and to assess its impact and identify the barriers to its implementation. In this task, the researcher is using the reviewed literature in Task 1, employing an action research to reduce the gap between Lean theories and practices and conducting an online survey with 76 participants involved in the action research (Survey 01), in order to understand the level of awareness of the Lean Construction method among workers in KSA. The diagram below (Fig T.2) shows the activities involved in Task Two.

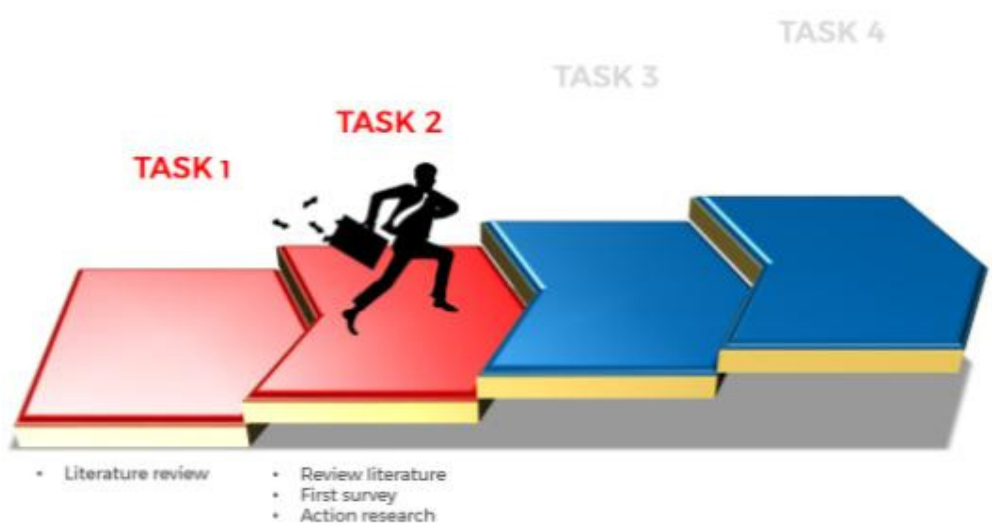

Figure T.2: Activities involved in Task Two

CHAPTER EIGHT: RESEARCH METHODOLOGY

8.1 INTRODUCTION

In the construction industry, new issues, actions and processes arise every day and practical strategies are required for facing them. As discussed earlier, the research aims at developing an innovative framework that facilitates the use of Lean Construction as a more efficient method of minimising the risks of Mega-Construction projects in the KSA. Chapters 2 to 7 provided a comprehensive literature review, which highlighted previous research activities in this domain, established the required knowledge base for the rest of the research tasks within the body of this proposal and provided a solid point of departure for the study through identifying its significance by means of the problem statement. However, an essential step, which is the focus of this chapter, in achieving the aforementioned aim is to establish an understanding of the current situation in KSA. Thus, Task Two, Chapter 8 and 9, presents the research framework, methodology, implementation steps, and achieved results associated with identifying the level of knowledge of Lean Construction, as well as the construction industry's susceptibility to change in KSA.

8.2 RESEARCH DESIGN

The research questions and the existing amount of knowledge of the area investigated, as well as the data accessible to the researcher, determine the process of choosing the most appropriate research method (Reiter et al., 2011). The choices of researchers vary from a single method to a mixed method approach. It is important that the method chosen is appropriate for achieving the objectives of the research, no matter what the choice may be (Ogunbiyi, 2014). Lean Construction and risk management within the construction industry form the basis of this research. Therefore, it is necessary to describe the research design and methods adopted in order to achieve the objectives of this study.

Research methodology and research method are two different things, and the distinction between these two terminologies is essential for the purpose of this study (Greener, 2008). Research methodology involves the principles and procedures of the logical thought processes which are applied to a specific investigation (Fellows & Liu, 2008). Research method refers to specific activities designed to generate data, for example questionnaires, interviews, focus groups and observation (Greener, 2008). The importance of identifying a study's research design lies in the information it provides concerning the key features of the study, which may vary between qualitative, quantitative, and mixed methods. However, data collection (numbers, words, etc.) is a common feature across research designs, though in different ways and for different purposes. Hence, qualitative studies collect and analyse qualitative data, while quantitative studies collect and analyse quantitative data (Harwell, 2011).

Dawson (2002, p.13) states that the two main types of research methods are (1) quantitative and (2) qualitative. Creswell (2009, P.3) states that research designs include research plans and procedures that proceed from broad assumptions to detailed methods of data collection and analysis. The three types of design are qualitative, quantitative and mixed. The difference between qualitative and quantitative research appears in the use of numbers (quantitative) rather than words (qualitative), or in using closed-ended questions (quantitative hypotheses) rather than open-ended questions (qualitative interview questions) (Creswell, 2009).

In some studies, research design may elaborate the entire research process, including problem development, literature review, research questions, methods, and conclusions, whereas in other studies it may describe the research methodology (e.g. data collection and analysis) (Harwell, 2011).

8.2.1 QUALITATIVE RESEARCH

Qualitative research is the process of determining and defining the reasons behind a certain social or human problem arising among individuals or groups, eventually resulting in a final written report (Creswell, 2009). Qualitative research methods could be regarded as a preparation process, i.e. a researcher develops theories or hypotheses, explanations, and conceptualisations based on available details (Harwell, 2011). Such methods could be applied in case of unknown expectations, undefined issues or lack of understanding of the reasons why, and the ways in which affected populations are impacted by an emergency. Both qualitative and quantitative data are obtained through practical investigation; however, qualitative research is mainly concerned with information provided from groups and individuals, as well as developing case studies and summaries, rather than lists of numeric data (The Assessment Capacities Project (ACAPS), 2012). When compared to quantitative research methods, the most important feature of qualitative research is that it requires more personal involvement on the researcher's part, compared to the more detached and objective approach involved in quantitative research (Spector, 2005). Table 8.1 below highlights the strengths and weaknesses of qualitative research methods.

When applying qualitative methods, research and analysis processes add value to the identification and exploration of intangible factors, e.g. cultural expectations, gender roles, ethnic and religious implications and individual feelings; when applying qualitative methods, the research process analyses relationships and perceptions of affected persons and communities. For this reason, smaller sample sizes are generally chosen; the main reasons for this are outlined below (Marshall, 1996):

- When the sample size for qualitative data collection is large, the analysis will be more complex, time-consuming and multi-layered;
- When selecting a true random sample, the studied characteristics of the whole population should be known, which is rarely possible at the early stage of the research;
- A representative sample could be generated from a random sampling of a population only if the features under investigation are evenly distributed within the population; and
- The researcher could receive greater insight into, and understanding of, the impact of a new method from specific informants, owing to factors including their social, economic, educational, and cultural position in the community. Choosing someone at random to answer a qualitative question and asking a passer-by, instead of a mechanic, about repairing a broken car would be quite similar.

Table 8.1: Strengths and weaknesses of qualitative data collection

STRENGTHS **(Chemaly, 2012)**:	WEAKNESSES **(Choy, 2014)**:
Rich and detailed information about affected populations	No objectively verifiable result
Perspectives of specific social and cultural contexts	Requirement for interviewers to be skilful
Inclusion of a diverse and representative cross-section of affected persons	Time-consuming during the interview process
In-depth analysis of the impact of a new method	
A data collection process requiring limited numbers of respondents	
A data collection process carried out with limited resources	

8.2.2 QUANTITATIVE RESEARCH

By contrast, quantitative research is the process of testing objective theories through the examination of relationships among variables which can be measured, with the data being analysed through statistical procedures, and the final written report having a set structure (Creswell, 2009). Quantitative research methods are characterised by the numeric analysis of the information collected, and their results are typically presented using statistics, tables and graphs (The Assessment Capacities Project (ACAPS), 2012). Table 8.2 highlights the strengths and weaknesses of quantitative research methods.

Table 8.2: Strengths and weaknesses of quantitative data collection

STRENGTHS **(Chemaly, 2012)**:	**WEAKNESSES (Chemaly, 2012):**
Numeric estimates	Gaps in information - issues which are not included in the questionnaire, or secondary data - will not be included in the analysis
Opportunity for relatively uncomplicated data analysis	A labour-intensive data collection process
Verified data	Affected persons participate in a limited way in the content of the questions or direction of the information collection process
Comparable data of different communities within different locations	
Non-analytical data regardless of how information will be presented	

8.2.3 BASIC DIFFERENCES BETWEEN QUANTITATIVE AND QUALITATIVE METHODS

There are many differences between quantitative and qualitative research methods, including the analytical objectives, the types of questions posed, the types of data collection methods applied, the forms of data produced and the degree of the study design's flexibility. These major differences are outlined in Table 8.3 (Jandagh & Matin, 2010).

Table 8.3: Comparison between quantitative and qualitative research methods

	QUALITATIVE (ACAPS, 2012)	QUANTITATIVE (ACAPS, 2012)
Type of application	▪ To deeply understand a specific issue and to reach an understanding of the behaviour, perception and priorities of the community concerned ▪ To present information gathered from quantitative data ▪ To highlight an integrated approach (processes and outcomes)	▪ To understand the situation comprehensively ▪ To describe the socio-demographic characteristics of the population ▪ To draw a comparison between the relations and correlations of different issues ▪ To derive accurate and precise data ▪ To offer evidence concerning the type and size of problems
Objectives and general features	▪ To explore and understand phenomena ▪ To arrive at a deep understanding of specific issues ▪ Gives detailed and complete information, contextualization, interpretation and description ▪ Outlines perspectives, opinions and explanations of affected populations towards events, beliefs or practices	▪ To seek precise measurements, for evaluating and proving hypotheses ▪ Gives a general overview ▪ Provides demographic characteristics ▪ Objective and reliable ▪ Suitable for generalisation ▪ Objectively verifiable ▪ Evaluates predictions, and gives causal explanations
Data format	▪ Data is observed rather than measured ▪ Deals with texts (words, pictures, audio, video)	▪ Data is counted and measured. ▪ Deals mainly with numbers and categorical values
Answers the questions	▪ Answers questions raised during discussions ▪ How? ▪ Why? ▪ What do I need to look for in more detail? ▪ Open-ended questions	▪ Answers a controlled sequence of questions which have predetermined possible answers ▪ What? ▪ How many? ▪ Closed questions

	QUALITATIVE (ACAPS, 2012)	QUANTITATIVE (ACAPS, 2012)
Perspective	▪ Studies the internal aspects of the context ▪ Searches for patterns ▪ Depends on community participation. Applies ongoing analysis to deeply investigate the perspective	▪ Studies the external aspects of the context
Methods	▪ Individual interviews ▪ Key informant interviews ▪ Semi-structured interviews ▪ Focus group discussions ▪ Observation	▪ Quick counting estimates ▪ Sampling surveys ▪ Population movement tracking ▪ Registration ▪ Structured interviews
Sampling	▪ Non-random (purposive)	▪ Random
Study design and instruments	▪ Flexible collection and analysis of data are undertaken by the primary instrument, the assessor.	▪ Fixed; the assessor's bias is controlled by certain standards
Questionnaire tool types	▪ Checklist containing open questions and flexible sequence	▪ Predetermined questionnaire containing a set sequence and structure
Analysis	▪ Uses inductive reasoning ▪ Depends on a systematic and constant process of searching, categorising and integrating data ▪ Depicts the research findings according to the mindset of the research participants ▪ Generalises results depending on a limited number of specific observations or experiences ▪ Analysis is descriptive	▪ Uses deductive methods ▪ Descriptive statistics ▪ Inferential statistics

8.2.4 MIXED METHOD RESEARCH

Mixed method research is an inquiry approach combining both qualitative and quantitative forms. It involves philosophical assumptions, the use of qualitative and quantitative approaches and the mixing of both approaches in a study (Creswell, 2009). Table 8.4 identifies the strengths and weaknesses of mixed research methods.

Table 8.4: Strengths and weaknesses of mixed method data collection

STRENGTHS (Johnson & Christensen, 2012):	WEAKNESSES (Johnson & Christensen, 2012):
Numbers could have an added meaning through the use of words, pictures, and narrative	The application of both qualitative and quantitative research can be difficult for a single researcher, especially if accuracy is required in two or more approaches
Words, pictures, and narrative could be made more precise by using numbers	The researcher is expected to study the application of multiple methods and approaches and understand the appropriate way to mix them
Can combine the strengths of quantitative and qualitative research	Methodological idealists believe that a researcher should stick to either a qualitative or a quantitative research method
A grounded theory could be generated and evaluated by researchers	It is more time-consuming
Since the researcher is not bound by a single method or approach, he/she can provide answers to a broader and more complete range of research questions	
The weaknesses of one method could be overcome by using the strengths of an additional method and applying both in one research study	
Conclusions could be supported by stronger evidence through convergence and validation of findings	

STRENGTHS (Johnson & Christensen, 2012):	WEAKNESSES (Johnson & Christensen, 2012):
Can add insights and understanding that might be missed when only a single method is used	
Generalisation of results is increased	

Research methodologists have analysed some of the details of mixed research, for example problems of paradigm mixing, the qualitative analysis of quantitative data and the interpretation of conflicting results. See Figure 8.1.

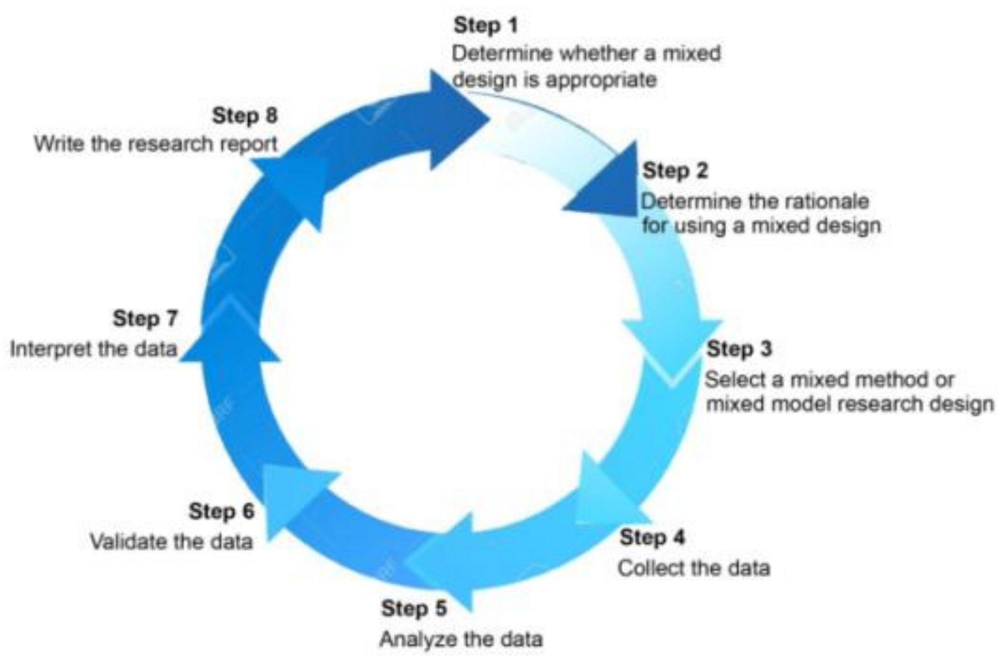

Figure 8.1: Important steps in a mixed research study (Johnson & Christensen, 2012)

8.3 RESEARCH PARADIGMS

Easterby-Smith et al. (1991) state that research paradigms and their assumptions control the process of choosing suitable methodologies and research methods. Denzin and Lincoln (1994) define the research paradigm as the philosophical stance taken by the researcher, comprising a basic set of beliefs that guides action, while Weaver and Olson

(2006) define research paradigms as patterns of beliefs and practices that regulate inquiry through the provision of lenses, frames and processes required for the accomplishment of investigation (Weaver & Olson, 2006). Regarding the selection of research design, Creswell (2009) states that researchers should consider the philosophical assumptions that they start from, and the research methods or procedures transforming the approach into practice (Creswell, 2009). Slife and Williams (1995) claim that philosophical ideas remain largely hidden in research. Creswell (2009, p.5) suggests that researchers "provide a design framework" (figure 8.2) and that they "make explicit the larger philosophical ideas they espouse and also explain why they chose qualitative, quantitative, or mixed methods".

Figure 8.2: A framework for design: the interconnection of world views, strategies of inquiry, and research methods (Creswell, 2009, p.5)

Saunders et al. (2007) refer to research philosophy as a term that relates to the development of knowledge and the nature of knowledge, and thus the developing of knowledge in a particular field (Saunders et al., 2007).

Post-positivist world view

First, the traditional form of research starts from a post-positivist assumption which is more suitable for quantitative research than qualitative research. This world view is sometimes called the scientific method, or doing scientific research. It is also called positivist/post-positivist research, empirical science and post-positivism. Post-positivists have a deterministic philosophy in which causes are seen to determine effects or outcomes. Thus, post-positivists study the problems that reflect the need to identify and assess the causes that influence outcomes, such as those found in experiments (Creswell, 2009).

The post-positivist world view challenges the traditional or existing notion about the 'truth' and maintains that scientists cannot remain 'positivist' about knowledge while studying human behaviours. Post-positivist methodology deploys careful observation about the real world and searches for various antecedents which have an impact on human actions or behaviour (Phillips & Burbules, 2000). Procedures involved according to the Post-positivist worldview include determining effects of outcomes, formulating the ideas to be tested (i.e., hypotheses and research questions), developing measurement criteria and finally testing existing theories (Phillips & Burbules, 2000).

Social constructivism world view

Second, social constructivism (often combined with interpretivism) is typically seen as a possible approach to qualitative research. Social constructivists hold the assumption that individuals seek understanding of the world in which they live and work (Creswell, 2009).

Constructivism takes a holistic approach towards research issues and assumes that individuals derive meaning from the world in which they live and work (Creswell, 2009). The researcher looks for complexity of views and tries to understand the participant's view of the situation, rather than narrowing down the meaning (e.g. post-positivism). Questioning is mainly open-ended so that participants can share their views based on their historical and social perspective (Crotty, 1998).

Advocacy/Participatory world view

Third, another group of researchers are still committed to the philosophical assumptions of the advocacy/participatory approach. In the 1980s and 1990s, this position arose among individuals who believed that post-positivist assumptions lead to structural laws and theories that are not appropriate for marginalised individuals in our society or social justice issues that need to be addressed. This world view is typically seen as leading to qualitative research; however, it can form the foundation for quantitative research as well. Historically, some of the advocacy/participatory (or emancipatory) writers have referenced the works of Marx, Adorno, Marcuse, Habermas, and Freire (Neuman, 2000). The advocacy/participatory worldview holds that a research inquiry should have a political agenda that may change the lives of the participants, the institutions in which individuals work or live, and the researcher's life. Moreover, specific issues need to be addressed so as to include important social issues of the day, such as empowerment, inequality, oppression, domination, suppression, and alienation (Creswell, 2009).

The Advocacy/Participatory world view maintains that the research agenda needs to be intertwined with the policy framework so that it improves the conditions of its participants (Creswell, 2009). It mostly represents marginalised sections of society and provides a voice to individuals for unchaining themselves from an unjust system that limits self-development. The Advocacy/Participatory world view engages with participants and makes them active stakeholders in their change and development (Kemmis & Wilkinson, 1998).

Pragmatic world view

Pragmatism derives from the work of Peirce, James, Mead, and Dewey (Cherryholmes, 1992). This philosophy takes many forms, but for many, pragmatism as a world view originates from actions, situations, and consequences rather than antecedent conditions (as in post-positivism).

The Pragmatic world view does not see the world as an absolute unity and has the freedom to adopt a range of methods, techniques and procedures, including the mixed method approach (Morgan, 2007). It focuses on the outcome of action, sequence and consequence rather than of antecedent conditions (as opposed to post-positivism). Pragmatism believes in the external world, independent of the mind, but it restricts researchers in asking question about the laws of nature (Cherryholmes, 1992).

Qualitative, quantitative or mixed research design is controlled by the researcher's worldview, the strategies, and the methods employed (Creswell, 2009). Creswell (2009, p.17) shows the distinctions that may be useful in choosing an approach in Table 8.5. This table also includes the practices of all three approaches.

Table 8.5: Qualitative, quantitative and mixed method approaches (Creswell, 2009)

Tend to or typically	Qualitative approaches	Quantitative approaches	Mixed method approaches
Use these philosophical assumptions	• Constructivist/ advocacy/ participatory knowledge claims	• Post-positivist knowledge claims	• Pragmatic knowledge claims
Employ these strategies of inquiry	• Phenomenology, grounded theory, ethnography, case study, and narrative	• Surveys and experiments	• Sequential, concurrent, and transformative
Employ these methods	• Open-ended questions, emerging approaches, text or image data	• Closed-ended questions, predetermined approaches, numeric data	• Both open- and closed-ended questions, both emerging and predetermined approaches, and both quantitative and qualitative data and analysis

Tend to or typically	Qualitative approaches	Quantitative approaches	Mixed method approaches
Use these research practices	• Collects participant meanings • Focuses on a single concept or phenomenon • Brings personal values to the study • Studies the context or setting of participants • Validates the accuracy of findings • Makes interpretations of the data • Creates an agenda for change or reform • Collaborates with the participants	• Tests or verifies theories or explanations • Identifies variables to study • Relates variables in questions or hypotheses • Uses standards of validity and reliability • Observes and measures information numerically • Uses unbiased approaches • Employs statistical procedures	• Collects both quantitative and qualitative data • Develops a rationale for mixing • Integrates the data at different stages of inquiry • Presents visual pictures of the procedures in the study • Employs the practices of both qualitative and quantitative research

Based on the aforementioned discussion and the nature of the problem under investigation, the research methodology adopted for the current research will utilise an online survey instrument as the means of data collection, based on a mixed method approach.

8.4 THE CHOSEN RESEARCH METHOD AND PARADIGM

The diagrams below (Figures 8.3 and 8.4) summarise the research design of this study showing the researcher's rationale in selecting the following methods in relation to research questions and hypothesis.

Action research

- Thorough investigation of an ongoing Mega-Construction project in KSA. Lean Construction is to be theoretically and practically applied.

Survey data analysis method

- The results of the survey will be used in the analysis of the research topic and as a basis for a more successful Lean implementation in KSA in order to:
- Understand the existing situation in KSA in terms of the level of awareness of Lean Construction method;
- Validate the developed framework and assessment tool, which will be explained in Chapter 11 and 14.

Interview method (Validation)

- The validation approach will be carried out by seeking experts' opinions and feedback through posing structured questions reflecting all the aspects of the framework and assessment tool.

Workshop method (Testing)

- After the validation of the assessment tool, a practical assessment will be conducted in order to test and pilot the proposed assessment tool by carrying out two workshops.

Figure 8.3: General structure of selected research method

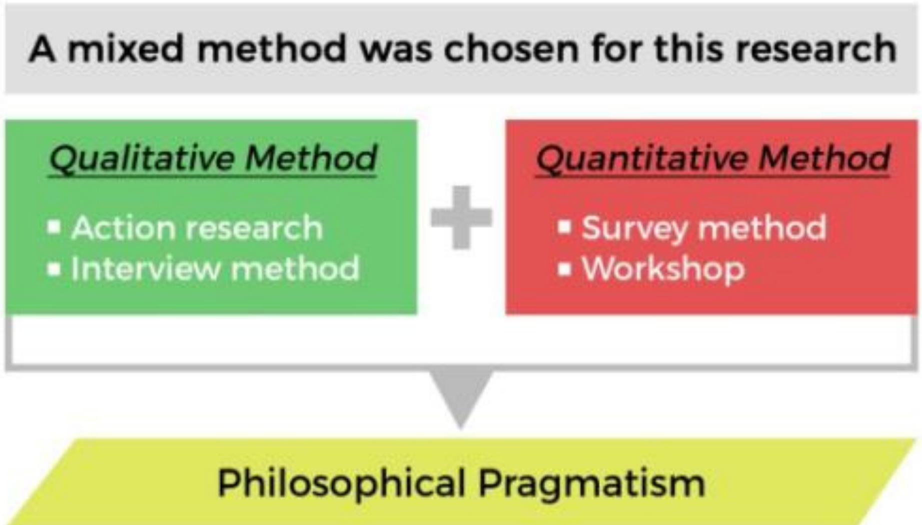

Figure 8.4: General structure of selected research method

The rationale for choosing a mixed method approach is that investigating the main topic of this study, Lean Construction in KSA, requires gathering data from workers (Survey method - Quantitative) that are directly involved with Mega-Construction projects (Action research - Qualitative). Professionals from other organisations related to the construction industry are then to validate the output of this research. It is necessary to discuss and examine the output with the workers and professionals involved in the action research (Interview method – Qualitative) to get a broader idea of the research and examine and test the effectiveness of the proposed assessment tool (workshop method – Quantitative).

8.5 ETHICAL APPROVAL

In every type of research, ethical considerations in field research are important aspects that increase the awareness of the researcher, so that priority is given to the ethical implications of data collection and analysis as well as the presentation of the results (De Vaus, 2014). Creswell (2009) states that the importance of ethical considerations lies in the capability of improving the quality of the research and avoiding inappropriateness as well as protecting the participants and their organisations. The research ensures the integrity and the confidentiality of the participants who have been informed of it, which encourages voluntary participation. Prior to contacting the participants in this research, ethical approval from the University's Ethics Committee was obtained (see Appendix 1).

8.6 ACTION RESEARCH

According to Mcniff and Whitehead (2011), action research is a form of enquiry enabling different practitioners to investigate and evaluate their work. Coghlan and Brannick (2014) define action research as an emergent inquiry process that integrates and applies both applied behavioural science knowledge and existing organisational knowledge to solve real organisational problems. Also, it is concerned with realising change in organisations, in developing self-help competencies in organisational members and adding scientific knowledge (Coghlan & Brannick, 2014).

Action research has been more widely documented than actual research studies, which is partly due to the fact that researchers involved in action research projects are often more interested in generating feedback than generating knowledge (Herr & Anderson, 2005). Kurt Lewin and the group-dynamics movement of the 1940s were claimed to be the originators of action research, because, although Lewin was not the first to use or advocate action research, it was he who started to develop a theory of action research, turning it into a respectable form of research in the social sciences, believing that real-life problem-solving assisted in the creation of knowledge (Lewin, 1946).

Action research is best done in collaboration with insider stakeholders as well as outsiders with relevant skills or resources (Herr and Anderson, 2005). Action research focuses on research in action, rather than research about action. The central idea is that action research scientifically studies the resolution of important social or organisational issues (Coghlan & Brannick, 2014). Furthermore, Mcniff and Whitehead (2011) state that action research aims at 1) generating new knowledge, in order to 2) create new theory. The objective of the action research is to make research methodology more effective while simultaneously building up a body of scientific knowledge (Coghlan & Brannick, 2014). Coghlan and Brannick (2014) outline an action research cycle comprising a pre-step, context and purpose, and four basic steps: constructing, planning action, taking action and evaluating action (Figure 8.5).

Figure 8.5: The action research cycle (Coghlan & Brannick, 2014, p. 9)

8.7 SURVEY METHOD

Check and Schutt (2012) explain that the survey method involves collecting information through the responses of a sample of individuals. The National Science Foundation switched to survey research for the 2000 National Survey, as it is considered an efficient method for systematic data collection from a wide range of individuals and educational settings (Check & Schutt, 2012).

The design of the survey questions of this research was developed in conjunction with the reviewed literature and a workshop conducted with the workers involved in the action research in order to develop practical questions that help develop a workable framework. The researcher's experience in KSA's construction projects, combined with feedback to be sought from professionals, facilitate the establishment of a valid pilot questionnaire.

Since the use of the questionnaire is a crucial part of the data gathering process, it is essential to define it within this context of the research. The Chambers dictionary defines a questionnaire as: "a prepared set of written questions, for purposes of statistical compilation or comparison of the information gathered; a series of questions". As for its practical use, in developing countries such as the KSA, such questionnaires may be misinterpreted as a mean of monitoring work as part of a financial assessment. This causes two problems: firstly, many informal workers do not want to be seen performing high-reward activities, for cultural reasons. Secondly, it may be understood as a way of forcing workers to pay more taxes. These problems were avoided by selecting questionnaire participants in a project in which the researcher is personally involved. In addition, the survey was designed to maintain the participants' anonymity, and participation was completely voluntary.

The survey is designed with the purpose of gathering information from workers involved in one of the ongoing construction projects in KSA, to get a preliminary view of the level of awareness of Lean Construction techniques in the area. The results of the survey will be used in the analysis of the research topic and serve as a basis for a more successful Lean implementation in the KSA.

The survey questions explore various aspects of the understanding of the new method known as Lean Construction. They aim to ascertain how this method will add value, and to determine to what extent site engineers and supervisors are aware of this method. The survey instrument, the questions of which are provided in appendix 2, was administered online for a period of 5 weeks. It gives an introduction and overview of Lean Construction and its principles for people who have never heard about it and specifies the objectives as well as the main focus of this research. Participation in this survey, which is designed to maintain participants' anonymity, and the nature of the data collection, was clearly outlined in the invitation email sent to select participants. There were no foreseeable risks associated with this empirical data collection. All related data is securely stored on the researcher's computer and on an online survey platform, which are both password-protected. All raw data collected during the research will be maintained securely for a period of three years, after which it will be destroyed.

Thirty (30) questions presented within the survey are provided in Appendix 2 in order to develop an innovative framework to facilitate the use of Lean Construction as an approach for minimising risks of Mega-Construction projects in KSA. The results of the survey will be used in the analysis of the research topic and as a basis for a more successful Lean implementation in KSA.

8.7.1 SAMPLE SIZE AND RESPONSE RATE

Deciding on the survey sample size is not straightforward, as it can sometimes be very complex. Nevertheless, sample size can be estimated by various methods. For example, according to Mbugua (2000), a rule of thumb limiting the minimum number of participants to 30 is seen as adequate for construction research (Mbugua, 2000).

Equation No.1 presents a rough formula for calculating sample size (n) in terms of (E), the maximum error permitted (Easterby-Smith et al. 2002).

$$\boldsymbol{n} = \mathbf{2500/E^2}$$

Equation No. 1

The minimum sample size would be 100 when using a standard error of no more than 5 per cent, for instance, while it would be 25 if the standard error was no more than 10 per cent. In this survey, the sample size obtained was 76 respondents, which, in the light of the previous discussion, is a reasonable sample size that gives a minimum standard error of 5.73 per cent. The standard error is an estimate of the anticipated deviation of sample size around the true population parameter. Everitt (2003) defines the standard error as the standard dispersion of the sampling distribution of a statistic. The sample will be more representative of the overall population when the standard error is small (Everitt, 2003).

In a postal survey, it is satisfactory to reach a response rate of 30 per cent or above, although 20-30 per cent is the norm of response rates within the construction industry, as Akintoye et al. (2000) argue.

The survey undertaken for this research achieved a 95% per cent response rate, i.e. 76 fully usable completed questionnaires were returned from the 80 questionnaires that were sent out. This high response rate resulted from the respondents' interest in the topic, in addition to the application of some of the improving response rate techniques suggested in Cooper and Emory (1995), such as a personalised approach, follow-ups, questionnaire length, and anonymity.

8.7.2 PILOT SURVEY

The pilot stage enables the researcher to ensure that all the relevant issues are included, the order is correct, ambiguous or leading questions are identified, the pre-codes are correct, and that any issues which may be important to the respondent are not forgotten or omitted (Mathers et al., 2009).Therefore, the researcher conducted a pilot survey study. The questionnaire was evaluated and validated by the researcher‘s supervisor and by a local academic professor in KSA, with two practising professionals in KSA who have a good knowledge of Lean Construction. This was done to ensure clarity and unambiguousness of the questions, and questions were modified based on the comments given. The pilot exercise carried out also revealed that the questionnaire could be completed in about 15 minutes.

8.8 INTERVIEW METHOD: FRAMEWORK AND ASSESSMENT TOOL VALIDATION

Naoum (1998) states that there are three forms of interview: unstructured, structured and semi-structured (Naoum, 1998). A structured form of interview, where questions may be recorded, was adopted in order to achieve the purpose of this research. This allows flexibility in the wording of questions so that the level of language may be adjusted; the interviewer may modify questions and make clarifications to the interviewee between successive items (Berg, 2009). Structured open-ended interview questions were adopted in carrying out the interview. The framework will be refined and validated by using structured questions. Experts comprising both academics and professionals will be chosen. The number of academics chosen for the study was three (3) and the number of practitioners twelve (12): fifteen (15) participants in total. The academics will be mainly university lecturers/professors, which will allow for useful feedback in incorporating a sound theoretical base into the initial developed framework.

Structured interviews, another form of qualitative research, ask people questions during an interview process. The interviewer usually has a framework of themes to be explored.

The experts (academics and practitioners) were chosen according to the following criteria: The academics must be experts in the field of Lean and Risk Management in order for their feedback to be useful in the improvement of the developed framework.

The practitioners should have a direct relation with Lean implementation in their organisation or with one or more of the previous approaches of the research study (action research or questionnaire survey). This was to ensure a minimum level of knowledge of Lean implementation and Risk Management, as well as their understanding of the research study.

There are 15 questions, and the structure of interview questions consists of three sections: (A) respondent information (1-4); (B) validation of the developed framework (5-10); and (C) validation of the proposed Lean Construction Assessment Tool (11-15), which will be discussed in Chapter 14 (see Appendix 5). These 15 questions are a mixture of open-ended and multiple choice type of questions. In addition, the method of recording will be written notes. Regarding the method of coding, the researcher will code the data and define the similarities.

8.9 WORKSHOP METHOD – ACTUAL ASSESSMENT

Workshops are a group-based method of research in which there is an emphasis on activity-based, interactive working, i.e. the focus is on everyone participating in and undertaking the work. Therefore, when using this type of research technique, the researcher acts as a facilitator, rather than leading the discussion or activity (Centre for Local Economic Strategies (CLES), 2011). The researcher will conduct two workshops with twenty (20) selected professionals, all working for the company managing the action research. Each group will have ten (10) workers, only one working on site and the others working in the head office (top management). The objective of this workshop is to introduce the developed assessment tool and provide an introduction to the research literature.

CHAPTER NINE: DATA ANALYSIS: QUESTIONNAIRE SURVEY (01)

9.1 INTRODUCTION

This chapter is organised according to research objective number one, which is “to develop an innovative framework for the application of Lean principles in the construction industry (Lean Construction)”, and presents the findings and outcomes of the survey. The survey questions are provided in Appendix 2. Thirty (30) questions are presented in order to develop an innovative framework to facilitate the use of Lean Construction as an approach for minimising risks of Mega-Construction projects in KSA. The results of the survey will be used in the analysis of the research topic and as a basis for a more successful Lean implementation in KSA.

At the beginning of the survey, the researcher established a series of questions to collect information and feedback from regular workers about their awareness of Lean Construction and their insights into the possible benefits, as well as the challenges that may need to be overcome. Feedback from respondents was then collected at the end of the survey and used as a baseline to achieve the main aim of this research. An example of the completed survey (01) by one respondent is provided in Appendix 3.

The literature review has helped the researcher formulate the survey questions by obtaining an overall understanding of Lean principles, their history and application. In addition, the reviewed current literature guided the researcher to identify related surveys and data collection instruments that have measured concepts similar to the research’s aims and objectives. The questionnaire was designed on the basis of research hypotheses that have been carefully studied and thought out.

Prior to finalising the final draft of the survey, the researcher conducted a pilot survey study in order to review, revise and test the survey questions and examine the questionnaire as a whole for flow and presentation, before sending it to the selected participants. The questionnaire was evaluated and validated by the researcher‘s supervisor, by a local academic professor in KSA and by two practising professionals in KSA who have a good knowledge of Lean Construction. Discussing the research problem with professionals and subject matter experts is critical to developing good questions.

At the beginning of the research work, the objective is to include all key workers involved in the action research so that they can provide a preliminary view of the level of awareness of Lean Construction techniques in the area. It was found that there are 80 workers whose feedback will be beneficial for that area. Even if some of them do not have a complete idea of Lean, they will give a better perspective on solving the current issues. The profile of those who were asked to complete the survey are key personnel in the action research, which covered all disciplines and from different perspectives (contractor, consultant and owner).

Below are brief explanations of each question asked in the survey. The purpose of this questionnaire is for the researcher to obtain a certain level of information from the workers involved in the selected Mega-Construction project in KSA by means of the action research, which includes the following points:

- Level of awareness of Lean Construction
- Level of interest in Lean Construction
- Value added to the company if Lean Construction is implemented
- Methods to be implemented to increase awareness of Lean Construction in KSA
- Importance of Mega-Construction in KSA
- Critical issues and benefits of implementing Lean Construction
- Awareness of Lean Construction tools
- Comparison between Lean Construction and traditional methods
- Barriers during implementation of Lean Construction in KSA
- Preferred output of the research
- Benefits of integrating risk management and Lean Construction
- Comments and suggestions

9.2 SAMPLE CHARACTERISTICS

A total of 80 copies of the questionnaire were sent out to potential respondents on the 9th of November, 2015. By the end of the 14th of December 2015, 76 completed copies had been returned, representing a valid response rate of 95 per cent. According to Akintoye et al. (2000), this is a high response rate, which can be attributed to the interest of the respondents in the research topic.

9.3 ANALYSIS OF SURVEY QUESTIONS

In this section, the researcher summarises the results of the conducted survey. Chapter Nine combines the presentation of the questionnaire findings and the discussion of these findings. The survey data analysis is divided into ten sections, each section including questions corresponding to the survey. The ten sections are set out in Table 9.1.

Table 9.1: Structure of the questionnaire designed for this research

Sections	Focus	Questions
Section 1	General information	1-4
Section 2	Validation of selected country (KSA)	5
Section 3	Understanding of the level of awareness of Lean in KSA	6-10
Section 4	Benefits of Lean Construction method implementation	11-16
Section 5	Motivation to adopt Lean Construction and satisfaction if applied	17 and 18
Section 6	Barriers and critical issues associated with the implementation of Lean	19 and 20
Section 7	Understanding the level of use regarding the Lean tool	21 and 22
Section 8	Comparison between conventional methods and the Lean Construction method and available information about Lean	23 and 24
Section 9	Risk management and Lean Construction integration	25-27
Section 10	Recommendations and suggestions	28-30

Section 1: General information

Question 1: Name (Optional), Company (Optional), and Email Address

Question 2: Title

Question 3: Number of years of experience in the construction industry

Question 4: Your organisation type

The first four questions were asked in order to collect general information from the participants and help the researcher prepare coded survey responses. Fifty-two participants (52), representing 70 per cent of the respondents, have more than 5 years of work experience (see figure 9.1). There were 2 missing entries in the work experience, which accounted for 2.63 per cent of the total participants. A good response from 17 participants, representing 23 per cent, came from participants who have more than 15 years of work experience. Many of the respondents were decision-makers in the construction company responsible for managing the Mega-Construction project in KSA, with 21 workers holding positions at the managerial levels. The majority of participants were engineers, (54 out of 76), representing 71 per cent.

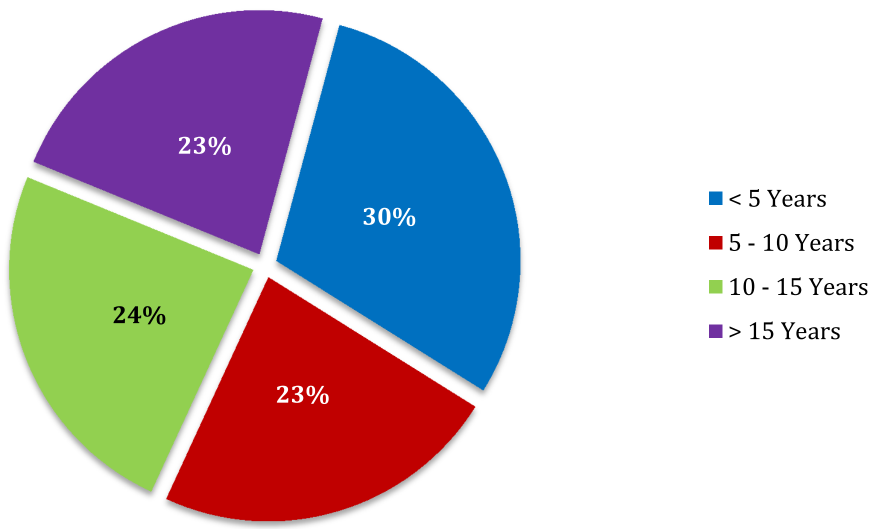

Figure 9.1: Number of years of experience in the construction industry

Section 2: Validation of selected country (KSA)

Question 5: The researcher has chosen a project in the Kingdom of Saudi Arabia as an action research to apply the Lean Construction method. Do you think the lessons learnt from projects in this country can be used as a guide for other countries in the Middle East?

Sixty-one (61) participants agreed with the researcher about choosing KSA as an action research location in which to apply the Lean Construction method. They also agreed that lessons learnt from projects in KSA can be used as a guide for other countries in the Middle East. Those respondents represented 82.43 per cent of the 74 respondents (see figure 9.2).

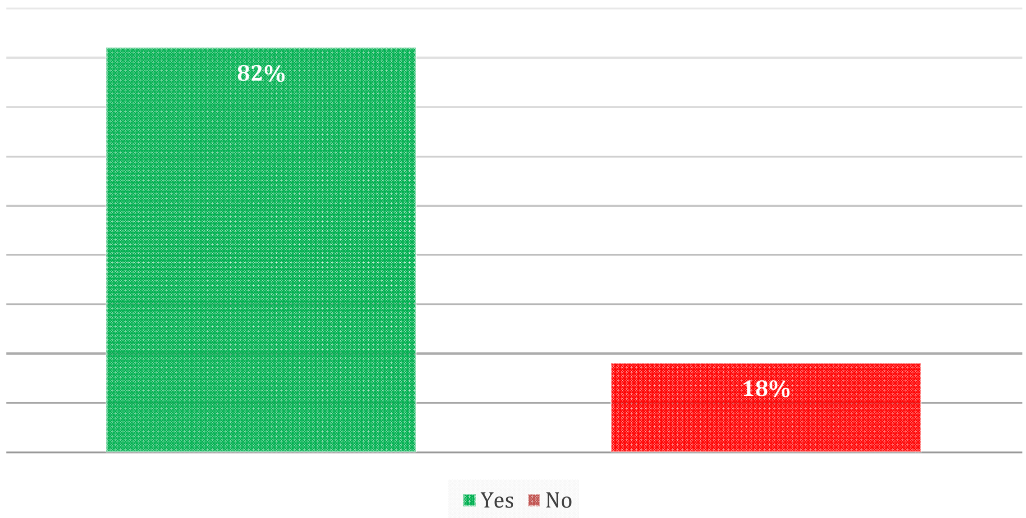

Figure 9.2: Number of participants who agreed with choosing KSA

Section 3: Understanding the level of awareness of Lean in KSA

Question 6: Have you heard about the Lean philosophy or the Toyota Production System's (TPS) philosophy?

Question 7: Do you know of any construction company in KSA that applies Lean Construction?

Question 8: Number of projects applying Lean Construction you have worked on:

Question 9: From your experience in KSA, provide a percentage of the workers that you think are aware of the concept of Lean Construction in KSA:

Question 10: In your opinion, what are the methods that should be implemented to increase awareness of Lean Construction in KSA?

The researcher asked the above questions (6, 7, 8, 9 and 10) in order to assess the level of awarness of Lean among the workers involved in the action research.

The participants were asked about their familiarity with the Lean philosophy or the Toyota Production System's (TPS) philosophy (question no.6). Seventy-four (74) participants answered, while 2 participants passed on answering this question; 50 per cent of the respondents indicated some knowledge of Lean Construction, while the other 50 per cent have never heard of this philosophy (see figure no.9.3). Question no.7 investigated the number of participants who know of a construction company in KSA that applies Lean Construction. Twenty-seven (27) participants stated that they were acquainted with such a company (see figure 9.4). Based on this number, it was realised that there is in fact more than one company that has applied the Lean Construction method in KSA, contrary to the predictions of the researcher. In addition, the participants were asked about the number of projects applying Lean Construction they have worked on (question no.8). This question indicated that 47 contributors (see figure 9.5) admitted that they have not worked in projects applying the Lean Construction method.

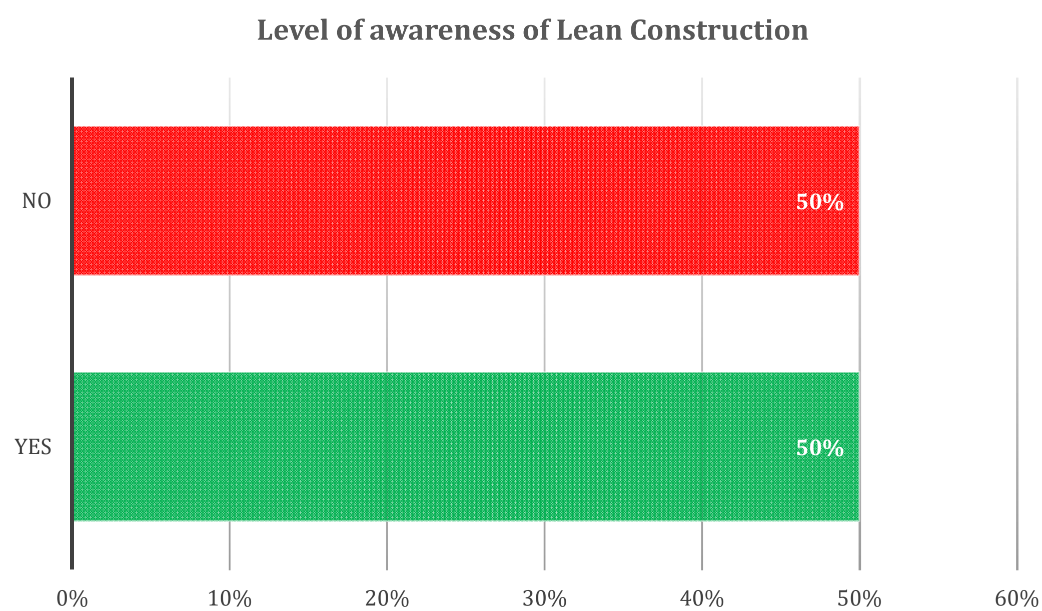

Figure 9.3: Construction companies in KSA that apply Lean Construction

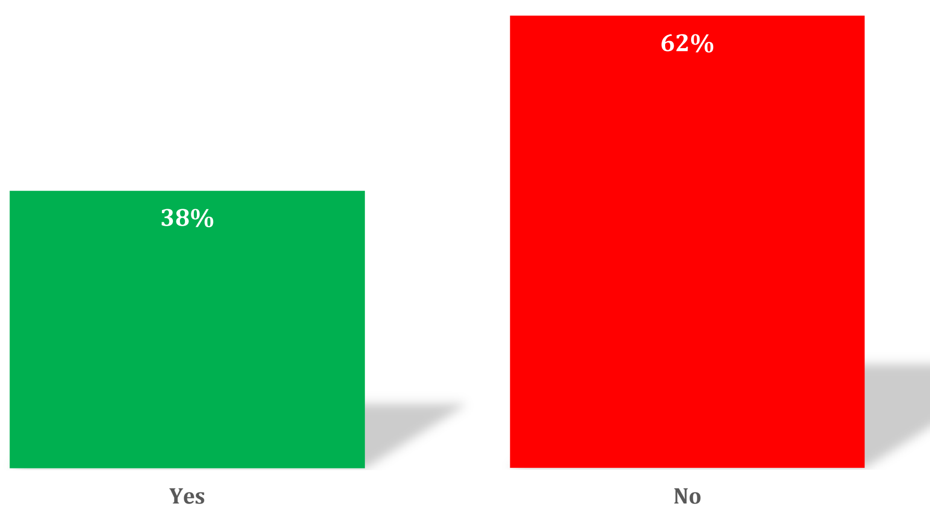

Figure 9.4: Number of participants who know of a construction company in KSA that applies Lean Construction

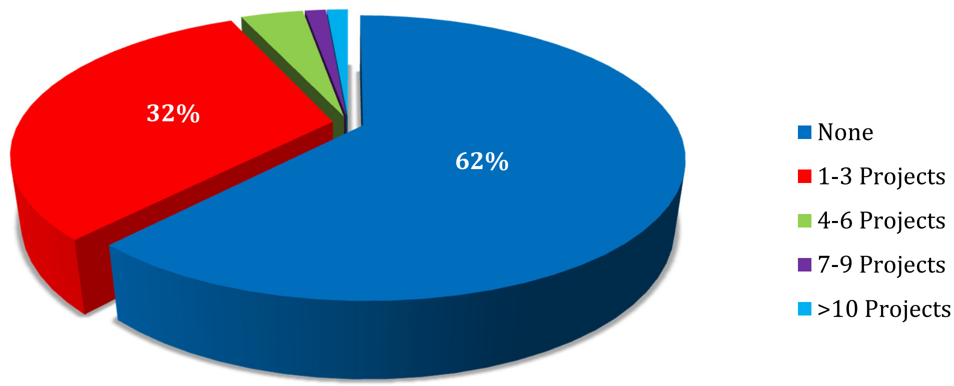

Figure 9.5: Number of projects applying Lean Construction that workers have participated in before

Further, question no.9 assesses the level of workers' perception regarding the concept of the Lean Construction method in KSA. Participants were asked to provide a percentage of the workers that they thought were aware of the concept of Lean Construction in KSA. The survey shows that there was a low percentage of workers who were aware of the concept of Lean Construction in KSA, representing 1-5 per cent, as shown in the figure (9.6).

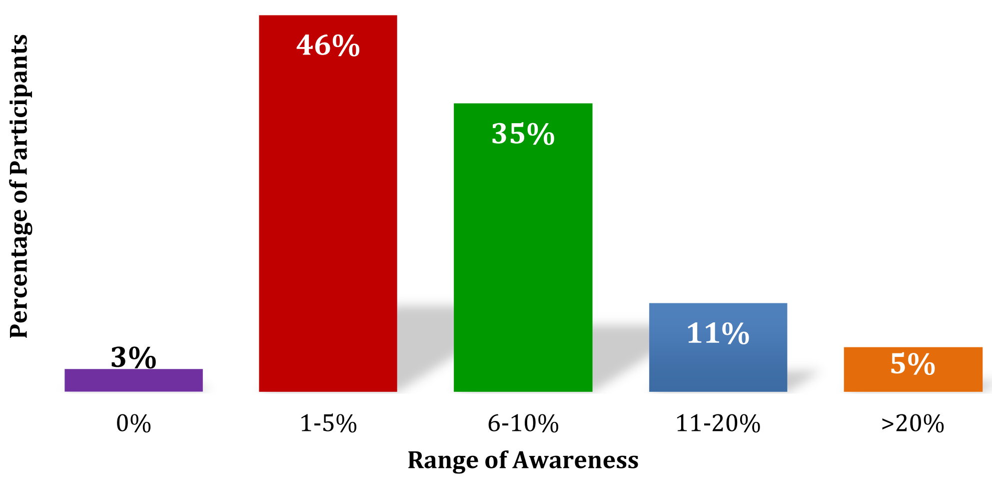

Figure 9.6: Percentage of workers aware of the concept of Lean Construction in KSA

In order to determine which method should be implemented to increase awareness of Lean Construction in KSA, the participants were asked in question no.10 to suggest the methods that should be implemented. It was found that training was considered to be the main method that should be implemented to increase the awareness of Lean Construction in KSA and the motivation to implement it (figure 9.7).

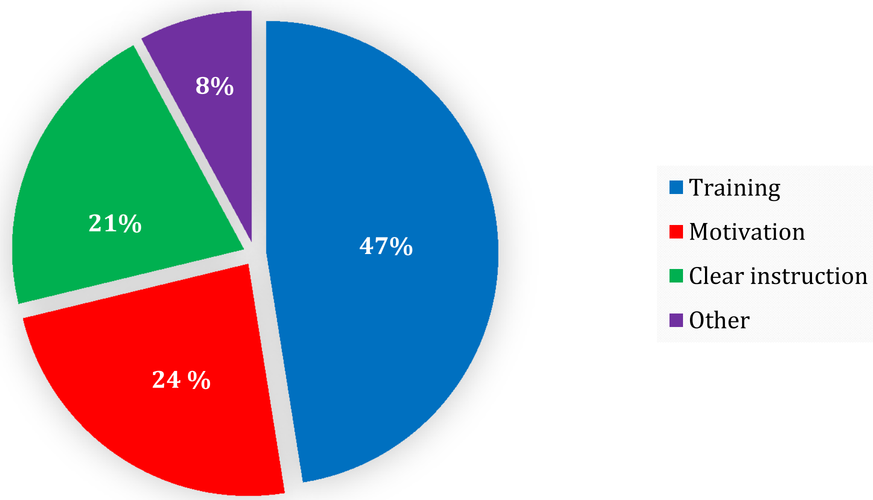

Figure 9.7: Methods of implementing Lean Construction awareness in the KSA according to respondents' answers

Section 4: Benefits of Lean Construction method implementation

Question 11: Do you think that if Lean Construction were applied in KSA and, specifically, at your company, it would add value?

Question 12: If Lean Construction is applied at your company, by what percentage do you think it will add value in general?

Question 13: If Lean Construction is applied at your company, by what percentage do you think costs will be reduced?

Question 14: If Lean Construction is applied at your company, by what percentage do you think waste will be reduced?

Question 15: What are the benefits/impact of implementing Lean Construction in Mega-Construction projects in KSA?

Regarding question no.11, eighty-eight (88) per cent of the participants confirmed that the Lean Construction method would add value if it were applied (see figure 9.8).

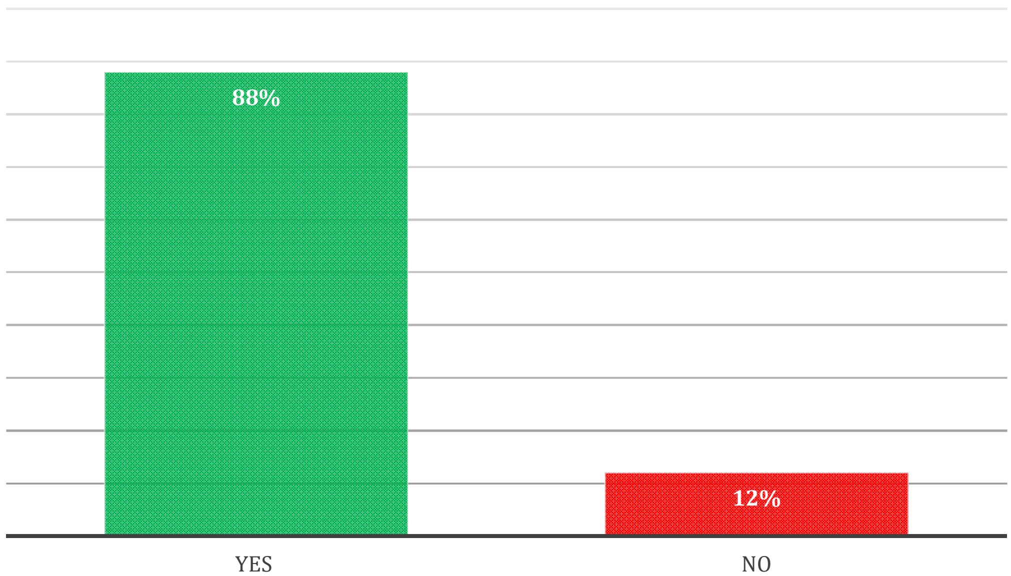

Figure 9.8: Participants who agreed that Lean Construction method would add value if it was applied to their company

Questions 12, 13, and 14 are intended to find the percentage of respondents who expect the Lean Construction method to add value, reduce cost and eliminate waste and to ensure that the respondents were aware of the benefits of the implementation of the Lean Construction method. Those three questions were included in the questionnaire relating to the extent of value added by the Lean Construction method, in the event of its application. Among the 75 respondents, 6 partcipants, representing 8 per cent, claimed that it would add value by 5-10 per cent; 27 partcipants, representing 36 per cent, said it would add value by 11-20 per cent; 22 partcipants, representing 29.33 per cent, said it would add value by 21-30 per cent; and 20 participants, representing 26.67 per cent, said it would add value by > 30 per cent. The largest number of responses who believed it would add value, 27 out of 75, claimed that the implementation of Lean Construction would add value by 11-20 per cent (figure 9.9).

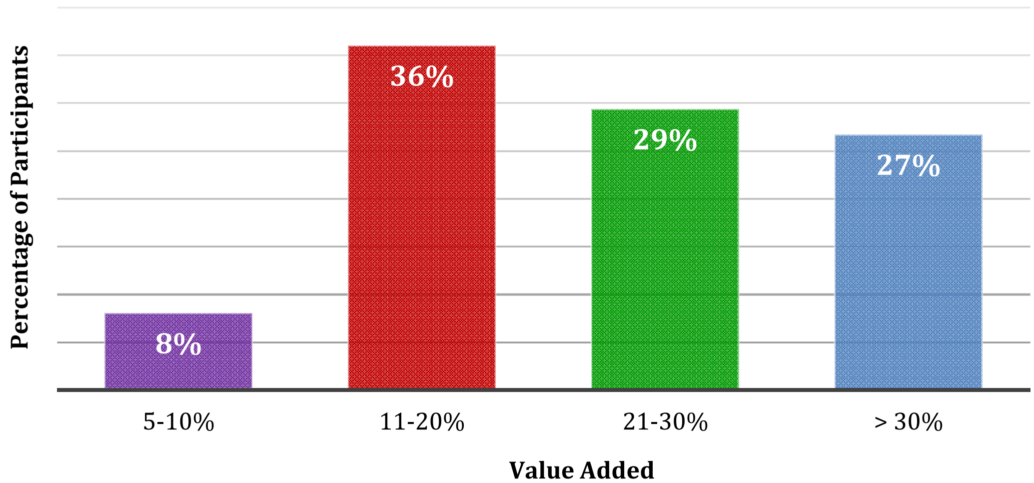

Figure 9.9: Percentage of respondents who expected added value if Lean Construction was applied

In terms of cost and waste reduction, the largest number of respondents believed that costs would be reduced by 21-30 per cent and 23 members agreed that waste would be reduced by the same percentage see (table 9.2 and figures 9.10, 9.11). Some of the questions presented in the survey allowed the option of multiple answers, so for some of the data collected, the answers added up to more than 100% (the percentage of feedback given as opposed to the number of participants in the survey).

The researcher assumed a range of cost and waste reduction (5-10, 11-20, 21-30, and >30%). The table below (9.2) shows the number and percentage of participants involved in each of the assumed cost and waste reduction percentages.

Table 9.2: Number of participants and weighted percentages for each percentage range of cost and waste reduction

Percentage	Cost reduction		Waste reduction	
	No. of participants	Percentage of participants	No. of participants	Percentage of participants
5-10	14	18.67	17	22.67
11-20	23	30.67	18	24
21-30	25	33.33	23	30.67
>30	13	17.33	17	22.67

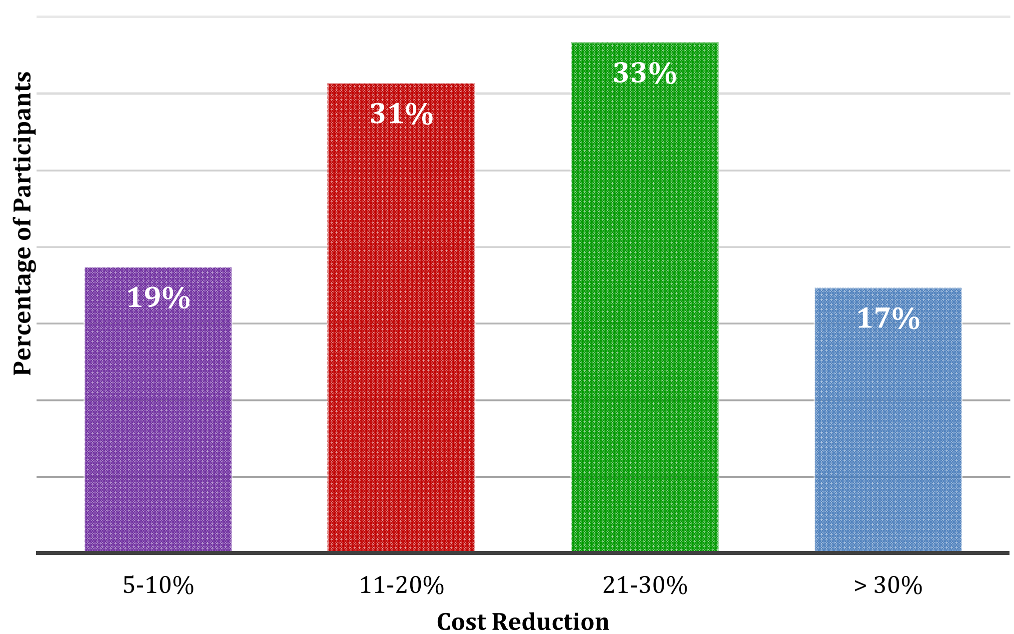

Figure 9.10: Percentage of respondents who expected cost reduction if Lean Construction were applied

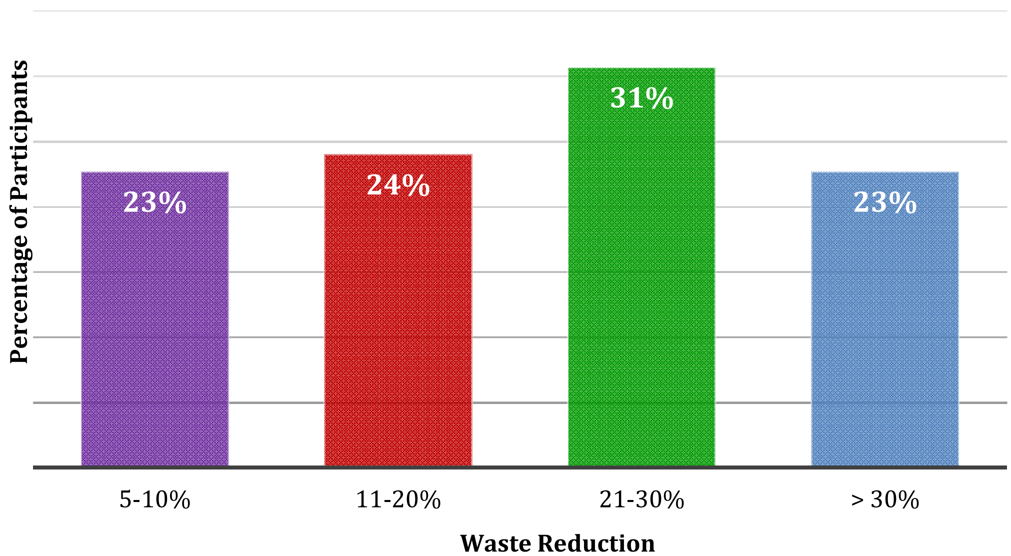

Figure 9.11: Percentage of respondents who expected waste reduction if Lean Construction were applied

Based on the data collected from question no.15, cost reduction, waste elimination, and value maximisation are seen to be the benefits of implementing Lean Construction in Mega-Construction projects in KSA(Table 9.3). Figure 9.12 shows that the majority of participants (72.97 per cent) believed that cost reduction, elimination of waste and maximising value are the benefits of the Lean Construction method.

Table 9.3: Number of participants and weighted percentages for each advantage of the Lean Construction method

Value added	No. of partcipants	Percentages
Cost reduction	22	29.73
Eliminate waste	11	14.86
Maximise value	5	6.76
All of the above	54	72.97

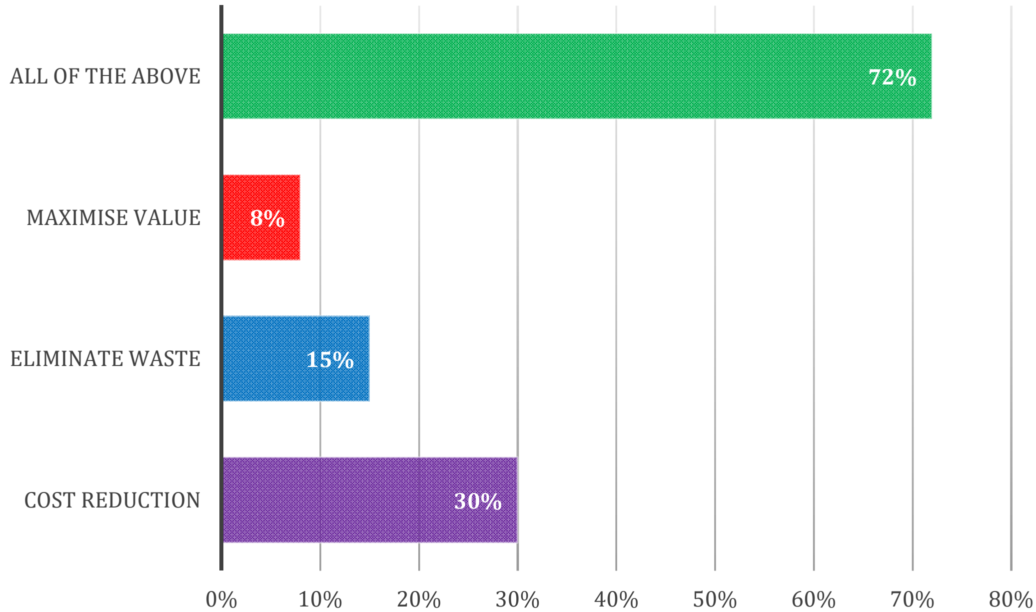

Figure 9.12: Percentage of respondents who selected each of the Lean Construction benefits

Section 5: Motivation and satisfaction of Lean Construction if applied

Question 16: If your organisation has applied Lean Construction, what was the motivation?

Question 17: What was the level of satisfaction with the implementation of Lean Construction in your organisation?

Question 18: Do you think that Lean Construction needs to be applied to Mega-Construction projects in KSA?

Questions 16 and 17 were posed in order to confirm whether the participants' organisation has applied Lean Construction and the motivation and level of satisfaction that allowed them to implement that method. The participants were asked in those two questions to write comments, rather than choosing answers. The data gathered from this questionnaire regarding the benefits and added value of Lean implementation indicated that the Lean Construction method would maximise performance for the customer at the project level, together with concurrent design, construction, and the application of project control throughout the life cycle of the project from design to delivery. Also, if Lean principles are applied, the more reliable the flows and the better the labour performance.

Moreover, the participants were asked in question 18about the importance of implementing the Lean Construction method in Mega-Construction projects in KSA. Sixty five (65) applicants believed that Lean Construction should be applied in Mega-Construction projects in KSA (figure 9.13).

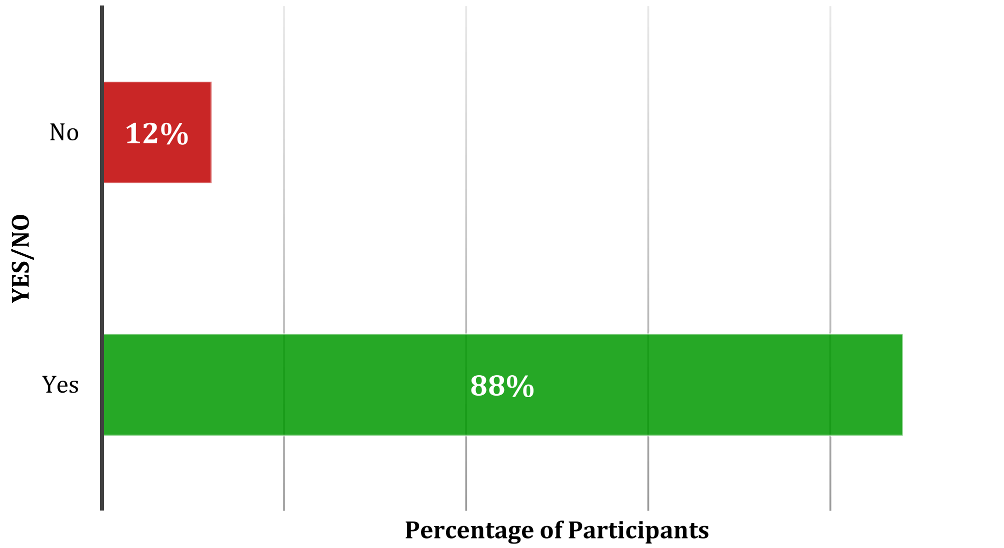

Figure 9.13: Percentage of participants confirming the importance of the implementation of Lean Construction in KSA

Section 6: Barriers and critical issues associated with the implementation of Lean

Question 19: What are the critical issues associated with the implementation of Lean Construction in Mega-Construction projects in KSA?

Question 20: What are the barriers to the implementation of Lean Construction in KSA?

The data collected from question 19highlighted the critical issues regarding the implementation of Lean Construction.The main critical issues associated with the implementation of Lean Construction in Mega-Construction projects in KSA are lack of awareness and knowledge (see figure 9.14).To that end, the researcher provided seven features that may be considered common barriers in KSA. Respondents were then asked to select what they thought were the barriers that may have the greatest effect.

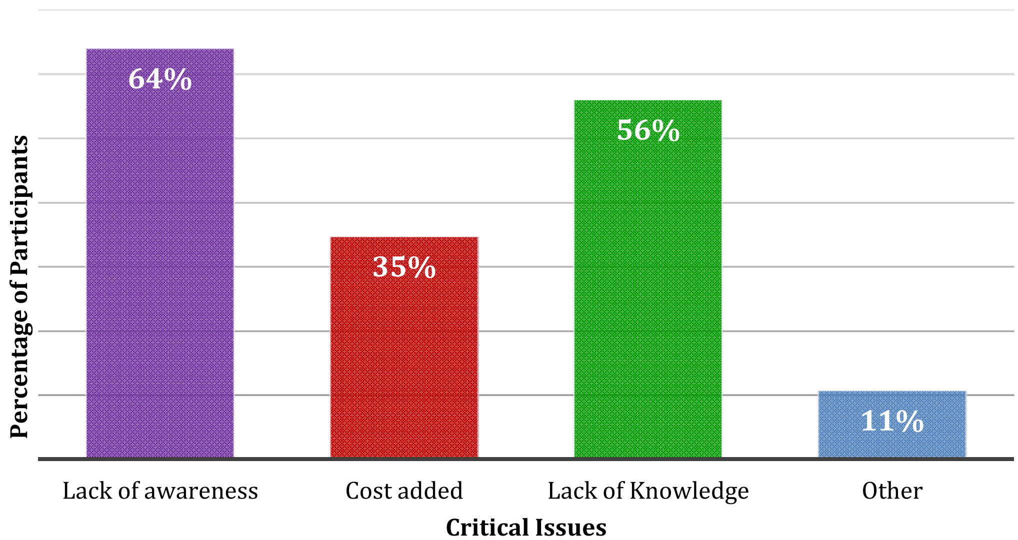

Figure 9.14: Percentages of anticipated critical issues associated with the implementation of Lean Construction

Lack of guidance and information, skills shortage, lack of experience of its use, client resistance, risk-averse culture, higher costs and higher capital costs were the barriers to the application of Lean Construction in KSA agreed on by the participants (question 20). Table 9.4 illustrates the number of employees, with the percentage and the level of agreement for each barrier.

Table 9.4: No. of employees who selected possible barriers

What are the barriers to the implementation of Lean Construction in KSA?						
Answer Options	Strongly Agree	Agree	Can't Say	Disagree	Strongly Disagree	Response Count
More expensive	13.33%	37.33%	30.67%	16.00%	2.67%	75
	10	28	23	12	2	
Higher capital cost	13.33%	33.33%	30.67%	18.67%	4.00%	75
	10	25	23	14	3	
Client resistance	8.00%	44.00%	24.00%	20.00%	4.00%	75
	6	33	18	15	3	
Lack of guidance and information	22.67%	64.00%	8.00%	5.33%	0.00%	75
	17	48	6	4	0	
No experience of its use	24.00%	53.33%	21.33%	1.33%	0.00%	75
	18	40	16	1	0	
Risk averse culture	10.67%	44.00%	37.33%	8.00%	0.00%	75
	8	33	28	6	0	
Skills shortage	18.67%	54.67%	17.33%	9.33%	0.00%	75
	14	41	13	7	0	
					Respondents	**75**
					Non-respondents	**1**

Section 7: Understanding the level of use regarding Lean tools

Question 21: What percentage do you think is the level of use of Lean tools and techniques/principles for maximising project value?

Question 22: Do you know any tool/software that would help companies to implement Lean Construction?

The data collected from questions 21 and 22 provided the assessment of the level of awarness of Lean tools. Table 9.5 and figure 9.15 showed the high number of particpants, 22 out of 75 (representing 29.73 per cent,) who believed that the use of Lean tools and techniques/principles for maximising project value falls between 21 and 30 per cent. However, most participants, 54 out of 75 (representing 72 per cent), were not familiar with any tool/software that would help companies to implement Lean Construction (see figure 9.16).

Table 9.5: Number of participants and weighted percentages for each percentage range for assessing the level of awareness of Lean tools

Value added	No. of partcipants	Percentages
5 – 10 %	17	22.97
11 – 20%	20	27.03
21 – 30%	22	29.73
> 30 %	15	20.27

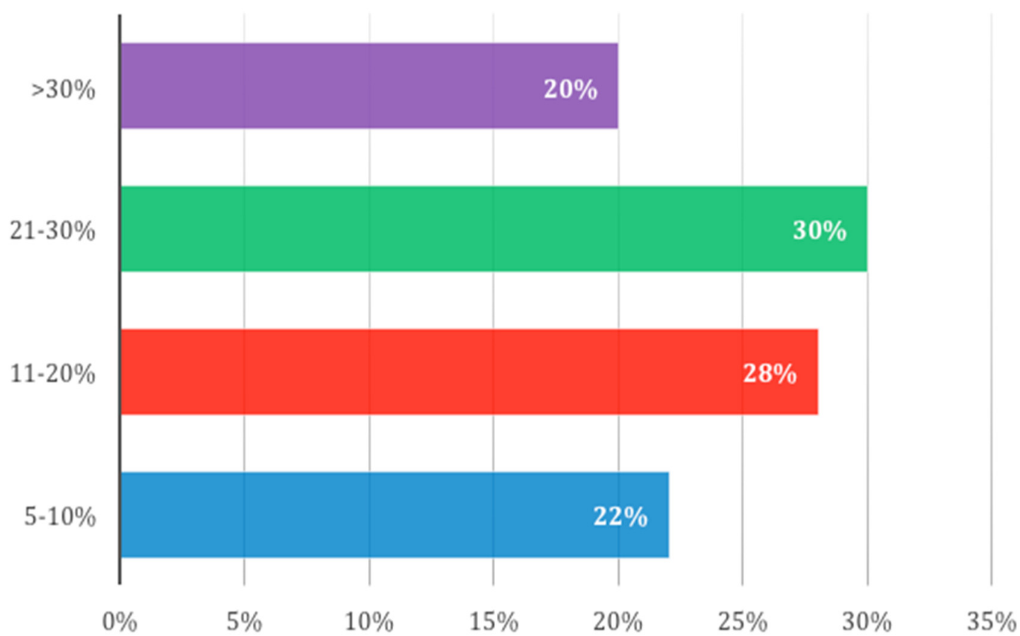

Figure 9.15: Percentages of participants who believed that the use of Lean tools and techniques/principles would maximise project value

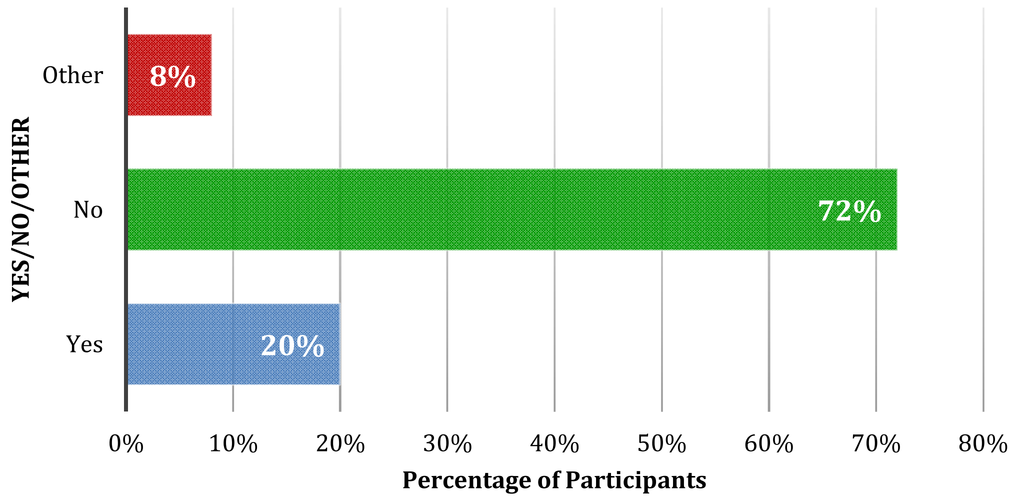

Figure 9.16: Participants who believed or did not believe that Lean tools would help companies to implement Lean Construction

Section 8: Comparison between conventional method and Lean Construction method and available information about Lean

Question 23: In your view, how do Lean Construction techniques compare to conventional methods?

Question 24: What types of information is available on Lean Construction techniques in KSA?

Participants gave their opinion regarding the difference between Lean Construction and the current implemented traditional methods in terms of flexibility in design, equipment usage, rework and site problems, speed of construction, quality, and safety in question 23.The gathered data relating to the comparison between the implementation of conventional methods and Lean Construction techniques showed that most participants believed flexibility in design, equipment usage, rework and site problems, speed of construction, quality and safety would be enhanced if Lean Construction techniques were applied in Mega-Construction projects in KSA. Table 9.6 gives the number of partcipants and percentage for each of the comparison aspects.

Table 9.6: Lean Construction techniques compared to conventional methods

In your view how do Lean Construction techniques compare to conventional methods?						
Answer Options	**Significantly more**	**More**	**Same**	**Less**	**Significantly less**	**Response Count**
Flexibility in design	27.03%	41.89%	22.97%	5.41%	2.70%	74
	20	31	17	4	2	
Equipment Usage	21.92%	43.84%	17.81%	13.70%	2.73%	73
	16	32	13	10	2	
Rework and site problems	25.00%	19.44%	15.28%	31.94%	8.34%	72
	18	14	11	23	6	
Speed of Construction	29.17%	55.56%	11.11%	4.16%	0.00%	72
	21	40	8	3	0	
Quality	37.50%	47.22%	9.72%	5.56%	0.00%	72
	27	34	7	4	0	
Safety	36.99%	43.84%	16.44%	1.37%	0.00%	74
	27	32	12	1	1	
					Respondents	**74**
					Non-respondents	**2**

The participants were asked about the types of available information on Lean Construction techniques in KSA. Table 9.7 shows the number of partcipants and the percentage for each type of information. The majority of respondents, 59.46 per cent (44 respondents), claimed that there was widely available information on general Web resources, while 23 respondents said that information from government and legislative sources were not available.

Table 9.7: Information available on Lean Construction techniques in KSA

What types of information is available on Lean Construction techniques in KSA?				
Answer Options	**Widely Available**	**Scarcely Available**	**Not available**	**Response Count**
Literature Review	26.39%	54.17%	19.44%	72
	19	39	14	
Successful case studies/best practices	19.18%	61.64%	19.18%	
	14	45	14	73
Technical research reports	20.55%	58.90%	20.55%	73
	15	43	15	
Government and legislative sources	15.28%	52.78%	31.94%	72
	11	38	23	
General Web resources	59.46%	39.19%	1.35%	74
	44	29	1	
			Respondents	**74**
			Non-respondents	**2**

Section 9: Risk management and Lean Construction integration

Question 25: Are there links between Lean Construction and Risk Management?

Question 26: Do you think that Risk Management should be linked to Lean Construction?

Question 27: What are the benefits of integrating Risk Management and Lean Construction?

The researcher proposed a framework that integrated the Lean Construction method with risk management. Participants were then asked their opinion about possible benefits of integration and its feasibility.

Sixty-one (61) participants,representing 82 per cent, agreed that risk management should be linked with Lean Construction (figure 9.17). Participants claimed that this integration would help the company improve the performance of construction projects and at the same time identify the problems that might arise in the future. The construction project system and culture focused primarily on risk-contributory metrics, such as workflow reliability and readiness, rather than on cost-budget performance metrics, such as earned value. In addition, if the philosophy of Lean Construction is linked with risk management, costs will be reduced as over-expenditure is eliminated; quality of work will be improved as rework is minimised. Work will be executed safely, which will minimise the indirect cost of the project. It has been found that this integration will provide more creative solutions to risk management, which will prevent significant problems in the future.

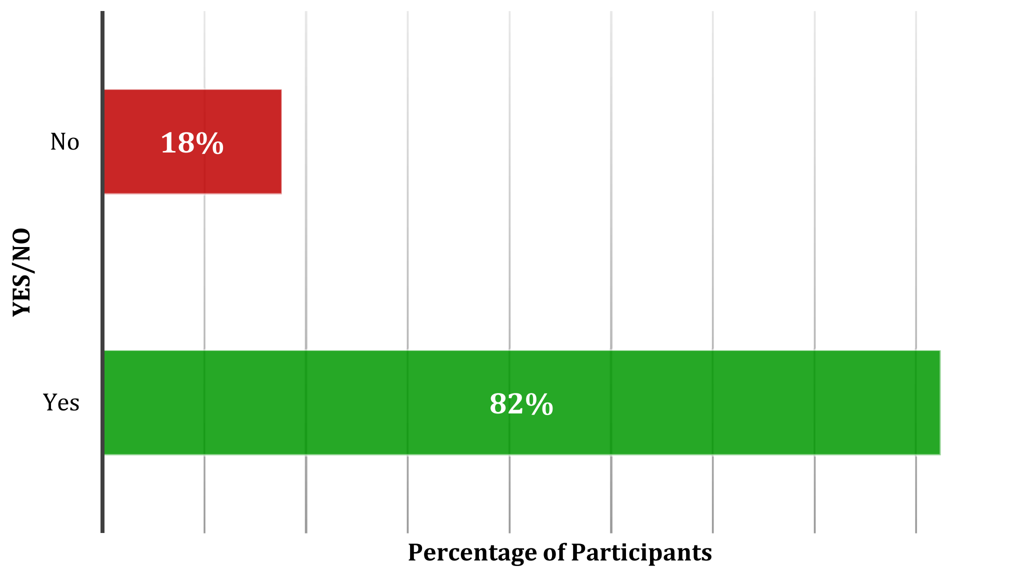

Figure 9.17: Percentage of participants that agree/disagree with the linkage of Risk Management and Lean Construction

Section 10: Recommendations and suggestions

Question 28: In which way would you prefer to implement Lean Construction?

Question 29: What type of output would you prefer to get from the research?

Question 30: Comments or Suggestions:

The researcher developed a framework to facilitate the implementation of the Lean Construction method. Question 28 investigated in which way participants would prefer to implement Lean Construction (theoretically, practically, or otherwise). It has been found that management prefers to implement the Lean Construction method practically, by applying specific tools, and theoretically, by increasing worker awareness (figure 9.18).

To ensure that the output of this research is useful, question 26 asked what type of output participants would prefer to get from the research. It has been suggested that the output of this research should provide a framework/guidance, findings from studying the current situation and recommendations based on the literature review (figure 9.19).

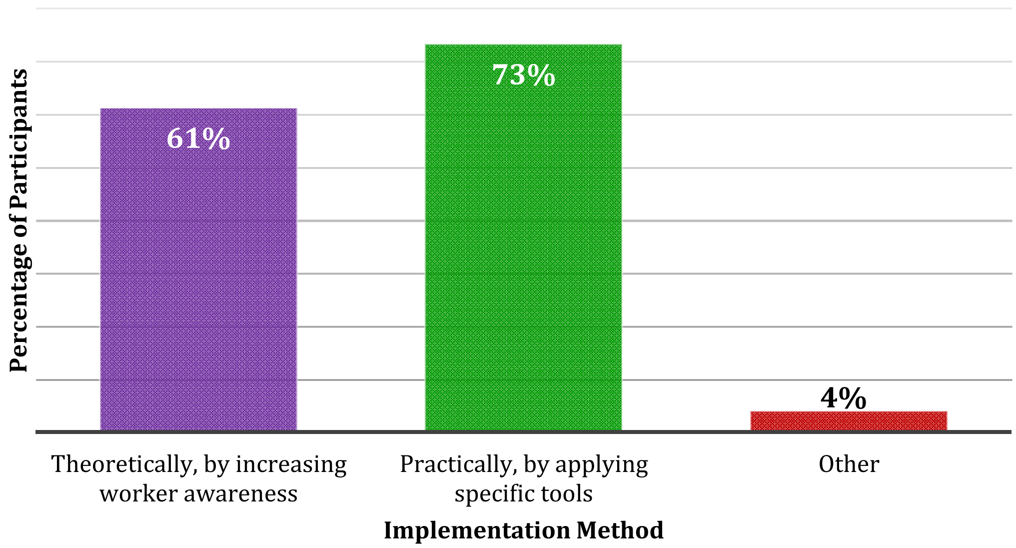

Figure 9.18: Percentage of selected methods of Lean Construction implementation

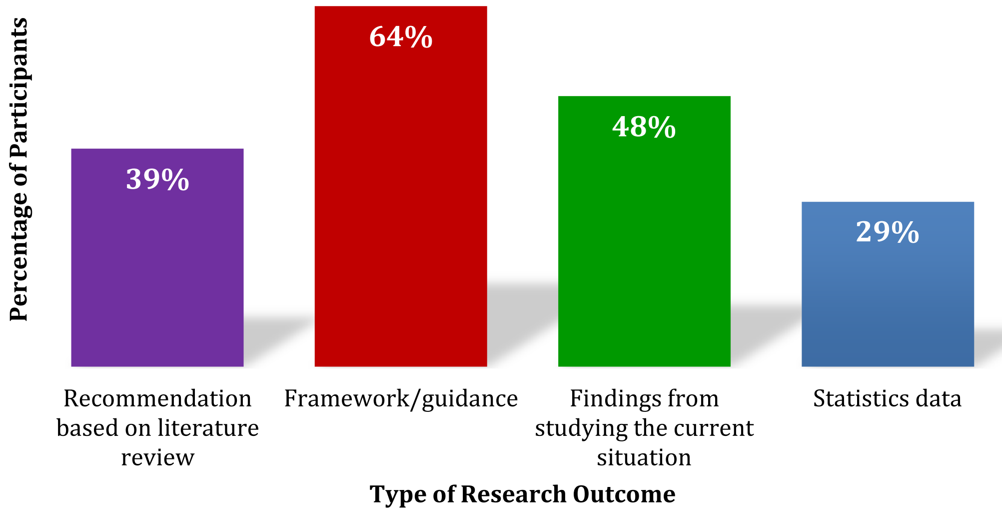

Figure 9.19: Percentage of preferred output of this research

In order to get a better insight from the participants, the researcher included an open question (question no. 30) to collect comments and/or suggestions. It has been noticed from the received suggestions that the philosophy of Lean Construction is seen to focus not only on overall reduction of waste, but also on profit. Utilising this methodology has been proven to increase profit. In order for this method of construction to be effective, all areas of management, along with the workers, have to be in accordance with regard to the plan. If there is a break in the chain, Lean methodology cannot work. Companies should therefore integrate Lean Construction in their projects. However, since it has been shown that this will increase the capital cost, many companies will not take it up because clients will think about the initial expense rather than the long-term benefits.

Judging from the respondents' feedback, waste management as well as environmental concerns, as a whole, are still not integrated into Middle Eastern culture. For example, waste segregation is not a common practice here. Recycling is also not very popular. Therefore, it has been found that, although Lean Construction is a very valuable tool for companies, there is a huge challenge regarding its implementation.

SUMMARY OF TASK TWO: UNDERSTANDING THE EXISTING SITUATION IN KSA (SURVEY 01)

Task Two can be summarised with reference to two chapters: Chapter Eight discussed the research methodology and Chapter Nine presented the survey data analysis. Chapter Eight also presented the research process adopted and the rationale for using both quantitative and qualitative methodologies. The choice of research design, paradigm and justification was made by the researcher. The qualitative methodology mostly describes phenomena using words, while the quantitative methodology measures them and describes results numerically. The strengths and weaknesses of qualitative and quantitative approaches can enrich the findings of the research, thus serving as a platform for triangulation. This is because quantitative methods tend to be broader and more easily generalisable, while qualitative methods can provide a much deeper, richer data set. Having established that, the various methodological options under each methodology were reviewed and the choice of an appropriate method for this study was made for both methodologies.

Chapter Nine discussed and presented in detail the collected results of the survey data analysis that allowed the researcher to assess the level of awareness of the Lean Construction method, validated the researcher's assumptions and selections, such as the selection of risk management to be integrated with Lean Construction, and also the selected country, KSA, to use an ongoing Mega-Construction project to be used as an action research. This was in order to utilise a real situation, rather than a contrived one, and its experimental study in solving real problems, implementing the developed framework practically and getting meaningful feedback from the workers, all of which are the primary focus of the research.

The reviewed literature (Task 1) and data collected (Task 2) from survey (01) have guided the researcher in developing a framework. The reason behind this strategy is that: (1) it is a clear structure that demonstrates the process that would facilitate the adoption of Lean Construction throughout the entire construction project life cycle; and (2) it was recommended by the participants. Forty eight (48) respondents, representing 64 per cent, in the conducted survey (01) indicated that they would prefer the outcome of this research to be a framework/guidance. The next task (Task 3) will be the development of the framework.

TASK 3: FRAMEWORK DEVELOPMENT AND VALIDATION

Task Three (Chapters 10, 11 and 12): Framework development and validation

This task consists of three chapters (10, 11, and 12). Chapter Ten discusses the elements of the framework, with links back to the literature and the findings from the survey (01) data analysis, presents the proposed framework for guiding Lean Construction implementation within construction organisations and discusses the development of the Lean Construction Framework integrated with Risk Management (LCFIRM). Chapter Eleven presents the deployed validation process and its outcome for this framework. Chapter Twelve presents the revised and validated Lean Construction framework.

In order to develop a framework to achieve one of the main objectives of this study, it is necessary to use the reviewed literature, action research and data collected from the conducted Survey 01 as a sound, realistic basis for this task. After the framework is developed, it needs to be validated by experts for feedback and suggestions. The researcher utilises two interviews and an online survey, with 15 participants for that purpose. The validation approach starts with the first interview, followed by an online survey (Survey 02), and then a second interview. The diagram below (FigT.3) shows the activities involved in Task Three.

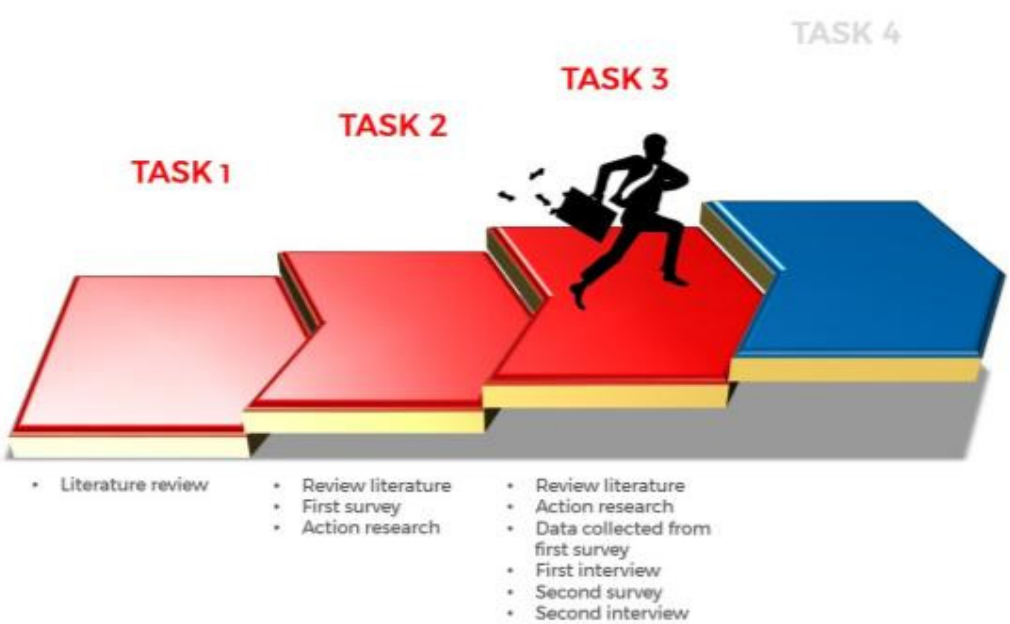

Figure T.3: Activities involved in Task Three

Chapter Ten: LEAN CONSTRUCTION FRAMEWORK DEVELOPMENT

10.1 INTRODUCTION

Based on a comprehensive study of the literature and the findings of the performed survey, a framework for implementing Lean Construction in construction organisations has been developed. The proposed framework focuses mainly on the implementation of the Lean approach integrated with Risk Management in Mega-Construction projects in KSA. Its purpose is to allow construction organisations to evaluate and analyse their Lean implementation strengths and assess the benefits of Lean that will add value within their organisations. Thus, the proposed Lean Construction framework is a guide that enhances the awareness of Lean implementation as well as its benefits.

The data collected from the conducted survey in Chapter 8 shows that Lean Construction could significantly benefit construction companies. The gathered data from Key decision makers and participants in that Survey, relating to the comparison between the implementation of conventional methods and Lean Construction techniques, showed that most participants believed flexibility in design, equipment usage, rework and site problems, speed of construction, quality and safety would be enhanced if Lean Construction techniques were applied in Mega-Construction projects in KSA (Refer to Table 9.6 in Chapter 8).

This task deals with the Lean implementation guidelines, i.e. the proposed framework to be applied for the purpose of enhancing KSA's construction performance. In order to validate the potential improvements that Lean can achieve, the framework was applied to an Action Research project to give the company the opportunity to consider the positive and negative effects of Lean implementation on the overall business performance.

In this task, the researcher responds to the question of why a specific framework is chosen to be the basis of the research and what it means. A framework is defined by the Merriam-Webster dictionary as a set of ideas, conditions or assumptions that determine how something will be approached, perceived or understood. The researcher has chosen "developing a framework for applying Lean Construction" to be the outcome of this research because it is a user-friendly and clear structure that demonstrates the process of facilitating the adoption of Lean Construction throughout all the phases of a construction project's life cycle. Ogunbiyi (2014) believes that the need for a more comprehensive framework is proven by the review of several Lean frameworks. Current frameworks focus more on process design as well as the implementation of Lean in projects rather than on improving organisational learning capacity to embrace Lean at the strategic level (Ogunbiyi, 2014). In the researcher's view, most of the developed frameworks are based on a theoretical approach. In contrast, the researcher developed a framework based on a specific type of construction project (infrastructure projects), which is the selected Mega-project (action research). The researcher used this type of construction project as a focus for deeply investigating the added value of the implementation of Lean Construction.

In Task One, the researcher covered all the subjects related to Lean Construction and other techniques that may add value to the research objectives. Task One concentrated on the theoretical aspects discussed by the researcher as a solid baseline for developing the approach applied in the construction project, taking into account the actual situations on site.

Based on the questionnaire findings in Task Two, the need to investigate issues relating to Lean implementation has emerged, such as drivers for Lean, success factors, barriers encountered and the assessment of Lean's impact on construction projects. The qualitative methodology adopted several research strategies that can be used to produce an in-depth research outcome.

The action research findings are expected to validate the applicability of the Lean Construction method within Mega-construction projects in KSA. One already running project was chosen; it was planned to start in November 2013 and the proposed duration was 3 years, but recently the scope of work has expanded, with a time extension of 12 months. The project is now planned to finish in October 2017. The data collected from the conducted survey and real examples of the current Mega-construction project in KSA were used to create a framework that can facilitate the adoption of Lean Construction.

Therefore, the aim of this task is to discuss and combine the outcome of the undertaken research endeavour to develop a framework that supports construction organisations in applying the Lean Construction method in KSA. This framework encompasses the attained first objective: to develop an innovative framework for the application of Lean principles in the construction industry (Lean Construction) and provides insight into the extent to which this approach can minimise the risks involved in Mega-Construction projects in developing countries and in KSA in particular.

10.2 FRAMEWORK TYPES

First, it is important to comprehend the meaning of a 'framework'. According to Liehr and Smith (1999), a research framework is a structure that "guides the researcher through the adjustment of study questions, the selection of variables, measurement methods and the planning of analyses". After the selection and analysis of data, the framework is used as a mirror to check whether or not the findings agree with the framework (Liehr & Smith, 1999).

The theoretical framework, which a researcher chooses to guide him/her in his/her research, is defined as the application of a theory, or a set of concepts derived from one and the same theory, to explain an event, or highlight a particular phenomenon or research problem. Imenda cites many examples, including set theory, evolution, quantum mechanics, particulate theory of matter, or similar pre-existing generalisations, such as Newton's laws of motion or gas laws, that could be deductively applied to a given research problem (Imenda, 2014).

A researcher may, on the other hand, state that one theory will not be sufficient for the study of his/her research problem. Hence, the researcher may have to "synthesise" the existing views of a given situation included in the literature according to both theoretical and empirical findings. This synthesis could be considered a model or a conceptual framework, providing an "integrated" perspective (Liehr and Smith, 1999), which could be used instead of a theoretical framework.

Thus, a conceptual framework could be seen as the final result of combining a number of related concepts to explain or predict a given event, or give a broader understanding of the subject/focus of interest or, simply, of a research problem (Imenda, 2014). Constructing a conceptual framework is similar to an inductive process, where small individual pieces, i.e. concepts, are combined to draw a bigger map of possible relationships. Therefore, a conceptual framework is derived from concepts, exactly as a theoretical framework is derived from a theory (Imenda, 2014). According to Miles and Huberman (1994, p.18), a conceptual framework is defined as a visual or written product that "explains, either graphically or in narrative form, the key factors, concepts, or variables and the presumed relationships among them." (Miles & Huberman, 1994).

The researcher maintains that the theoretical framework stands on an existing theory or theories, while the conceptual framework, on the other hand, can be developed based on this theoretical framework. Also, the researcher may add his own relevant concept/constructs/variables to the conceptual framework and then proceed to explore or test the relationship between them. The researcher develops the conceptual framework to find a solution for a particular problem, whereas he develops the theoretical framework according to theories or a general representation of relationships between various things.

10.3 LEAN CONSTRUCTION FRAMEWORK INTEGRATED WITH RISK MANAGEMENT [LCFIRM]

Based on (1) data collected from documents concerning completed construction projects in which the researcher has been professionally involved; (2) the researcher's experience in the field of construction project management in the Middle East and risk management in particular; and (3) extensive study of the literature in this domain, a set of the most common problems associated with construction projects in one of the Gulf Area countries - the Kingdom of Saudi Arabia (KSA) - was identified and categorised into three individual risk types, namely Construction Waste; Delayed Schedule; and Project Over Budget. Following a detailed identification and assessment of implemented strategies commonly used by contractor teams to overcome each of those problems and a study of the Lean Construction method as the "new" strategy introduced recently to the field, it is proposed that the Lean Construction method could lead to better results in solving the problems faced by construction projects.

The decision makers involved in the action research assumed that Lean Construction could significantly benefit their company, and during the actual validation (refer to section 12.6) it has been confirmed that the Lean Construction method is increasing project value, eliminating waste and reducing associated risks. Furthermore, Lean Construction has been gaining a lot of ground in solving the aforementioned problems in other domains and it seemed to be a suitable solution for Mega projects within the construction industry.

Regarding the transition from the reviewed literature and data collection to the framework, from the beginning the researcher knew that he needed to develop a framework, and during the literature review and the analysis of the data collected, he began to formulate one. He set up a white board in his studying room and every day added sticky notes with the key points of Lean Construction from the reviewed literature. When he reached the point of formulating the framework, he had all the key activities that should be incorporated with the framework, but arriving at the structure/shape of the framework took some time, as the researcher wished to create something that was not traditional and would also be interesting for users. Therefore he chose the shape of a snake and during the validation all the participants liked it.

10.3.1 INTRODUCTION TO LCFIRM

The researcher used the theoretical framework developed from previous theories, as well as frameworks and models reviewed in Chapter 7 in Task 1, as the theoretical basis and support for the developed conceptual framework. Similarly, the assessment of Lean implementation efforts in construction organisations has been developed based on the theoretical aspects discussed in Task 1 (Chapters 2-7), and the findings of the questionnaire survey in Task 2 (Chapter 9). The Framework was developed in order to both show the impact of applying certain Lean principles to the project performance and to proactively control the project deliverables. The proposed framework presented practical guidelines which, if followed, will ensure that Lean thinking will be appropriately applied to the construction industry.

The researcher used the Lean Implementation Assessment (LIMA) Framework developed by Ogunbiyi (2014), the review of The Highways Agency Lean Maturity Assessment Toolkit (HALMAT) and the Lean Construction Assessment Framework developed by Engineers Australia (2012) as a solid foundation that helped develop the proposed framework. In addition, he called on the reviewed literature, data collected from survey (01), his own experience in KSA and the current major issues that KSA is suffering from (construction waste, project delays and project over budget).

10.3.2 THE RATIONALE FOR DEVELOPING THIS FRAMEWORK

One of the most significant current discussions in the construction industry is the required improvement of the productivity of this industry. In Chapter 2 in Task 1 it was demonstrated that the major construction issuesthat the KSA construction industry suffers from are Construction Waste; Delayed Schedule; and Project Over Budget. Sage et al. (2012) claim that the past decade has seen the rapid development of Lean Construction in this industry, and Lean Construction is referred to as the most prominent strategy for improvement regarding these issues. Therefore, there is a need for a systematic structure to guide construction organisations and support them in applying the Lean Construction method.

The findings from the previous two tasks of the research, i.e. the comprehensive literature review and the existing situation in KSA, emphasised the need for a framework for facilitating Lean Construction implementation. The researcher has employed mixed methods to investigate to what extent and how to apply the Lean Construction method in order to fulfil the developing of the framework as an aim of this research.

10.3.3 STRUCTURE OF THE FRAMEWORK

The basic structure is illustrated in Figure 10.1. This framework supports construction organisations in KSA in implementing the Lean Construction method. The proposed developed framework consists of eight Lean Construction processes congregated in the five process groups of the project management life cycle. The project management lifecycle process group describes what is needed to manage the implementation of the Lean Construction method through the whole life of the project, whereas the Lean Construction processes describe what is needed to implement the Lean Construction method in an effective manner. Activities defined within the Lean Construction implementation groups of the LCFIRM are considered to be performance processes within the developed framework, as shown in Table 10.3. The eight principles applied by the researcher and considered as Lean Construction implementation groups in the LCFIRM framework, as shown in Figure 10.1 and appendix 4, are as follows:

1. Lean philosophy, policy and strategy
2. Lean leadership and structure
3. Lean principles and drivers
4. Lean techniques and tools
5. Built-in Quality and process flow
6. Delivery of value
7. Lean impact (barriers and success factors)
8. Risk management

10.3.4 SOURCE OF THE EIGHT LEAN CONSTRUCTION PROCESSES

Prior to describing the eight Lean Construction processes and their defined activities within the Lean Construction implementation processes, the researcher explains in this section how they are arrived at. They are based on the reviewed literature (Chapters 2 to7), but mainly on the Lean Implementation Assessment (LIMA) Framework, the Lean Construction Assessment Framework developed by Engineering Australia, and The Highways Agency Lean Maturity Assessment Toolkit (HALMAT). After the literature review and survey (01) data analysis had been completed, the researcher wrote keynotes for the main activities/actions of Lean Construction implementation; in other words, the researcher created sticky notes for the key aspects of Lean. Then he conducted a brainstorming session with three professionals working on the action research who have previous experience in Lean Construction. During the brainstorming session, the researcher presented and discussed all keynotes with the professionals, based on the KSA construction industries' cultural perspectives and existing issues. As a result of the brainstorming session, the researcher and professionals implemented Strengths, Weaknesses, Opportunities, and Threats (SWOT Analysis), which is a useful technique for understanding a construction company's Strengths and Weaknesses, and for identifying both the Opportunities open to it and the Threats it faces, if such a company implemented the Lean Construction method in KSA (see table 10.1). This is how the researcher came up with the eight processes.

Table 10.1: Conducted SWOT analysis

Strengths Lean philosophy, policy and strategy Lean leadership and structure	**Weaknesses** Lean principles and drivers Lean techniques and tools
Opportunities Built-in Quality and process flow Delivery of value Lean impact (success factors)	**Threats** Lean impact (barriers) Risk management

Table 10.2 shows the source of each process. One of the topics that was considered during the brainstorming was the sequence/logic of the eight processes. The researcher proposed this sequence based on his experience and the logic that he sees will help in Lean

Construction implementation. This will be verified during the validation process in the next chapter.

Table 10.2: Source of the eight processes

Lean Construction Process	Source
Lean philosophy, policy and strategy	LIMA framework
Lean leadership and structure	LIMA framework and HALMAT
Lean principles and drivers	Added by the researcher
Lean techniques and tools	LIMA framework
Built-in Quality and process flow	Engineering Australia
Delivery of value	HALMAT
Lean impact (barriers and success factors)	Added by the researcher
Risk management	Added by the researcher

The proposed developed framework consists of eight Lean Construction processes congregated in the five process groups of the project management life cycle, whereas the Lean Construction processes describe what is needed to implement the Lean Construction method in an effective manner. There are five assessment gates to measure the maturity level of the implementing organisation in order to decide the initial phase to start with and whether the organisation is eligible to move to the subsequent phase. The closing gate relates to creating lessons learned and feedback throughout the development.

Regarding the logic of the framework and how the different parts are related, the idea came from the effective flow of the project's life cycle being ensured by project management processes, which include the required actions or Lean Construction processes involved in the application of Lean Construction skills and capabilities. Each process has five activities; the researcher put them in order of the required tasks that should be conducted in each project phase (initiation, planning, execution, monitoring and controlling, and closing).

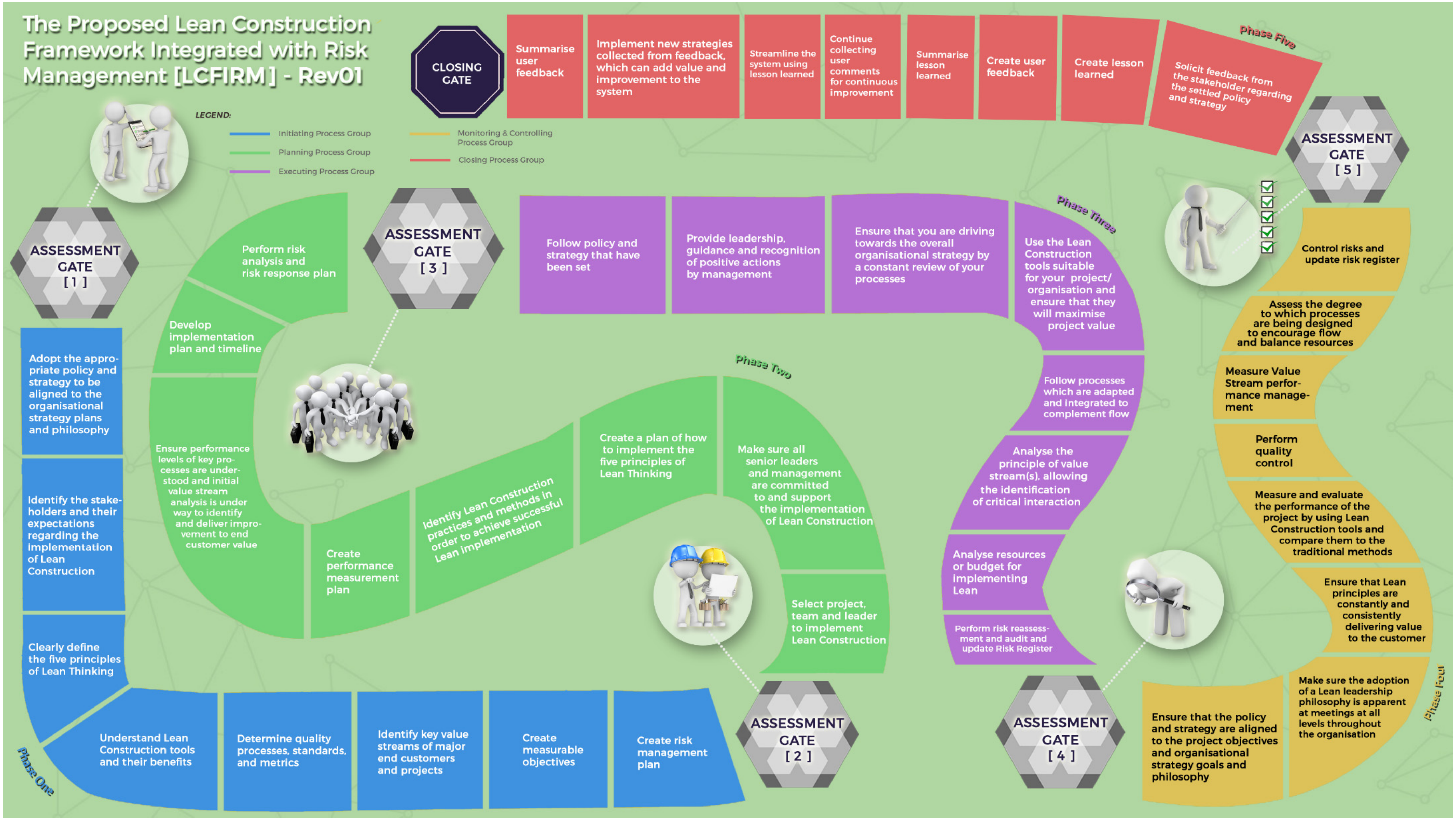

Figure 10.1: The proposed Lean Construction framework [LCFIRM] RV01

10.3.5 LEAN CONSTRUCTION IMPLEMENTATION GROUPS

Figure 10.2 presents the roadmap of the developed framework to illustrate the processes and guidelines for using the developed Lean Construction framework. The following section provides more information about the adopted 8 steps.

Lean Construction Implementation Road Map

1- Create Lean philosophy and policy aligned to the strategic goals of the company

2- Ensure organisation leaders are actively encouraged and mentor the implementation of Lean Construction

3- Increase workers' awareness regarding the concept of Lean Construction and its principles and drivers

4- Select the appropriate Lean tools and conduct proper training for organisations and employees

5- A successful Lean implementation requires the application of quality standards throughout the organisation

6- Identify and analyse the key processes delivering end customer value

7- Understand the barriers and success factors of the impact of Lean

8- Integrate risk management with Lean Construction to minimise the effects of risks on the performance of construction projects

Figure 10.2: LCFIRM Roadmap

Lean philosophy, policy and strategy

First, construction organisations should create/define the policy and philosophy and ensure that it is aligned with the organisation's strategy in order to achieve successful Lean implementation. Moreover, the organisation's original mission, vision and values should support the Lean philosophy, policy and strategy.

Forster and Browne define policy and strategy as the process of making decisions related to framing the path an organisation takes to fulfil its objectives (Forster & Browne, 1996). Deployment of policy or strategy is an effective management process for organisations that connects the improvement practices with the business strategy on an annual basis, with monthly reviews (Zayko, 2006). This improves the clarification of the scope and pace of improvement, as well as the specification of expected targets, in order to help balance and connect activities through the divisions of the organisation. Policy and strategy should be aligned to the organisational strategy plans and philosophy.

In order to ensure that the organisational purpose is realised, various strategies should be employed. Thus, introducing a new strategy to an organisation and guaranteeing its success necessitates some changes to the organisational structure. The importance of linking Lean to business strategy has been emphasised; it was suggested that Lean techniques should be applied to every business activity so as to form the basis of the organisation's strategy. According to Womack and Jones, Lean provides the opportunity and the resolve to generate and sustain profitable growth (Womack and Jones, 2003). This process presupposes the understanding and introduction of the philosophy of Lean management based on the "Toyota Production System". It also combines Lean principles with the organisation's strategic and planning processes to ensure the fulfilment of customer expectations. Organisations should apply a strategic business improvement method, demonstrating year-on-year output improvements linked to corporate targets; develop a long-term strategic Lean training plan linked to the business improvement method and achievement needs; and create a full and detailed supply chain management system, incorporating a supply chain business performance improvement mechanism (Highways England, 2012).

Lean leadership and structure

After defining the Lean policy, philosophy and strategy, the organisation's top management and leaders should build a commitment to support the implementation of Lean Construction.

This section proposes that organisation leaders should actively encourage the introduction of Lean and mentor the practitioners (Highways England, 2012). The successful implementation of Lean requires the support and commitment of strong leadership and top management. Kotter (1990) emphasises the importance of stressing the distinction between leadership and management. Leaders foster change and create an environment where change is the norm, whereas managers guarantee the stabilisation of the organisation as well as the implementation of the changes (Kotter, 1990). Almeida and Salazar (2003) argue that, although the implementation process may be boosted by the top management, successful implementation is not inevitable (Almeida & Salazar, 2003).

Suitable behaviour of management and leaders is required to achieve excellence, and each specific stage of the Lean transformation process determines the different approaches needed at different times. According to Womack and Jones (2003), the Lean application strategy should include the creation of a simulated crisis, obliging the organisation to adopt Lean thinking. The overall leadership issues regarding Lean implementation include the formulation of business objectives, documentation of the expected benefits, removing resistance to change, stressing the potential future benefits to be derived from Lean implementation, outlining a vision of the improvement in performance of the organisation that Lean implementation can bring about, and maintaining the focus and participation of all team members (Donovan, 2005).

Lean principles and drivers

After the Lean philosophy, policy and strategy have been identified and a commitment from the top management has been obtained, the organisation should choose the team that will be involved in the implementation of Lean and start to conduct a training programme to improve their awareness regarding Lean principles and drivers.

Lean behaviour should be promoted, encouraged and supported by policies and processes of the organisation which should increase workers' awareness regarding the concept of Lean Construction and its principles. Constructing Excellence (2004) defines the five Lean principles that should be aligned across the overall organisation processes as follows: (1) elimination of waste; (2) precise specification of value according to the ultimate customer; (3) clear identification of the process, delivering what the customer values and eliminating all non-value-adding steps; (4) quickly working upon customers' orders; and (5) continuous improvement. Value stream requirements directly generate team structure, skills and resource levels, processes, performance measures and targets.

Lean drivers need to be identified at the initial stage in order to pressure the change to Lean, which could derive from internal or external factors. In order to introduce a successful change, the organisation and its employees must be ready for the transformation. Parks (2002) suggests that a robust change management strategy is needed for successful Lean implementation (Parks, 2002). Significant loss of time, energy and hard work may lead to a failure to assess organisational and individual changes.

Lean techniques and tools

There are several supported tools that will help the application of the Lean Construction method, and organisations should select the appropriate one that will suit their company and projects. Training is essential to ensure that the team will have appropriate familiarity with the Lean tools features.

Lean Construction performance requires appropriate practices (tools and techniques). Kaufman Global (2003) states that tools limitations will lead to further limitation of an organisation's ability to solve problems and improve processes in comparison to those organisations with a larger tool inventory (Kaufman Global, 2003). The various tools and techniques that can be applied within an organisation include value stream mapping, continuous improvement, total quality management, visualisation tools, 5S, Just-In-Time, Fail Safe for quality, Kanban, pull approach, value analysis, and total preventive maintenance.

Task One discusses the use of some of these tools and techniques which can be applied once the organisation achieves stability. According to Liker (2004), continuous improvement tools can determine the root cause of inefficiencies so that effective counter-measures can be applied. The team and management should professionally use Lean tools for planning all activities rather than design and construction only. All team members, including subcontractors, should demand that Lean tools form the basis for planning and commitments. Organisations should select the Lean Construction tools suitable for supporting the project objectives (Liker, 2004).

Built-in Quality and process flow

Organisations should ensure that the implementation of Lean Construction will achieve the required quality and be aligned with the organisation’s quality standard and, in addition, create process flow to record, manage and monitor the performance of Lean implementation.

Quality processes should be planned and designed along value streams, fulfilling customer demands while guaranteeing flow and minimum waste in all aspects of delivery, design, construction, and maintenance. This section assesses the degree of control, analysis and design of the processes in order to reduce variability, as well as the number of defects, and consequently reduce rework and inspection. Highways England states that the word ‘defect’ could be defined by the accepted Lean definition of any process output that does not fulfil customer value specifications (Highways England, 2012). A formal process is undertaken to record and manage performance problems and monitor the effectiveness of corrective actions. Root cause identification determines source problems and effectively and permanently resolves them. A lessons-learned log is developed and used to improve future processes.

The concept of Total Quality Management (TQM) is a management strategy fostering quality awareness at all organisational levels. TQM requires the application and sustainment of quality standards throughout the organisation. For the purposes of meeting customer needs, organisations adopting the TQM concept encourage the integration of all functions and processes in order to guarantee continuous improvement of their products and services. Ross summarises the issue by stating that quality starts with understanding customer needs and ends with the satisfaction of those needs (Ross, 1999).

Delivery of value

One of the Lean principles is 'precise specification of value according to the ultimate customer'. Therefore, the organisation should ensure that the five previous processes will lead to customer satisfaction and deliver what the customer needs.

In order for the organisation to identify waste, it should identify and analyse the key processes delivering end customer value. It should be noted that the term 'end customer' refers to the end receiver of the overall supplier service. Interdependencies across the organisation are exposed by the depth and breadth of knowledge of value stream analysis and supporting processes, while performance improvement opportunities are addressed by Value Stream Mapping. The supply chain is crucial for achieving the analysed value stream performance. The performance of value streams and their interdependencies should be evaluated and managed across the organisation and its supply chains. For delivering step changes in performance, Value Stream Mapping should be used effectively as opportunities are identified (Highways England, 2012).

Lean impact (barriers and success factors)

Organisations should understand the barriers they may face and create a plan to overcome them. One of the main ways to support the organisation to overcome any barriers is to understand the success factors that will add value to the organisation.

Lean implementation could be facilitated by organisational culture and employee attitude. Identification and classification of success factors should be carried out in the process of Lean implementation. These comprise leadership and management factors, organisational cultural factors and resource and expertise factors which cover the broad area of Lean, i.e. people and process issues. If the organisation is to realise risk management benefits, success factors for Lean implementation should be fully comprehended (Ogunbiyi, 2014).

Lean implementation becomes easier once the success factors are understood and in operation. The success factors identified in this study are derived from the questionnaire survey and the action research findings. They include leadership and management commitment, organisational culture, good working environment, customer focus and integration, system and process change management, effective planning, regular training of work force, team integration, end-to-end supply chain, adoption of continuous improvement culture, benchmarking of suppliers against each other, communication and coordination between parties, wide adoption of Lean and risk management concepts, understanding of Lean benefits integrated with risk management and performance review, and progress towards targets. The benefits of Lean implementation can occur in various forms; they could relate to customer satisfaction, employee satisfaction and the impact on society (Ogunbiyi, 2014).

Risk management

One of the main values added by the implementation of Lean Construction is the minimisation of risks. The researcher suggests integrating risk management to control and monitor the associated risks. A clearly defined Risk Register will be created for each barrier. The Risk Register will include analysis, assessment and response plan and identify the responsible person assigned for actions entailed.

Implementation of Lean construction techniques minimises the effects of risks on the performance of construction projects. Moreover, the risk management process mainly aims at the reduction of the effects of risk on the project objectives and consequently improves the process of decision-making. It depends both on the prevention of potential problems and the early detection of actual problems as they occur (Churchill & Coster, 2011). Planning for the following risk management processes is crucial in order to guarantee compatibility between the level, type, and visibility of risk management and the risk and importance of the project to the organisation. The size and importance of the project determine the magnitude of the risk management task. Both effective risk management and project success have a direct relationship, since risk assessment calculates/estimates their potential effect on the objectives of the project. There have been significant changes in this respect in the construction industry, particularly in procurement methods, with contractors incurring greater risks than clients (Issa, 2013).

10.3.6 PROJECT MANAGEMENT LIFE CYCLE PROCESS GROUP

The effective flow of the project's life cycle is ensured by project management processes, which include the required actions or Lean Construction processes involved in the application of Lean Construction skills and capabilities. The following are the Project management group processes (Project Management Institute (PMI), 2013):

1) Initiation of Process Group: these processes mark the start of a new project or a new phase of an existing project through obtaining authorisation to launch the project or phase.
2) Planning of Process Group: these processes establish the scope of the project, refine the objectives, and define the course of action required to attain the objectives promoted by the project.
3) Execution of Process Group: these processes complete the work drawn up in the project management plan so as to meet the project specifications.
4) Monitor and Control of Process Group: these processes track, review, and regulate the progress and performance of the project; identify any areas requiring plan change; and initiate the required changes.
5) Closing of Process Group: these processes finalise all activities across all Process Groups to announce the formal closure of the project or phase.

For any project, there are five Project Management Process Groups with clear dependencies. These Process Groups are independent and include individual Lean Construction processes. An overall summary of the basic flow Process Groups is introduced in the process flow diagram, Figure 10.3. Project Management Process Groups are linked to the produced outputs. They are not overlapping activities carried out throughout the project: the output of one process generally becomes an input to another process. It is assumed that the project management life cycle processes are sequentially linked to specific inputs and outputs, i.e. one process leads to the input of another process: for example, the initiation phase has to be finished before the planning phase is started, and the same for other processes. Each project management process has related activities, as shown in the developed framework (Project Management Institute (PMI), 2013).

Figure 10.3: Project management life cycle process group

10.3.7 IMPLEMENTED PERFORMANCE ACTIVITIES

Table 10.3 presents the proposed activities that should be implemented in each Lean Construction processes. Each process has five activities; the researcher put them in order of the required tasks that should be conducted in each project phase (initiation, planning, execution, monitoring and controlling, and closing).This table provides the Lean implementation activities which the company has to follow to implement the Lean Construction method. Each of the activities under the Lean Construction implementation groups has been described in more detail in the below table (10.3). The diagram (10.4) illustrates the logic of the five activities in each Lean Construction process.

Figure 10.4: Sequence of activities in each Lean Construction process

Table 10.3: Presented implemented performance activities RV01

Lean philosophy, policy and strategy	
Adopt the appropriate policy and strategy to be aligned to the organisational strategy plans and philosophy	Adopting the right policy is essential and must be suited to the culture of the organisation, as policy should be linked to organisation strategy and philosophy (Ogunbiyi, 2014). A policy can be described as a good one when there is a definite purpose for its creation and it is flexible and can be modified to change, is formed by both the employees and interested stakeholder, and is well understood by relevant parties. In addition, organisations should identify which key areas, tasks or crews they will target by implementing Lean Construction; they should also understand customer value and focus on its key processes to continuously increase it (Ogunbiyi, 2014).
Select project, team and leader to implement Lean Construction	Good management of people and processes guarantees successful implementation of Lean (Ogunbiyi, 2014). Therefore, organisations should identify the project team and assign a leader to supervise the implementation of Lean Construction. The leader should have a good knowledge and past experience of Lean Construction methods, introduce the Lean Construction process to the team, determine the

	planning method of implementing Lean Construction, and understand the application of the "Toyota Production System", and tailor it to fit the organisation's philosophy.
Follow policy and strategy that have been set	Ensure that the policy has a definite purpose for its creation and that it is developed through the involvement of employees and interested stakeholders. Organisation strategies and processes should be the basis for the development of a communication strategy/plan, awareness raising and training plan in order to guarantee future compliance and improvement (Ogunbiyi, 2014). Execute the work according to the Lean Construction plan. Moreover, implement the concepts of the two pillars of the Toyota production system, "Jidoka" and "Just-in-Time".
Ensure that the policy and strategy are aligned to the project objectives and organisational strategy goals and philosophy	Ensure that the Lean management process aligns both vertically and horizontally with the organisation's functions and activities and with its strategic objectives. Take action to control the project according to the Lean Construction plan, and analyse and evaluate the performance of the Toyota production system. Realisation of the organisational purpose is ensured by the employment of strategies. There could be some changes to the organisational structure in order to guarantee the success of implementing a new strategy within an organisation.
Solicit feedback from the stakeholder regarding the settled philosophy, policy and strategy	Confirm work is done according to the Lean Construction plan. Create lessons learned and strengths, weaknesses, opportunities, and threats (SWOT) analysis for the implementation of TPS for future projects.
Lean leadership and structure	
Identify the stakeholders and their expectations regarding the implementation of Lean Construction	During the processes of decision-making and project delivery, the implementation of the Lean approach should be fully supported by top and senior management, who should be committed to the integration of Lean and risk management. Also, Lean policy should be completely comprehended by employees who are assigned to specific roles and responsibilities (Highways England, 2012).
Make sure all senior leaders and management are committed to and support the implementation of Lean Construction	All managers have completed some formal Lean training. Lean forms an element of the Personal Objectives for senior managers. Senior leaders actively communicate and demonstrate by example the organisation's expected Lean behaviours, and their benefits, to their teams (Womack and Jones, 2003).
Provide leadership, guidance and recognition of positive actions by management	All staff should receive Lean education through recorded training and education in Lean leadership principles and improvement tools from the organisation's leadership. The organisation should perform an analysis of the training needs of both its staff and relevant stakeholders on a regular basis

	and launch training programmes that are suitable for forcing cultural change (Smeds, 1994).
Make sure the adoption of a Lean leadership philosophy is apparent at meetings at all levels throughout the organisation	Senior leaders monitor, communicate and demonstrate the organisation's expected Lean behaviours and their benefits to their teams and lead their teams in their achievement. Senior Management should provide a continuous training programme for forcing the change and innovation of the culture and behaviour (Smeds, 1994).
Create lesson learned	Ensure that all senior leaders and management within the organisation enthusiastically embrace the concept of Lean and support the transition to a Lean culture. Ensure that philosophy, policy, and strategy are developed and communicated by the involvement of organisation leaders.
Lean principles and drivers	
Clearly define the five principles of Lean Thinking	Ensure that all employees have a good level of awareness. Define waste, identify its types and ensure it includes all non-value-adding processes. Consider other kinds of non-value-added work/activity which are equivalent to waste (Engineers Australia, 2012).
Create a plan of how to implement the five principles of Lean Thinking	Identify the drivers of Lean as an important aspect to be considered prior to implementing Lean in an organisation. Create a plan for managing the identified wastes among the whole project team, and create a process improvement plan.
Ensure that you are driving towards the overall organisational strategy by a constant review of your processes	Follow the identification of Lean drivers in an organisation to lead the organisation to sustain a Lean focus. Implement the principle of Lean and ensure that it aims mainly at waste elimination in processes in order to reduce the length of process cycles, improve quality, and increase efficiency. Implement Value Engineering Analysis to eliminate possible generated waste. In addition, apply the 3Rs (Reduce, Reuse and Recycle) for the waste generated after the implementation of Lean Construction (Aadal et al., 2013).
Ensure that Lean principles are constantly and consistently delivering value to the customer	Increase workers' perception of the Lean Construction method (training). Identify value from the client's point of view. Revisit construction processes and seek to add more value to the client by reducing waste and enhancing additional willed features. Follow continuous improvement.
Create user feedback	Document the value added by implementing the five principles.
Lean techniques and tools	
Understand Lean Construction tools and their benefits	Determine which tool is suitable for your project and required by your organisation. Integration of practices and methods guarantee the success of Lean implementation; integrated practices and methods lead to effectiveness of the Lean operating system, i.e. the tools, techniques and methods cannot work separately, as they should be implemented and tied together into a complete system (Drew et al., 2004).

Identify Lean Construction practices and methods in order to achieve successful Lean implementation	There are many Lean tools and techniques that organisations can apply, including Value Stream Mapping, Last Planner System, etc. Discuss and understand the Last Planner System and the concepts of Make Work Ready and Weekly Work Planning (Engineers Australia, 2012).
Use the Lean Construction tools suitable for your project/organisation and ensure that they will maximise project value	Lean success can not only be ensured by the application of Lean tools and techniques; other issues including people and process can affect the successful implementation of Lean in the field of construction in KSA. Make sure that selected Lean tools are effective for the organisation/project to achieve organisation/project objectives.
Measure and evaluate the performance of the project by using Lean Construction tools and compare them to the traditional methods	Evaluate the completed works according to three weeks' look-ahead and weekly work plan by calculating Percent Plan Completed (PPC) to show what has been done (Engineers Australia, 2012). An organisation's strategy should be based on Lean techniques, since it provides both the opportunity and the resolve to generate and sustain profitability growth.
Summarise lesson learned	All team members prepare and submit final project performance based on the use of Lean Construction tools and document the value added by using its tools.
Delivery of value	
Identify key value streams of major end customers and projects	Identify the key processes which deliver end customer value in order to identify waste (Highways England, 2012).
Ensure performance levels of key processes are understood and initial value stream analysis is under way to identify and deliver improvement to end customer value	Organisation process should be designed based on customer and stakeholder needs and requirements. Prioritise and deliver improvement to end customer value (Highways England, 2012).
Analyse the principle of value stream(s), allowing the identification of critical interaction	Look for opportunities to eliminate waste and create value aligned with the business objectives. Value Stream Mapping should be used effectively to deliver step changes in performance as opportunities.
Measure Value Stream performance management	Evaluate the ongoing performance of Value Streams and their interdependencies and how they are managed across the organisation (Highways England, 2012).
Streamline the system using lesson learned	There should be a complete analysis for key Value Streams of major end customers and projects in addition to clear definition and effective management of handover points and interfaces.

Built-in Quality and process flow	
Determine quality processes, standards, and metrics	Determine the required processes for the project that will be used for implementing Built-in Quality. Design processes to encourage flow and balance resources. This will apply to all processes, including design, purchasing, etc., not just construction (Engineers Australia, 2012).
Create performance measurement plan	Create an implementation process of Built-in Quality by using Standardised Work and 5S. Develop a quality management plan and Total Quality Management. Create key processes within value streams to enhance flow and reduce inventory/buffer levels (Engineers Australia, 2012).
Follow processes which are adapted and integrated to complement flow	Perform quality assurance and audit to ensure that the created processes are followed and conducted properly. Review key project deliverables and processes for satisfactory quality level.
Perform quality control	Determine if deliverables are being produced to an acceptable quality level and if the project processes used to manage and create the deliverables are effective and properly applied. Assess the degree to which processes are being designed to encourage and balance resources. Ensure the stability of processes throughout the internal and external Value Stream (Engineers Australia, 2012).
Continue collecting user comments for continuous improvement	Confirm work is done according to the required quality
Lean impact (barriers and success factors)	
Create measurable objectives	Identify the drivers, benefits, and success factors in the implementation of Lean Construction to the organisation and project. In order for organisations to apply Lean, there should be a transition team, as well as a vision and guiding principles with a Lean impact assessment at the same time (Ogunbiyi, 2014).
Develop implementation plan and timeline	Identify tangible and intangible benefits derived from Lean Construction implementation. There should be an identification and quantification of benefits which can be assigned financial figures because they are measurable outcomes from the application of Lean principles, tools and techniques (Ogunbiyi, 2014).
Analyse resources or budget for implementing Lean	Keep focusing on the benefits and success factors of Lean Construction implementation. Success factors should be identified and their impact on Lean implementation assessed (Ogunbiyi, 2014).
Assess the degree to which processes are being designed to encourage flow and balance resources	Ensure the positive impact of Lean and its alignment to the project/organisation goals.
Implement new strategies collected	Top management commitment is necessary to integrate Lean into core business processes and decision-making. Lean

from feedback, which can add value and improvement to the system	implementation benefits, which could relate to either customer satisfaction or employee satisfaction and the impact on the society, should be seen as the business result.
Risk Management	
Create risk management plan	Establish an agreed-upon approach for conducting risk management activities and risk evaluation. Identify risks; determine which risks might affect the project and document their characteristics. This process is an iterative process, since either occurring risks may trigger new risks, or the status of the identified risk may change. The risk register is the output of the risk identification process; it is a list of all identified risks with their potential impact and probability of occurrence (Project Management Institute (PMI), 2013).
Perform risk analysis and risk response plan	Analyse qualitatively the risks identified in the risk register in order to prioritise them for further action such as quantitative analysis and response plan. Assess the likelihood of occurrence of all risks as well as the potential impact on all project aspects such as cost, time and quality. Use the probability-impact matrix and the risk criteria previously defined in the Risk Management Plan to calculate the risk score. High risks shall need further quantitative analysis where the expected monetary value can be determined. For the previously analysed risks, plan risk responses to develop options and determine actions to enhance opportunities and mitigate risks. Risk responses must be appropriate to the significance of the risk, cost effective, realistic and made in a timely manner (Project Management Institute (PMI), 2013).
Perform risk reassessment and audit and update Risk Register	During the execution phase, a risk's status may change due to site conditions. Therefore, risk analysis described in the previous step should be repeated to reassess the risk's impacts and probabilities. Moreover, the risk owner may need to conduct quality audits to ensure the effectiveness of the risk responses implemented for previous and ongoing risks. In addition, the Risk Register must be updated to reflect the current status of all risks (Project Management Institute (PMI), 2013).
Control risks and update Risk Register	The Control Risks process applies techniques, such as variance and trend analysis, which require the use of performance data generated during project execution in order to review the implementation of risk responses while evaluating their effectiveness. The Control Risks process can involve choosing alternative strategies, executing a fall-back plan, taking corrective action and modifying the risk management plan. Fall-back plans are the Plan-B response for either identified or unidentified risks. The Risk Register must be again updated to reflect the changes implemented during the Control Risks process (Project Management Institute (PMI), 2013).

Summarise user feedback	Lessons are experiences distilled from a project such as risk responses and assumptions that should be actively taken into account in future projects.
Assessment gate	
Organisation requirements, plans and strategies are compiled and studied to provide a solid foundation to enable an applicable programme to be implemented and lead the organisation towards success. The researcher developed five assessment gates (shown in Figure 10.1) to measure the maturity level of the implementing organisation in order to decide the initial phase to start with and whether the organisation is eligible to move to the subsequent phase.	
Closing gate	
Lessons Learned and feedback throughout the development and execution stages are created to serve as a guide to the users to further streamline the programme and continue improvement of the system through the usage of information and the users' comments.	

10.3.8 HOW TO USE THE DEVELOPED LCFIRM

This section presents a flowchart as guidance for organisations to implement Lean Construction, illustrating how the Lean Construction processes interacts with the project management life cycle and assessment gates mentioned in Section 10.3.6. Figure 10.5 presents the structure of Lean construction implementation.

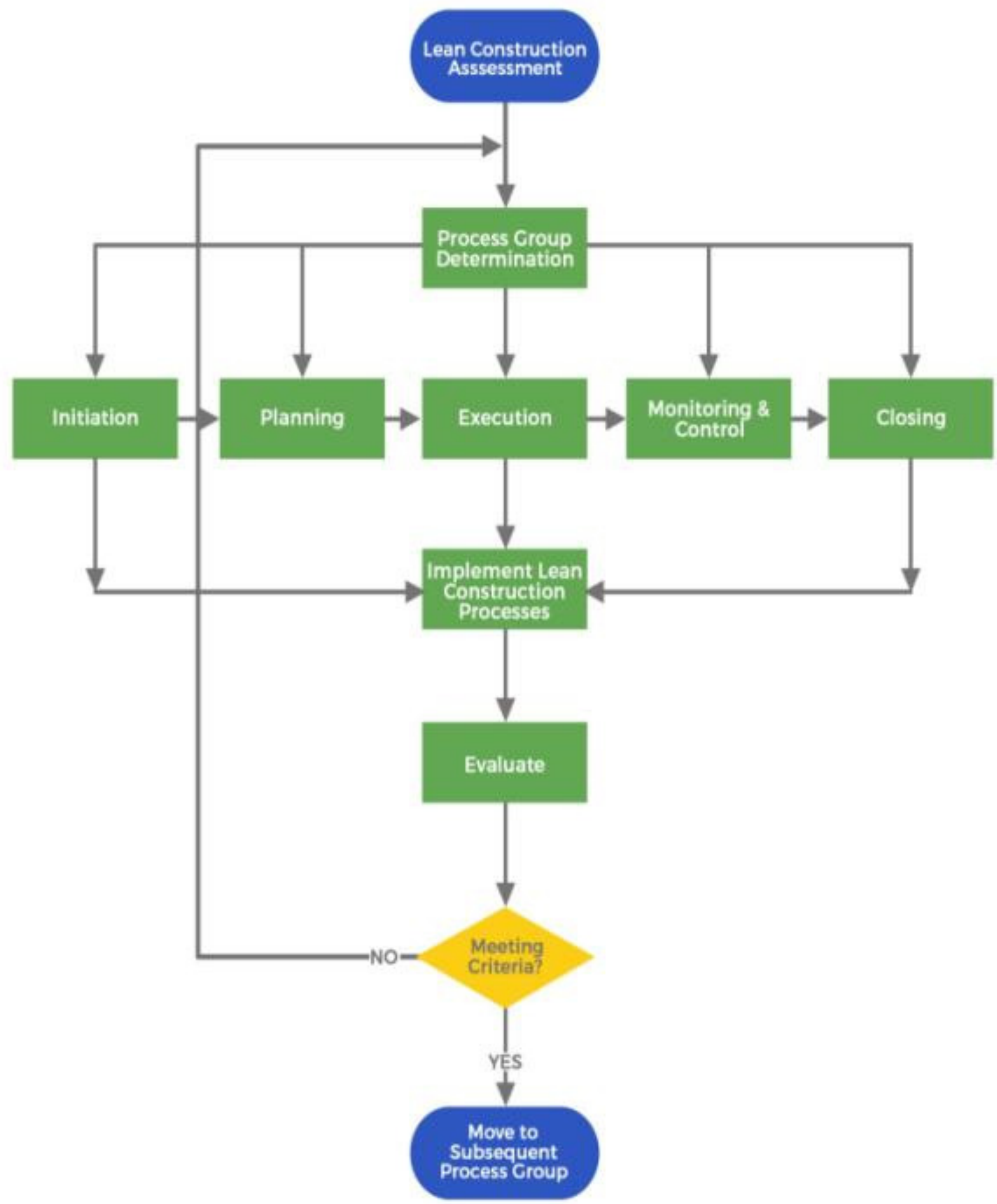

Figure 10.5: Structure of Lean Construction Implementation

The researcher developed the LCFIRM on the assumption that the organisation has zero awareness of Lean Construction and is starting from scratch. However, some organisations may skip phases according to their degree of awareness. The implementation steps of the LCFIRM should be as follows:

1) Conduct the pre-assessment to determine the level of awareness.
2) According to the generated score range, determine the initial process group with which to start implementation.
3) If the organisation did not start with the Initiation Process group, ensure that previous processes are completely fulfilled.
4) Implement the processes within the current process group in an orderly way.
5) Redo the assessment to evaluate the organisation's performance.
6) If the evaluation meets the predefined criteria, the organisation should move to the subsequent process group. If not, the organisation should repeat the processes and reassess until the desired score is achieved.

CHAPTER ELEVEN: VALIDATION OF DEVELOPED FRAMEWORK

11.1 INTRODUCTION

This chapter presents the validation approach for developing the Lean Construction Framework integrated with Risk Management (LCFIRM). In this chapter, the results of implementing the developed Lean Construction framework are validated and presented according to both the current and desired circumstances of the project.

This chapter outlines a framework for the evaluation of Lean construction implementation efforts as well as the advantages offered by Lean integrated with risk management for construction projects in the KSA. There are eight main Lean construction implementation processes in the proposed framework, addressing (1) Lean policy, strategy and philosophy; (2) Lean leadership and structure; (3) Lean principles and drivers; (4) Lean techniques and tools; (5) Risk management; (6) Delivery of value; (7) Built-in Quality and process flow; and (8) Lean impact (barriers and success factors).Therefore, this chapter is intended to validate what has been developed.

11.2 VALIDATION APPROACH

This section presents the validation process that has been conducted for validating the developed framework.

Validation can be applied using either a quantitative or a qualitative method. Smith (1983) claims that the validation of complex and non-quantitative models can be carried out using a qualitative approach through conducting interviews and survey techniques while highlighting the pros and cons of the model under validation (Smith, 1983). The researcher implemented a validation approach by seeking experts' opinions and feedback through posing structured questions reflecting all aspects of the framework (Ogunbiyi, 2014). As stated by Avison et al. (1999), in order to conduct relevant academic research, theories should be tested with practitioners in real situations and real organisations. They believe that theory should be combined with practice, practitioners with researchers, together in a constant process through action research, within a cycle of activity that includes problem diagnosis, action intervention and reflective learning.

11.2.1 SELECTED MIXED METHOD

At this stage of the research, the researcher used mixed methods in order to validate the developed framework. The methods of interview and survey are the methods of data collection used in this task. The validation approach is carried out in three phases:

A) The first phase was an interview with the participants in order to introduce the proposed framework and to describe the eight Lean Construction implementation groups and sets of activities of the action required for the practical implementation of Lean Construction in the developed framework. Moreover, during the interview, the nine steps of Lean Construction Assessment were explained, as well as the ten areas of coverage of the assessment tool. In addition, the parameters of the proposed weighting and scoring system to determine the desired level of maturity for construction organisations were explained by the researcher. This first step is considered an introduction to the participants before they answer the questions.

B) The second phase was an online survey that included structured questions to get feedback from the participants about the developed framework and assessment tool.

C) The last phase was another interview for the discussion of their feedback and critical analysis of the perceived pros and cons of the outcome of this research.

The rationale behind the selected mixed method was that the selected participants were too busy for the researcher to sit with them for a longer time. In addition, the researcher attempted to avoid any misunderstanding on the part of the respondents regarding any aspect of the developed framework and assessment tool. Moreover, the researcher preferred to get the respondents' feedback in writing and allow them to take more time to answer the proposed questions in order to obtain valuable comments and feedback.

Naoum (1998) states that there are three forms of interview: unstructured, structured and semi-structured. A structured form of interview, where questions may be recorded, was adopted in order to achieve the purpose of this research. This allows flexibility in the wording of questions so that the level of language may be adjusted; the interviewer may answer questions and make clarifications to the interviewees between successive items (Berg, 2009). Structured open-ended interview questions through an online survey were adopted to carry out the interview.

The researcher employed the interview method to collect data, because it enables direct communication and the acquisition of practical data first-hand from the project's participants. In addition, the researcher conducted an online survey in order to get quantitative results. These two methods were used to test and validate the developed framework and assessment tool by interviewing a number of key engineers and academic staff (15 experts in Lean Construction) working on Mega-construction projects and at universities in KSA, in order to extract as much data as possible, allowing the collection of a wide range of opinions and points of view (Yin, 1994).

In order to validate the framework, the same 15 professionals in KSA were interviewed to find out whether or not they agreed on the proposed framework based on the implementation of Lean Construction, as well as the strategies proposed for the purpose of enhancing the efficiency of Mega-Construction projects in KSA. It has been taken into consideration that these 15 professionals differed from those who participated in the survey phase mentioned in Task 2. Also, they are at different positions in different companies, selected according to the opinions of the owner, consultant and contractors. According to O'Keefe et al. (1986), for the purposes of validating the results, the number of workers can be less than ten, but not less than five.

This research was intended to be balanced by having a broad representation from the organisation. Fifteen (15) experts in the construction field in KSA were interviewed for the purpose of framework validation. The interview asked for their opinion regarding the applicability and efficiency of the proposed Lean Construction Framework. The researcher developed 15 interview questions, tackling the following main areas (see appendix 5):

1. Interviewees' background;
2. Barriers facing the implementation of Lean at organisational/project level; and
3. Drivers/success factors and benefits of implementing Lean.

Experts enhanced and validated the proposed framework and assessment tool through structured questions. The experts included both academics and practitioners. Professionals who worked on the action research were selected by the owner, consultant and contractor, in addition to academics from three different universities. The same 15 participants were selected for the study: four by the owner, four by the consultant and four by the contractor, as well as another three academics. These participants provided useful feedback on the incorporation of a sound practical and theoretical base into the initial developed framework.

The experts (academics and practitioners) were chosen according to the following criteria:

- The academics should have an in-depth understanding of the theory of Lean and risk management. Thus, the academics must be experts in the field of Lean and risk management in order for their feedback to be useful in the improvement of the developed framework.
- The practitioners should have a direct relation with Lean implementation in their organisation or with one or more of the previous approaches of the research study (action research or questionnaire survey). This was to ensure a minimum level of knowledge of Lean implementation and risk management, as well as their understanding of the research study, which facilitates the continuity and validity of the framework.

Initial pilot studies as well as two pilot interviews were carried out. This required both an expert in the implementation of Lean from a construction company and a professional academic with grounded knowledge in Lean construction and risk management. Feedback from the interview session assisted in the refinement of the interview guide, following the pilot interviews. Ambiguous questions were modified and the questions were grouped under themes to avoid long questions.

The researcher interviewed fifteen selected (15) interviewees from five (5) different companies and three (3) universities, most of them face to face, for a period that ranged between 1 and 2 hours for the first interview before they answered the survey questions, and 1 to 2 hours for the second interview after the survey; other interviews took place by phone. The researcher sent them the developed framework two days after the first interview and during the first interview a discussion was conducted to explain the aim of the interview. The interviewees received the developed framework before the first interview.

An invitation email was sent out to all participants, providing a link to an online platform survey with fifteen (15) questions to validate the proposed framework. The second set of interviews was conducted by way of open discussion between the researcher and selected participants, and this allowed the researcher to get more detailed feedback/criticism and also helped enhance the proposed framework.

The invitation email explained the nature of participation in this interview, maintaining participants' anonymity by removing the contributors' names and other information which could help identification, such as job title, as well as the nature of the data collected prior to the interview. The interview maintains confidentiality of data collected from participants, and data from this research was reported only collectively. The researcher kept all related data protected with a password and stored on his own computer desktop, and this will be maintained securely for three (3) years after which it will be destroyed.

11.2.2 STRUCTURED QUESTIONS FOR MIXED METHOD

The validation questions were sent to the professionals in order to obtain their feedback. This allowed for useful feedback in relation to integrating a sound theoretical base with the initial developed framework. The developed framework was sent out to the interviewees before the interviews. The findings from Task 1 and 2 of the research (i.e. literature review, questionnaire survey and the action research) established the need for a framework. In addition, the researcher provided the 15 practitioners with a brief overview of the research study to ensure that they already had an overall understanding regarding the research aims in order to assess the validity of the developed framework.

The structure of the mixed method questions consists of three sections: (A) respondent information (1-4); (B) validation of the developed framework (5-10); and (C) validation of the proposed Lean Construction Assessment Tool (11-15), will discussed in Chapter 14 (see Appendix 5) which was created to cover the following aspects:

Section one: Respondent information (questions 1-4)

Section two: Validation of the developed framework (questions 5-10), covering:

1) Evaluation of the framework in terms of level of coverage of the overall content;
2) Overall recommendations for the use of the framework within construction companies;
3) The proposed framework possibly overcoming the obstacles/barriers mentioned

in the interview questions;

4) The developed framework adding value to construction projects;
5) The proposed framework being easy to use/implement for construction projects;
6) Comment on areas considered worthy of being deleted/included/improved

11.3 ANALYSIS OF DATA COLLECTION FROM INTERVIEW AND SURVEY (02) METHOD

In this section, the researcher starts by presenting the results and discusses the findings of the conducted interview and survey method. This section is divided into subsections: (1) data analysis: validation of developed framework and (2) data analysis: validation of proposed assessment tool. An example of a completed sheet from survey 02 by one respondent is provided in Appendix 6.

Questions Nos. 1 to 4:
Question 1: Job title
Question 2: Background
Question 3: Organisation
Question 4: Area of proficiency (if academic staff)

The researcher asked the respondents general information such as job title, background, organisation/university and area of proficiency (if academic staff). As per the researcher selection, the owner selected four participants; the consultant selected four participants, the contractor selected four participants, in addition to three academics selected by the researcher. Two of the academic participants are also working in the industry. All of them hold positions at senior and top management levels and thus they are considered decision makers. Background and area of proficiency are directly related to construction management and most of them have a high level of understanding regarding the Lean Construction method.

11.3.1 DATA ANALYSIS – VALIDATION OF DEVELOPED FRAMEWORK

Questions No. 5:
Evaluation of the proposed framework

This question is the main one regarding the evaluation of the proposed framework. It has four sub-questions, as follows: 1) what is your overall rating of the proposed framework in terms of its overall content?; 2) what is your overall opinion of the level of understanding of the proposed framework?; 3) what is your opinion of the selected 8 (Lean Construction Implementation groups) areas provided (Lean policy and strategy, Lean philosophy, etc.) in terms of the level of coverage and understanding?; and 4) In your view, how would you describe the level of coherence in terms of the overall logic of the process (e.g. flow of necessary steps to be taken in implementing the Lean Construction method)? Table 11.1 summarises the results of the four sub-questions as follows:

Table 11.1: Number of respondents in each rating level

Sub-Questions	Very low	Low	High	Very high	Total
S-Q1	0	0	10	5	15
S-Q2	0	0	12	3	15
S-Q3	0	1	11	3	15
S-Q4	0	1	10	4	15

This shows that most of the respondents gave a high rating to the proposed framework; in addition, they stated that the selected eight areas provided in the framework covered most of the aspects for the Lean Construction method. The level of coherence in terms of the overall logic of the process (e.g. flow of necessary steps to be taken in implementing the Lean Construction method) are validated and approved by the participants.

<u>Question No.6:</u>
Would you recommend the framework for use within the construction companies?

The participants have been asked their opinion regarding whether or not they recommended the framework for use within construction companies. 93.33% of the participants (14 respondents) recommended that the developed framework be used within construction companies. Some comments were received regarding the proposed framework, which the researcher has summarised and critically analysed later in this chapter. Figure 11.1 graphically presents the respondents who have recommended the developed framework to be used within construction organisations.

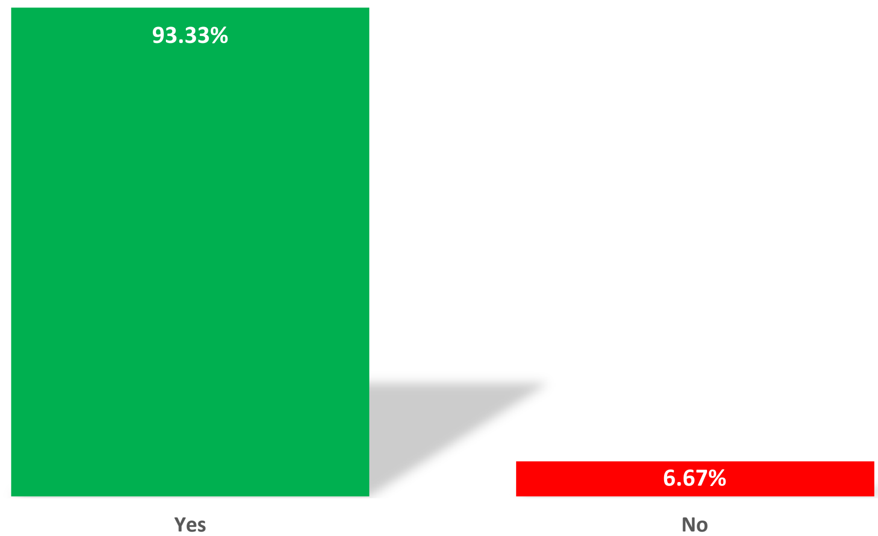

Figure 11.1: Percentage of respondents who agreed on the use of the developed framework within construction organisations

<u>Question Nos.7:</u>

Which of the obstacles/barriers mentioned below could the proposed framework overcome?

Seven barriers have been presented in question no. 7 for the respondents to state their opinion as to which of them the proposed framework could overcome. The seven barriers are: (1) client resistance; (2) higher capital cost; (3) greater expense; (4) risk- averse culture; (5) skills shortage; (6) no experience of its purpose; and (7) lack of guidance and information. The question allows the respondents to choose multiple answers or all of the above or none of the above. Figure 11.2 below shows that the main three obstacles chosen by the respondents were: skills shortage, no experience of its purpose, as well as lack of guidance and information. Therefore, the training program is essential for implementing the Lean Construction method within construction organisations in KSA.

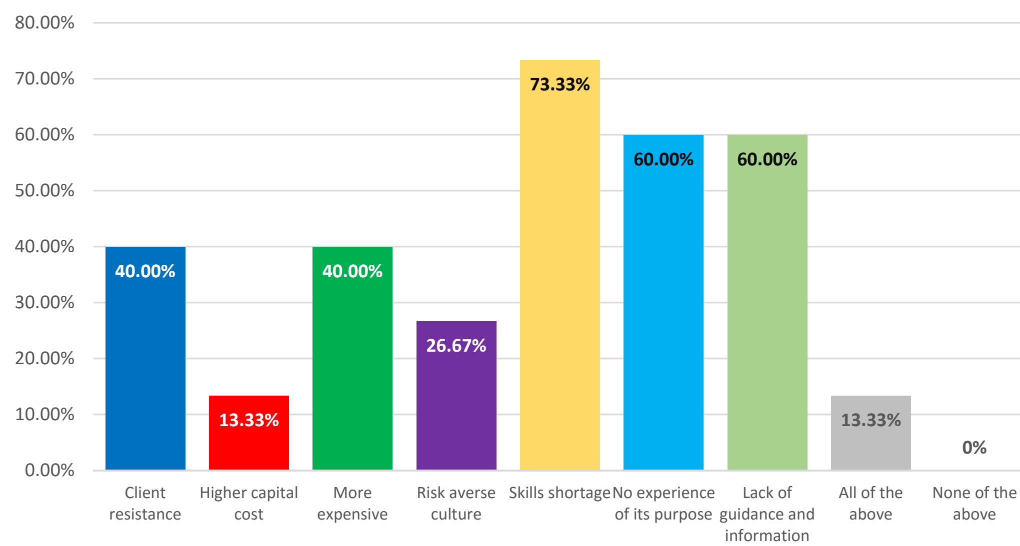

Figure 11.2: Distribution of selected barriers by the respondents

Question Nos. 8:
Do you think the developed framework will add value to construction projects?

This question asked the participants if they thought the developed framework would add value to construction projects in terms of cost reduction, waste elimination, maximisation of value, flexibility in design, rework and site problems, speed of construction and quality and safety. Table 11.2 presents the results. Around 14% of the respondents did not agree that the developed framework would add value to construction projects in terms of the above-mentioned aspects. During the second interview, the researcher asked those 14% for the reason behind their disagreement. Their justification was the lack of knowledge regarding the Lean Construction method among the majority of workers in KSA, and skills shortage.

Table 11.2: Number of respondents who agree or disagree with the mentioned type of value added

	Strongly agree	Agree	Can't say	Disagree	Strongly disagree	Total respondents
Cost reduction	4	9	1	0	1	**15**
Waste elimination	5	5	4	0	1	**15**
Maximisation of value	3	10	1	0	1	**15**
Flexibility in design	0	8	5	1	1	**15**
Rework and site problems	1	9	2	2	1	**15**
Speed of construction	2	6	3	3	1	**15**
Quality	2	10	1	1	1	**15**
Safety	3	5	4	2	1	**15**

Question No. 9:
Do you think the proposed framework is easy to use/implement for construction projects?

It was essential to ask the participants to what extent the proposed framework was easy to use/implement in construction projects. Figure 11.3 shows that 80% of the respondents confirmed that the proposed framework was easy to use/implement in construction projects. The remaining respondents asked the researcher to provide a practical example from a real construction project for the provided eight areas of Lean Construction to facilitate the implementation of Lean Construction through the developed framework. This feedback is addressed in more detail in the concluding section.

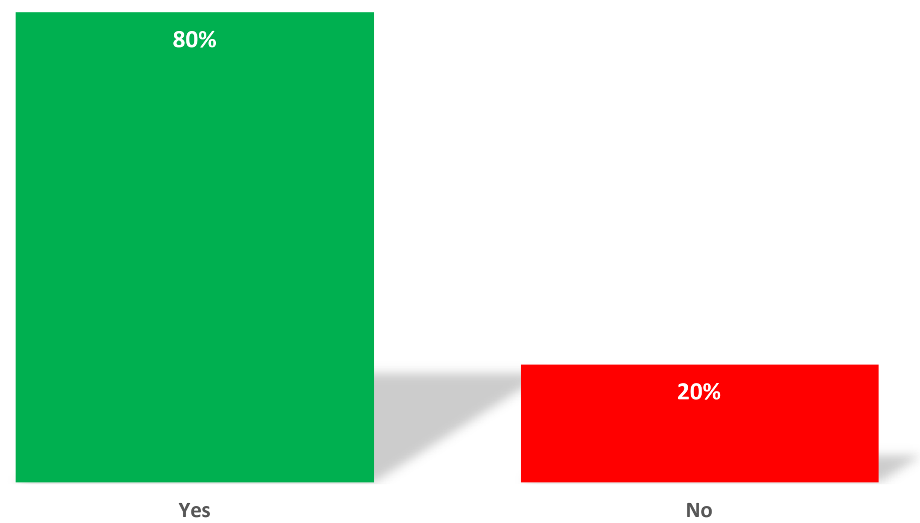

Figure 11.3: Percentage of respondents who agreed that the developed framework was easy to use

11.3.2 CONCLUSION OF THE DEVELOPED FRAMEWORK VALIDATION

The validation of the proposed framework was achieved through experts' feedback on various issues relating to the framework. Fifteen (15) structured expert interviews were conducted in order to validate the framework. The framework was assessed in terms of general comprehensiveness, usefulness, clarity and level of coverage of features of the framework, as well as practical considerations and possible adoption of the framework. Many practitioners complemented the structured interviews by providing deeper insights as to how the framework differed from other implementation assessment frameworks. In addition, the proposed framework provided performance factors for the necessary action for practical Lean application at an organisational/project level. This is one of the respondents' comments: "The proposed framework is comprehensive and integrates risk management with Lean construction, which, if applied, will improve performance in the construction industry. However, the main barrier that will be faced using this framework is the lack of experienced personnel in most of the organisations to implement such a framework. As such, it is highly recommended that there be an effective training programme to help organisations obtain the appropriate expertise to enable them to implement such a framework."

Question No. 10:

Please provide a brief comment and your constructive criticism on the framework provided.

The researcher asked the participants to provide a brief comment and their constructive criticism on the framework provided. The following is a summary of the received comments and suggestions:

1. Participants suggested providing a practical example of each of the eight processes: 1) Lean policy, strategy and philosophy; 2) Lean leadership and structure; 3) Lean principles and drivers; 4) Lean techniques and tools; 5) Risk management; 6) Delivery of value; 7) Built-in Quality and process flow; and 8) Lean impact (barriers and success factors) in order to facilitate the adoption and implementation of the developed framework. Some of the participants said that the eight groups need to be linked practically, by providing an example that flows through each point so as to provide clear visualisation for the reader.
2. To add one more group that deals with continuous improvement through adding the lessons learned in each phase, vertically not horizontally.
3. Another major comment was received relating to the Lean Construction Assessment Tool; it was suggested that the project management life cycle process group (initiation, planning, execution, monitoring and controlling and closing) be changed to the appropriate maturity level (Uncertain/level 0, Awakening/level 1, Systematic/level 2, Integrated/level 3 and Challenging/level 4). The reason for this suggestion was to appropriately and logically link the developed framework and the assessment tool.

The received suggestions and ideas were considered and critically analysed by the researcher, who saw that those suggestions would enhance the developed framework. Therefore, it was decided to have the developed framework revised, based on the above recommendations, in the last part of this task.

CHAPTER TWELVE: REVISED FRAMEWORK DEVELOPMENT

Based on the comments and suggestions received from the professionals during the first and second interview as well as the survey conducted in between, the researcher decided to revise the developed framework in order to enhance the output of this research. This chapter presents the revised framework and also presents an actual validation as part of the validation process.

The vertical columns and the project management life cycle process group (initiation, planning, execution, monitoring and controlling and closing) have been changed to maturity level (Uncertain/level 0, Awakening/level 1, Systematic/level 2, Integrated/level 3 and Challenging/level 4).

One more group has been added to deal with continuous improvement. This was achieved by adding the "lesson learned activities" in each phase, in the form of a vertical column, not a horizontal bar, as previous. Therefore, the new nine principles applied by the researcher and considered as Lean Construction implementation groups in the LCFIRM framework as shown in Figure 12.1 and Appendix 7 are as follows:

1) Lean philosophy, policy and strategy
2) Lean leadership and structure
3) Lean principles and drivers
4) Lean techniques and tools
5) Built-in Quality and process flow
6) Delivery of value
7) Lean impact (barriers and success factors)
8) Risk management
9) Continuous improvement

The revised activities defined within the Lean Construction implementation groups of the LCFIRM are considered to be performance processes within the developed framework RV02 and are shown later in Table 12.1.

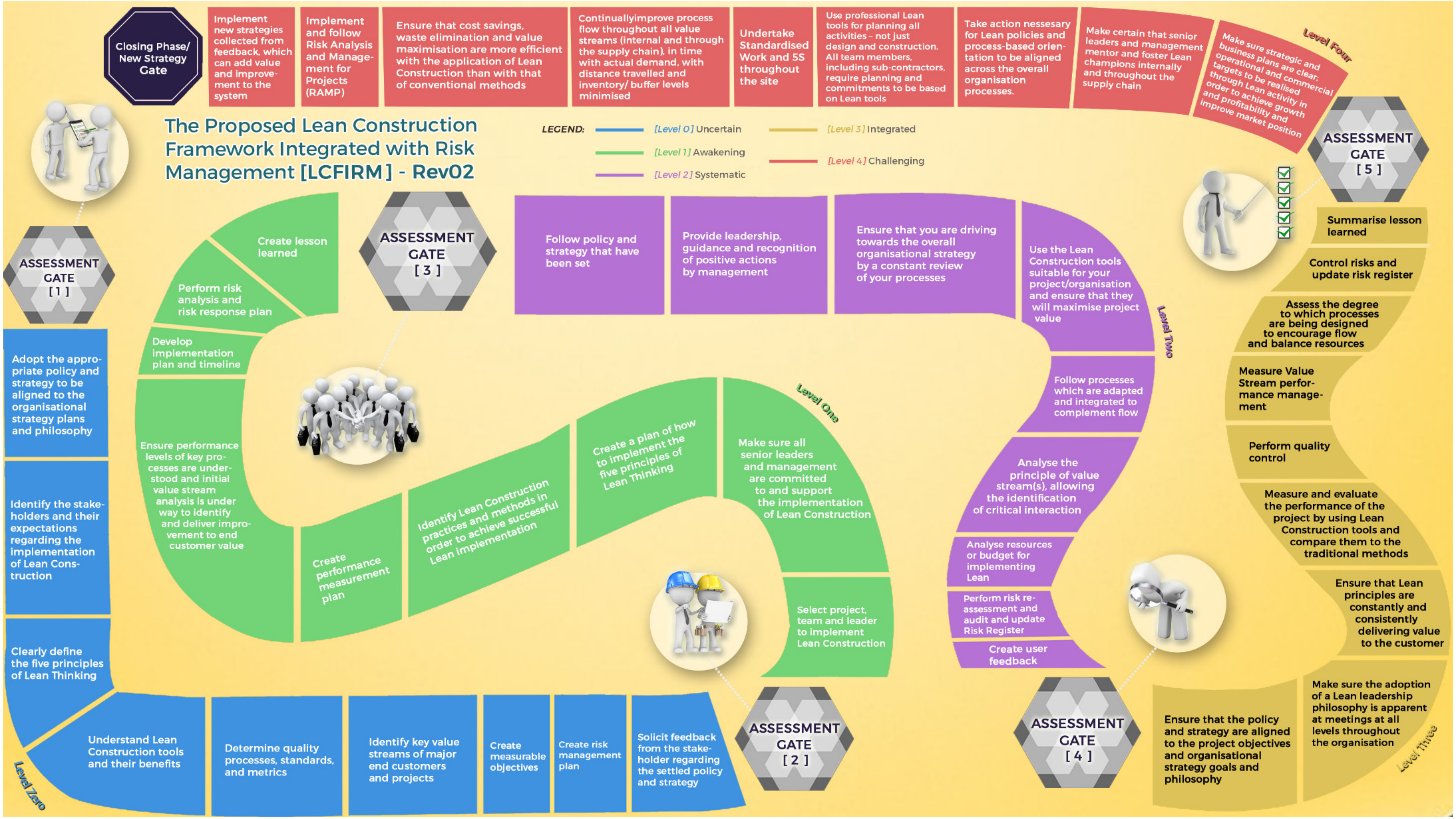

Figure 12.1: Developed framework (LCFIRM) RV02

12.1 REVISED LEAN CONSTRUCTION IMPLEMENTATION GROUPS

In order for the nine processes to be linked practically, an example that flows through each point should be supplied to provide clear visualisation for the reader. The theoretical part has been discussed earlier in Chapter 10 in this Task and a practical example for each Lean Construction implementation process is presented below. The researcher used real examples from the organisation managing the action research and called it company X.

12.1.1 LEAN PHILOSOPHY, POLICY AND STRATEGY

Theoretical part

Discussed in Chapter 10, Section 10.3.5

Practical example

Company X is a major construction company that is running an underlying infrastructure project. After invitation of the owner, board members and key decision makers to an introductory seminar about Lean Construction and outlining the philosophy, summarising its strategy and pointing to the suggested policies, they were ready to answer the call of Lean Construction. The company's original mission, vision and values were presented, followed by Lean's mission, vision and values proposal. This is the first step that Company X started with and it took five days to update the company vision, mission and value to supporting Lean philosophy and policy.

The outcome was that the Company X owner, board members and key decision makers believed that Lean Construction can significantly benefit their business. The infrastructure project was chosen for applying the Lean Construction methods. Updated mission, vision and values statements were re-created out of Lean philosophy and aligned to the strategic goals of the company. Team leaders were elected, and then a series of dynamic lectures was drawn up to educate and enhance the knowledge of attendees regarding TPS and Customer Value Chain, with practical implementation in each session to be applied by the key persons to their areas of work and execution.

12.1.2 LEAN LEADERSHIP AND STRUCTURE

Theoretical part

Discussed in Chapter 10, Section 10.3.5

Practical example

The key persons in Company X are now asked to instruct and teach their departments' workers the Lean Construction philosophy. This is a paradigm shift that ensures that top management is fully engaged through making it the inspirer of the philosophy instead of only a recipient. Next, the top management coaches the employees to generate their preferred method of recognition for top followers and implementers of the new methods, the ones that would share the beliefs, and assist others to believe the same. The second step was the challenge of selecting the team and supervisors that will be involved in the implementation of Lean. Leaders were chosen not only according to their knowledge of the Lean Construction method, but also to their leadership and communication skills and strategies. Qualifications and experience were the main criteria for choosing the team, and it took almost two weeks to select interested workers with appropriate knowledge and experience.

The outcome was that continuous sessions were held between top management and their departments' workers explaining the positive impact of the Lean Construction philosophy both tangibly and intangibly. The sessions included: 1) clearly communicating the re-formulated business strategy that adopts the Lean philosophy and is directly aligned to the business goals; 2) breaking the ice with the new methodology; 3) identifying resistance to the suggested changes and managing it in a healthy manner; and 4) stressing the potential advantages that will influence each of them.

12.1.3 LEAN PRINCIPLES AND DRIVERS

Theoretical part

Discussed in Chapter 10, Section 10.3.5

Practical example

After Company X's culture had been revolutionised and the Lean Philosophy had been established in the employees' mind-sets, the selected team had to meet frequently to assess where the major waste-causing processes had accumulated. Value stream maps were constructed and the opinion of the customer was considered and discussed openly. These meetings were held with constant encouragement from management; agendas were approved beforehand and afterwards results were shared and rewarded. This step was the most difficult one to achieve because it requires a culture change to allow Lean Construction implementation to be one of the company's strategic goals. A big announcement was made and posters were placed on the company's advertisement board. Everyone in the company is anticipating this achievement; they are excited and waiting for the value added by Lean implementation. This step took around four weeks and at this stage the company held a kick-off meeting for launching Lean implementation.

The outcome was that these meetings and lectures determined the imperative values that drive customer satisfaction, the most important one being the delivery time of the project, since delays were the chief concern for the stakeholders. This finding was articulated and emphasised as the driver for all subsequent efforts. Preliminary KPIs were set to measure the dates of the project phases.

12.1.4 LEAN TECHNIQUES AND TOOLS

Theoretical part

Discussed in Chapter 10, Section 10.3.5

Practical example

Senior executives educated their employees in the Lean philosophy and clarified how the new methodology would fundamentally impact the business; core obstacles were acknowledged, appropriate measures were launched and continuous support was granted. The employees were eager to comprehend the required tools to realise and crown their efforts. Employees were assembled to get to know the techniques that they should exercise to tackle the root causes of waste. This step was mainly about conducting training in the most suitable Lean tools that fit in with the company and projects requirements.

The Last Planner System was the first tool chosen and training was conducted for 15 working days.

The outcome was that the selected team leader reached an agreement with his team members, which is that the "Last Planner System" tool should be implemented to effectively and pro-actively monitor and augment the shortcomings of project dates. Using Lean Construction tools such as Last Planner enables the application of theory to provide more solid outcomes. Last Planner was integrated with Primavera, one of the Critical Path Methods (CPM). The results of this integration have not yet been shown to save time, but up to now they have shown that benefits were gained in terms of improving construction planning and site management. The fact that one of the main activities in project managing by company X, road paving, was finished two weeks ahead of schedule was clear evidence of improvement.

12.1.5 BUILT-IN QUALITY AND PROCESS FLOW

Theoretical part

Discussed in Chapter 10, Section 10.3.5

Practical example

Company X was not investing sufficiently in efforts and measures to link the Lean philosophy and tools to the current meetings and project. Company X aims to institute the changes and involve the applications across all stages. This means ensuring that adoption is embraced by the employees and merged into their work tasks. This stage is mainly intended to update the company's quality manual so that it is aligned with Lean philosophy and policy. Company X has just started to understand Value Stream Mapping in order to analyse and plan flows of the project delivery from its beginning through to the customer. This step was also challenging because at this time the team members first heard about Value Stream Mapping. As a result, extensive training in Value Stream Mapping was conducted for 2 weeks in order to prepare the team to apply that knowledge.

The outcome was that documented procedures were written to guide any employee performing the task in a consistent manner. Performance measures are to be embedded in various phases and quality control is to be performed at each stage.

Now Company X is committed to seeking continuous improvement in all areas related to the Quality System. Quality performance indicators applied to implementation of QC procedures were based on construction operations. The operation will be completed in a systematic manner, which will ensure the high quality of current work duties. A quality manager coordinates the activities required to meet quality standards, monitor and advise on the performance of the quality management system, produce data and report on performance and measurement according to set standards, and liaises with other managers and staff throughout the organisation to ensure that the quality system is functioning properly.

12.1.6 DELIVERY OF VALUE

Theoretical part

Discussed in Chapter 10, Section 10.3.5

Practical example

Because Company X understands that the Lean process must be alive and stay dynamic, senior executives regularly revise the procedures and methods followed and implemented to ensure they are still directed towards the satisfaction of the customer.

The outcome is that value stream maps are continuously updated and aligned to the value from the customers' perspective. KPIs and performance measures are reviewed and assessed. All employees are aware of the importance of such appraisals.

12.1.7 LEAN IMPACT (BARRIERS AND SUCCESS FACTORS)

Theoretical part

Discussed in Chapter 10, Section 10.3.5

Practical example

Company X has reached a stage where its major goals and strategies have been aligned to the Lean philosophy, regular meetings have been organised to convey the magnitude of the methodology, an exclusive team has been assigned, a definite project has been chosen for applying the methodology, a precise hindrance has been identified, and the process of rectifying it has been commenced. Success factors and barriers are identified by Company X and listed in a checklist. Success factors are considered opportunities to improve the company's ability to achieve the aim of Lean implementation. On the other hand, barriers are considered as an event that could be a threat to the company's ability to achieve its aims.

The outcome was that across the hierarchy of the organisation, meetings were held to address all of the difficulties faced, on personal and procedural levels, and assess how each one that participated in the Lean journey has managed to conquer and surmount such blocks.

12.1.8 RISK MANAGEMENT

Theoretical part

Discussed in Chapter 10, Section 10.3.5

Practical example

Company X understands that life is not ideal, and utilising Lean tools alone is not sufficient. For the selected Lean tool to yield the desired outcome, areas of deficiencies need to be discovered prior to their impact, and - better yet -the occurrence of deficiencies needs to be prevented. Managing project risks will increase the certainty of successfully delivering the project on time, on budget and to the appropriate standard. Company X used risk management to enhance Lean implementation in terms of minimising the associated risks.

Outcome: focal barriers for on-time delivery were identified, and a clearly defined Risk Register was created for each barrier. The Risk Register included analysis, assessment, response plan and responsible person assigned to actions entailed. Company X developed a project risk management plan to eliminate unexpected cost, safety, quality and time delays whilst supporting planning and control through the identification, assessment, mitigation and control of identified risks related to the project, business, environment and external changes. In addition, potential events that may impact on the project were reviewed and solutions were found to eliminate the risk or minimise it to an acceptable level.

12.1.9 CONTINUOUS IMPROVEMENT

According to KPMG International, the organisation's leadership is required in order to ensure that continuous improvement is ingrained in the cultural DNA of the organisation (KPMG International, 2012). Application of Lean principles to create a culture of continuous improvement ensures that the comprehensive process from the customer's perspective and the design and management of those processes are identified to guarantee that the information and material flow as smoothly and efficiently as possible (KPMG International, 2012). At this Lean Construction implementation process group, the researcher focused on the creation of lessons learned at the end of each maturity level. Organisations will not effectively generate the new knowledge required to support strategic objectives and contribute to business value without collecting lessons learned and establishing an organisational culture committed to enabling learning.

Practical example

Company X has now achieved the anticipated goal of all the past endeavours: not from an internal opinion, but rather from feedback solicited from the customer. Company X, after applauding the accomplishments, is now mature enough to start considering additional tools and techniques to employ.

The outcome was that lessons learned were collected and brought together from every aspect and contributor, and those lessons were overtly discussed and announced, together with the customers' reaction. Proposals were welcomed for the succeeding Lean tool and beyond.

12.2 PROPOSED LEAN MATURITY LEVELS

Previously, in the developed framework discussed in this task (3) (Chapter 10, section 10.3.6), the researcher suggested the project's life cycle of project management processes (initiation, planning, execution, monitoring and controlling and closing), which involves a set of actions to be implemented regarding Lean Construction processes, based on the suggestions received during the validation process and agreed by the researcher. Those projects' life cycles have been changed to maturity level (Uncertain/level 0, Awakening/level 1, Systematic/level 2, Integrated/level 3 and Challenging/level 4). The reason for this suggestion was to properly or logically link the developed framework and assessment tool.

12.3 REVISED IMPLEMENTED PERFORMANCE ACTIVITIES

This section presents the revised implemented performance activities based on the revised framework. The researcher explains only the new activities; for the same activities, see Chapter 10, section 10.3.6.

Table 12.1: Presented implemented performance activities RV02

Lean philosophy, policy and strategy	
Adopt the appropriate policy and strategy to be aligned to the organisational strategy plans and philosophy	Presented in Chapter 10, Section 10.3.6
Select project, team and leader to implement Lean Construction	Presented in Chapter 10, Section 10.3.6
Follow policy and strategy that have been set	Presented in Chapter 10, Section 10.3.6
Ensure that the policy and strategy are aligned to the project objectives and organisational strategy goals and philosophy	Presented in Chapter 10, Section 10.3.6
Make sure strategic and business plans are clear; operational and commercial targets to be realised through Lean activity in order to achieve growth and profitability and improve market position	The necessary performance improvement gains from Lean 'management' are factored into business and strategic plans. A strategic business improvement approach is deployed and demonstrates year-on-year output measure improvements linked to corporate targets (Highways England, 2012).
Lean leadership and structure	
Identify the stakeholders and their expectations regarding the implementation of Lean Construction	Presented in Chapter 10, Section 10.3.6
Make sure all senior leaders and management are committed to and support the implementation of Lean Construction	Presented in Chapter 10, Section 10.3.6
Provide leadership, guidance and recognition of positive actions by management	Presented in Chapter 10, Section 10.3.6
Make sure the adoption of a Lean leadership philosophy is apparent at meetings at all levels throughout the organisation	Presented in Chapter 10, Section 10.3.6

Make certain that senior leaders and management mentor and foster Lean champions internally and throughout the supply chain	Ensure that all senior leaders and management within the organisation enthusiastically embrace the concept of Lean and support the transition to a Lean culture. Ensure that philosophy, policy, and strategy are developed and communicated by the involvement of organisation leaders (Highways England, 2012).
Lean principles and drivers	
Clearly define the five principles of Lean Thinking	Presented in Chapter 10, Section 10.3.6
Create a plan of how to implement the five principles of Lean Thinking	Presented in Chapter 10, Section 10.3.6
Ensure that you are driving towards the overall organisational strategy by a constant review of your processes	Presented in Chapter 10, Section 10.3.6
Ensure that Lean principles are constantly and consistently delivering value to the customer	Presented in Chapter 10, Section 10.3.6
Take action necessary for Lean policies and process-based orientation to be aligned across the overall organisation processes	Lean policies and process-based orientation are aligned across the overall organisation processes. Decisions should be made in full alignment with the goals of the organisation to ensure that the maximum benefit for the adaption of Lean Construction principles is achieved (Ogunbiyi, 2014).
Lean techniques and tools	
Understand Lean Construction tools and their benefits	Presented in Chapter 10, Section 10.3.6
Identify Lean Construction practices and methods in order to achieve successful Lean implementation	Presented in Chapter 10, Section 10.3.6
Use the Lean Construction tools suitable for your project/organisation and ensure that they will maximise project value	Presented in Chapter 10, Section 10.3.6
Measure and evaluate the performance of the project by using Lean Construction tools and compare them to the traditional methods	Presented in Chapter 10, Section 10.3.6
Use professional Lean tools for planning all activities – not just design and construction.	All team members prepare and submit final project performance based on the use of Lean Construction tools and document the value added by using its tools. All team members, including subcontractors, require planning and

	commitments to be based on Lean tools (Engineers Australia, 2012).
Delivery of value	
Identify key value streams of major end customers and projects	Presented in Chapter 10, Section 10.3.6
Ensure performance levels of key processes are understood and initial value stream analysis is under way to identify and deliver improvement to end customer value	Presented in Chapter 10, Section 10.3.6
Analyse the principle of value stream(s), allowing the identification of critical interaction	Presented in Chapter 10, Section 10.3.6
Measure Value Stream performance management	Presented in Chapter 10, Section 10.3.6
Undertake Standardised Work and 5S throughout the site	There should be a complete analysis for key Value Streams of major end customers and projects in addition to clear definition and effective management of handover points and interfaces (Engineers Australia, 2012).
Built-in Quality and process flow	
Determine quality processes, standards, and metrics	Presented in Chapter 10, Section 10.3.6
Create performance measurement plan	Presented in Chapter 10, Section 10.3.6
Follow processes which are adapted and integrated to complement flow	Presented in Chapter 10, Section 10.3.6
Perform quality control	Presented in Chapter 10, Section 10.3.6
Continually improve process flow throughout all value streams (internal and through the supply chain), in time with actual demand, with distance travelled and inventory/ buffer levels minimised	Make sure that processes are being designed to encourage flow and balance resources. Provide optimum value to the customer through a complete value creation process. Confirm work is done according to the required quality standards(Engineers Australia, 2012).
Lean impact (barriers and success factors)	
Create measurable objectives	Presented in Chapter 10, Section 10.3.6
Develop implementation plan and timeline	Presented in Chapter 10, Section 10.3.6
Analyse resources or budget for implementing Lean	Presented in Chapter 10, Section 10.3.6
Assess the degree to which processes are being designed to encourage flow and balance resources	Presented in Chapter 10, Section 10.3.6
Ensure that cost savings, waste elimination and value maximisation are more efficient with the application of Lean Construction than with that of conventional methods	Top management commitment is necessary to integrate Lean into core business processes and decision-making. Lean implementation benefits, which could relate to either customer satisfaction or employee satisfaction

	and the impact on society, should be seen as the business result in terms of cost savings, waste elimination and value maximisation. In addition, prepare a comparative statement to show the value added by the implementation of the new method compared to current conventional methods (Ogunbiyi, 2014).
Risk Management	
Create risk management plan	Presented in Chapter 10, Section 10.3.6
Perform risk analysis and risk response plan	Presented in Chapter 10, Section 10.3.6
Perform risk reassessment and audit and update Risk Register	Presented in Chapter 10, Section 10.3.6
Control risks and update risk register	Presented in Chapter 10, Section 10.3.6
Implement and follow Risk Analysis and Management for Projects (RAMP)	Adapt the RAMP framework for analysing and managing the risks involved in projects, in order to achieve enhanced economic earnings for the customer.
Continuous improvement	
Solicit feedback from the stakeholder regarding the settled policy and strategy	Confirm work is done according to the Lean Construction plan. Create lessons learned and strengths, weaknesses, opportunities, and threats (SWOT) analysis for the implementation of TPS for future projects.
Create lesson learned	Ensure that all senior leaders and management within the organisation enthusiastically embrace the concept of Lean and support the transition to a Lean culture. Ensure that philosophy, policy, and strategy are developed and communicated by the involvement of organisation leaders (Highways England, 2012). Document the learning gained from the process of implementing the Lean Construction method. Formally conduct lessons learned sessions throughout the project's life cycle. The purpose of creating lessons learned is to share and use knowledge resulting from the implementation of the new method (Highways England, 2012).
Create user feedback	Always keep the customer/stakeholders in touch with the results of Lean Construction implementation and take

	necessary actions to satisfy their expectations and requirements.
Summarise lessons learned	All team members prepare and submit final project performance based on the implementation of Lean Construction integrated with risk management and document the value added by its application.
Implement new strategies collected from feedback, which can add value and improvement to the system	After successful Lean Construction implementation and archive records and documented lessons learned, maybe a new strategy can be implemented or integrated to enhance the organisation/project performance (Ogunbiyi, 2014).
Assessment gate	
Presented in Chapter 10, Section 10.3.6	
Closing phase/new strategy gate	
Presented in Chapter 10, Section 10.3.6	

12.4 HOW TO USE THE REVISED DEVELOPED LCFIRM

This section presents an updated flowchart as guidance for organisations to use the developed Lean Construction framework with the proposed assessment tool. Figure 12.2 presents the structure of the use of the developed framework and assessment tool. It is assumed that the score range represents each level of maturity.

Level 0: Uncertain (score range: 20.0 - 30.0): your company urgently needs to improve these aspects

Level 1: Awakening (score range: 31.0-45.0): your company needs to address the gaps in its knowledge

Level 2: Systematic (score range: 46.0-60.0): your company has moderate capability and maturity and scope for improvement

Level 3: Integrated (score range: 61.0-75.0): your company has high capability and maturity

Level 4: Challenging (score range: 76.0-100): your company needs continuous improvement

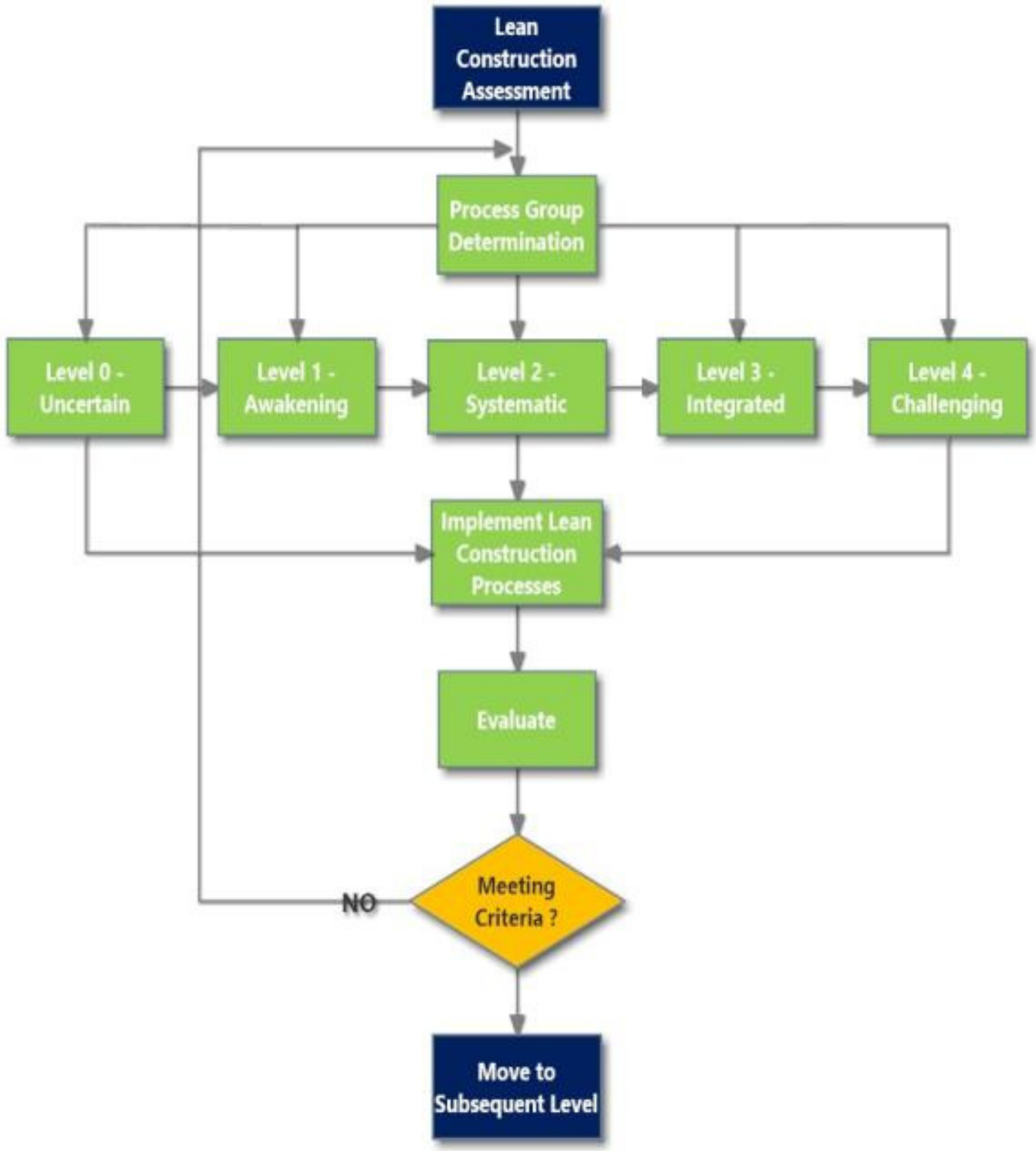

Figure 12.2: Structure of the developed Lean Construction framework RV02

12.5 SUMMARY OF THE DIFFERENCE BETWEEN DEVELOPED FRAMEWORK RV01 AND RV02

Tables 12.2 and 12.3 below summarise the difference between the developed framework 01 and the revised framework 02 after the conducted validation process, in terms of Lean Construction implementation processes, phases/levels, and performance activities. The differences are shown in bold and italic styles.

Table 12.2: The differences between framework RV01 and 02 in terms of processes and phase/level

	Developed Framework 01	Developed Framework 02
Lean Construction Implementation Processes	1) Lean philosophy, policy and strategy 2) Lean leadership and structure 3) Lean principles and drivers 4) Lean techniques and tools 5) Built-in Quality and process flow 6) Delivery of value 7) Lean impact (barriers and success factors) 8) Risk management	1) Lean philosophy, policy and strategy 2) Lean leadership and structure 3) Lean principles and drivers 4) Lean techniques and tools 5) Built-in Quality and process flow 6) Delivery of value 7) Lean impact (barriers and success factors) 8) Risk management 9) Continuous improvement
Phases/Levels	Initiation, Planning, Execution, Monitoring and controlling closing	***Uncertain/level 0, Awakening/level 1, Systematic/level 2, Integrated/level 3 Challenging/level 4***

Table 12.3: The differences between framework RV01 and RV02 in terms of performance activities

Lean Processes	Developed Framework 01	Developed Framework 02
Lean philosophy, policy and strategy	Adopt the appropriate policy and strategy to be aligned to the organisational strategy plans and philosophy	Adopt the appropriate policy and strategy to be aligned to the organisational strategy plans and philosophy
	Select project, team and leader to implement Lean Construction	Select project, team and leader to implement Lean Construction
	Follow policy and strategy that have been set	Follow policy and strategy that have been set

Lean Processes	Developed Framework 01	Developed Framework 02
	Ensure that the policy and strategy are aligned to the project objectives and organisational strategy goals and philosophy	Ensure that the policy and strategy are aligned to the project objectives and organisational strategy goals and philosophy
	Solicit feedback from the stakeholder regarding the settled philosophy, policy and strategy	***Make sure strategic and business plans are clear; operational and commercial targets to be realised through Lean activity in order to achieve growth and profitability and improve market position***
Lean leadership and structure	Identify the stakeholders and their expectations regarding the implementation of Lean Construction	Identify the stakeholders and their expectations regarding the implementation of Lean Construction
	Make sure all senior leaders and management are committed to and support the implementation of Lean Construction	Make sure all senior leaders and management are committed to and support the implementation of Lean Construction
	Provide leadership, guidance and recognition of positive actions by management	Provide leadership, guidance and recognition of positive actions by management
	Make sure the adoption of a Lean leadership philosophy is apparent at meetings at all levels throughout the organization	Make sure the adoption of a Lean leadership philosophy is apparent at meetings at all levels throughout the organisation
	Create lesson learned	***Make certain that senior leaders and management mentor and foster Lean champions internally and throughout the supply chain***
Lean principles and drivers	Clearly define the five principles of Lean Thinking	Clearly define the five principles of Lean Thinking
	Create a plan of how to implement the five principles of Lean Thinking	Create a plan of how to implement the five principles of Lean Thinking
	Ensure that you are driving towards the overall organisational strategy by a constant review of your processes	Ensure that you are driving towards the overall organisational strategy by a constant review of your processes
	Ensure that Lean principles are constantly and consistently delivering value to the customer	Ensure that Lean principles are constantly and consistently delivering value to the customer
	Create user feedback	***Take action necessary for Lean policies and process-based***

Lean Processes	Developed Framework 01	Developed Framework 02
		orientation to be aligned across the overall organisation processes
Lean techniques and tools	Understand Lean Construction tools and their benefits	Understand Lean Construction tools and their benefits
	Identify Lean Construction practices and methods in order to achieve successful Lean implementation	Identify Lean Construction practices and methods in order to achieve successful Lean implementation
	Use the Lean Construction tools suitable for your project/organisation and ensure that they will maximise project value	Use the Lean Construction tools suitable for your project/organisation and ensure that they will maximise project value
	Measure and evaluate the performance of the project by using Lean Construction tools and compare them to the traditional methods	Measure and evaluate the performance of the project by using Lean Construction tools and compare them to the traditional methods
	Summarise lesson learned	***Use professional Lean tools for planning all activities – not just design and construction.***
Delivery of value	Identify key value streams of major end customers and projects	Identify key value streams of major end customers and projects
	Ensure performance levels of key processes are understood and initial value stream analysis is under way to identify and deliver improvement to end customer value	Ensure performance levels of key processes are understood and initial value stream analysis is under way to identify and deliver improvement to end customer value
	Analyse the principle of value stream(s), allowing the identification of critical interaction	Analyse the principle of value stream(s), allowing the identification of critical interaction
	Measure Value Stream performance management	Measure Value Stream performance management
	Streamline the system using lesson learned	***Undertake Standardised Work and 5S throughout the site***
Built-in Quality and process flow	Determine quality processes, standards, and metrics	Determine quality processes, standards, and metrics
	Create performance measurement plan	Create performance measurement plan

Lean Processes	Developed Framework 01	Developed Framework 02
	Follow processes which are adapted and integrated to complement flow	Follow processes which are adapted and integrated to complement flow
	Perform quality control	Perform quality control
	Continue collecting user comments for continuous improvement	***Continually improve process flow throughout all value streams (internal and through the supply chain), in time with actual demand, with distance travelled and inventory/ buffer levels minimised***
Lean impact (barriers and success factors)	Create measurable objectives	Create measurable objectives
	Develop implementation plan and timeline	Develop implementation plan and timeline
	Analyse resources or budget for implementing Lean	Analyse resources or budget for implementing Lean
	Assess the degree to which processes are being designed to encourage flow and balance resources	Assess the degree to which processes are being designed to encourage flow and balance resources
	Implement new strategies collected from feedback, which can add value and improvement to the system	***Ensure that cost savings, waste elimination and value maximisation are more efficient with the application of Lean Construction than with that of conventional methods***
Risk Management	Create risk management plan	Create risk management plan
	Perform risk analysis and risk response plan	Perform risk analysis and risk response plan
	Perform risk reassessment and audit and update Risk Register	Perform risk reassessment and audit and update Risk Register
	Control risks and update risk register	Control risks and update risk register
	Summarise user feedback	***Implement and follow Risk Analysis and Management for Projects (RAMP)***
Continuous improvement		***Solicit feedback from the stakeholder regarding the settled policy and strategy***
		Create lesson learned

Lean Processes	Developed Framework 01	Developed Framework 02
		Create user feedback
		Summarise lessons learned
		Implement new strategies collected from feedback, which can add value and improvement to the system

12.6 ACTUAL VALIDATION – DEVELOPED FRAMEWORK

This part of the validation process includes analysis and insight into the meaning of the results. This is an actual validation of the implementation process. For example, a simulation of some construction processes could be developed with or without the use of the framework. Chapter 11 was an assessment of the developed framework, including the presentation of the results.

The implementation of Lean in the long term and its beneficial impact can be shown at any stage of the implementation process. Some of the participants in the validation process, who are working in the action research, worked with the researcher to use the developed framework. After considering the processes and performance activities presented in the developed framework, the team members are considering Lean and how they will use its principles and philosophy in the project. The project team came up with an idea for eliminating the generated waste. The example below illustrated the difference or the value added by implementing the Lean Construction method compared to traditional methods.

A specific construction activity executed by Company X from the action research (Construction of Open Channel)

The main purpose of the construction of an open channel in Saudi KSA is aimed at reducing the impact of floods and torrents, which are causing widespread damage, as shown in Fig. 12.3. All present construction projects in KSA have focused on the open channel as a means to attaining a perfect and sustainable solution to the control of floods (Fig. 12.4).

Figure 12.3: Road cut by torrents

Figure 12.4: Constructed Open Channel in KSA (from the selected ongoing Mega-project, action research)

Implementing the traditional method

In the action research, the Issued For Construction (IFC) drawing called for a construction joint every 3.0 M for the open channel's concrete lining, as per the drawing below (Fig. 12.5).

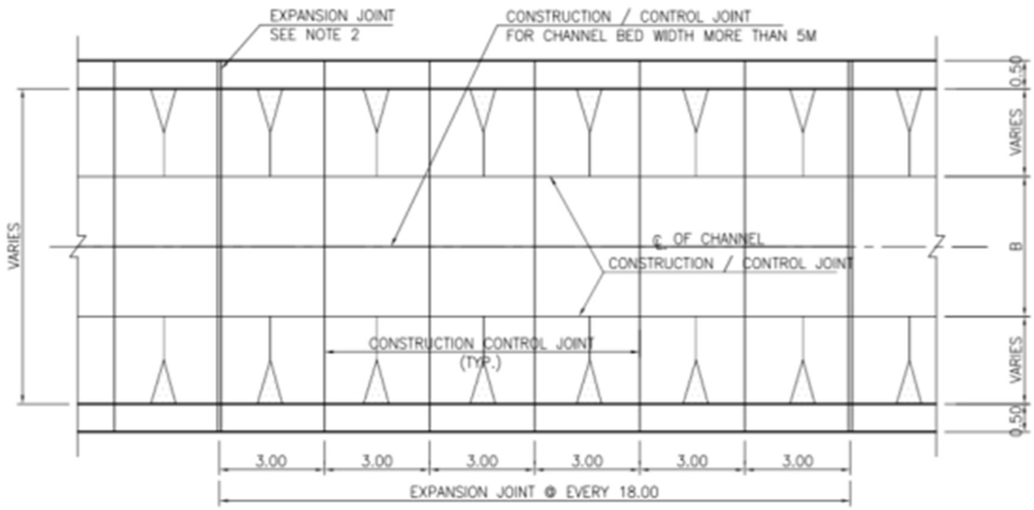

Figure 12.5: Key plan for expansion and construction joints based on the traditional proposal

One of the materials used in the construction of the open channel is Geogrid (see Fig. 12.6). Geogrid is a synthetic material characterised by woven bands of narrow elements in a regular, grid-like pattern with large voids between the woven bands. It is the tensile strength of the woven bands and the voids between those bands that lends stabilising strength to the projects they are used in (Ground Trades Xchange, 2013).

Figure 12.6: An example of Geogrid material

Following the IFC drawing, the Geogrid material originally supposed to be used was 2.5 M in width, which is 0.50 M less than the IFC required width of the open channel strip. To follow this requirement, an overlap of 0.30 M had to be made during the installation of Geogrid all around the open channel’s concrete lining area, which exceeds 1,427,567m^2.

Implementing the Lean Construction method

During the initiation phase, a workshop was conducted by the researcher to introduce the Lean Construction method and its implementation. The researcher concentrated on the three issues mentioned (Construction Waste; Delayed Schedule; and Project Over Budget). The company considered the positive and negative effects of implementing Lean Construction on the overall performance of the project. The construction team implemented Value Engineering analysis to eliminate the generated Geogrid material waste and they have suggested altering the width of the open channel concrete lining strips from 3.0m to 3.9m as per the proposed drawing below (Fig. 12.7).

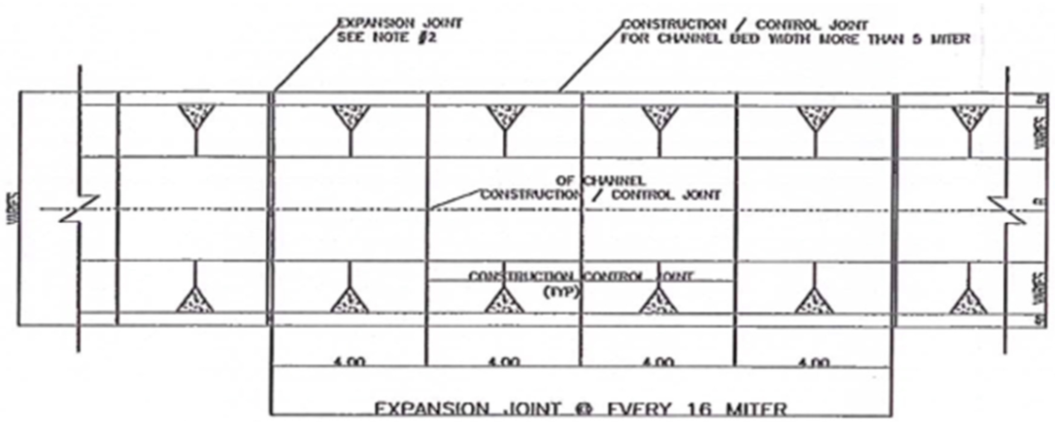

Figure 12.7: Key plan for expansion and construction joints based on the original proposal

With the new proposal, a Geogrid material width of 3.90m has been used. That width has covered the full concrete strip width without any need for overlap. The proposal was approved by the client (Royal Commission) and that has saved a total of 2,490 rolls of Geogrid material (= 319,476 m^2) with a value of SR (Saudi Riyal) 1,437,661, equal to GBP 268,800.00. The table below (12.4) illustrates the value added when the construction team’s awareness, in the action research, has been enhanced regarding the Lean Construction method as a new approach.

Table 12.4: Comparison between the traditional and the Lean Construction method for the construction of the Open Channel in the action research

Item	Traditional Method	Lean Construction Method	Results
Waste	Estimated Geogrid material = 1,427,567 M2	Actual Geogrid material =1,108,089.50 M2	Waste eliminated =319,477.50 M2
Time	Estimated time = 13 months	Actual time = 9 months	Time saved = 4 months
Cost	Estimated Cost = GBP 948,429.61	Actual Cost = GBP 679,629.61	Cost saved = GBP 268,800

SUMMARY OF FRAMEWORK DEVELOPMENT AND VALIDATION (TASK 3)

Task Three consists of Chapters Ten, Eleven and Twelve for presenting the developed Lean Construction Framework integrated with Risk Management (LCFIRM).

Chapter Ten presented a framework for Lean Construction implementation efforts as well as the integration of risk management. The proposed framework comprised eight main Lean Construction implementation groups addressing: (1) Lean philosophy, policy and strategy; (2) Lean leadership and structure; (3) Lean principles and drivers; (4) Lean techniques and tools; (5) Risk management; (6) Built-in Quality and process flow; (7) Delivery of value; and (8) Lean impact (barriers and success factors). The developed framework provides a set of activities of the action required for practical implementation of Lean construction at an organisational/project level. The framework is particularly useful for the management of organisations in order to take proactive steps necessary to ensure the successful implementation of Lean construction. Chapter Eleven presented the results of the validation of the developed framework process; all proposed assumptions and ideas have been validated in Chapter Eleven by questioning experts' opinions through interviews conducted with fifteen professionals.

Chapter Twelve presented the revised developed framework based on the consequences of the validation approach. Generally, the validation of the framework presented overall positive feedback. The experts interviewed gave positive comments on the overall framework and its components, as well as its applicability to construction contracting organisations. Three suggestions have been addressed and resulted in changing the developed framework in terms of providing practical examples for each Lean Construction implementation process (nine processes), then adding one more process, which is the continuous improvement aspect to be considered for each maturity level to ensure the improvement of the implementation of the Lean Construction method within construction organisations; finally, to change the project management life cycle process group (initiation, planning, execution, monitoring and controlling and closing) to be maturity level (Uncertain/level 0, Awakening/level 1, Systematic/level 2, Integrated/level 3 and Challenging/level 4). All those suggestions have been considered and consequently the researcher developed a revised framework.

In addition, in Chapter Twelve, the researcher conducted an actual validation to show the value added by using the developed framework compared with the traditional method.

TASK 4: ASSESSMENT TOOL DEVELOPMENT AND VALIDATION

Task Four (Chapters 13, 14 and 15): Assessment tool development and validation

In order to develop an assessment tool to achieve one of the main objectives of this study, it is necessary to use the reviewed literature, action research and data collected from the conducted Survey 01 as a sound, realistic basis for this task. In addition, the proposed assessment tool needs to be validated in order to get experts' feedback and suggestions. The researcher employs two interviews and an online survey with fifteen (15) participants. The validation approach starts with the first interview, followed by an online survey (Survey 02), and then a second interview. After the validation of the developed assessment tool, a practical assessment is conducted in order to test and pilot the proposed assessment tool. The practical assessment is performed by carrying out two workshops with ten members in each, a total of twenty (20) members working within the organisation responsible for managing the action research. The diagram below (Fig T.4) shows the research methods adopted.

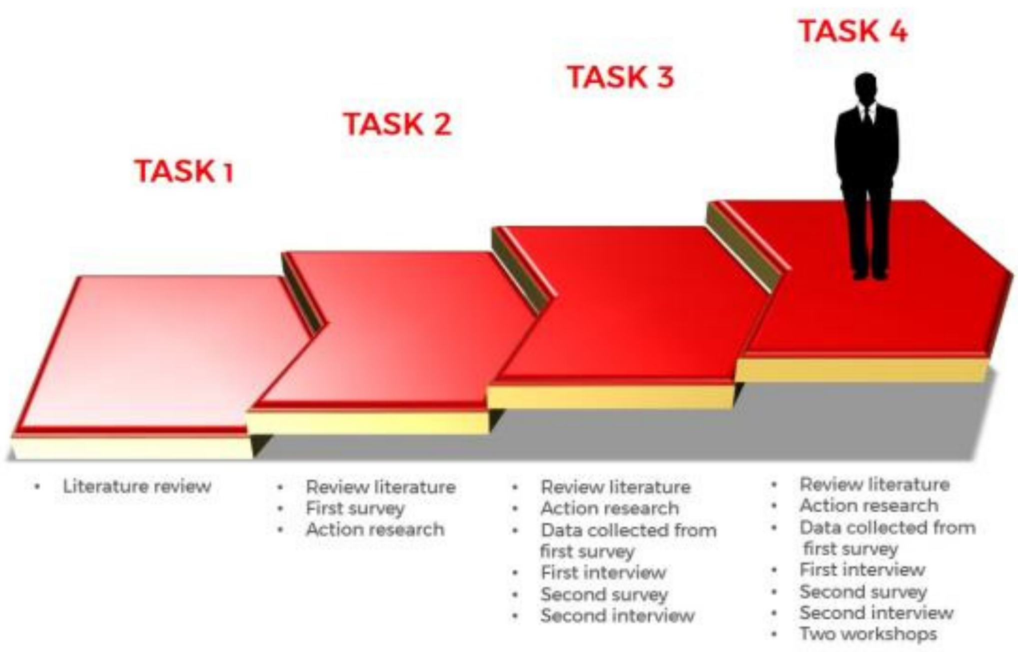

Figure T.4: Activities involved in Task Four

Task Four (4) presents the development and validation approach of the Lean Construction Assessment Tool; in addition to this, an actual assessment has been conducted. This task consists of three chapters (13, 14, and 15).

Chapter Thirteen (13) provides an assessment tool to evaluate the awareness of Lean Construction within construction companies in KSA. This is to enable construction organisations to assess the impact of implementing the concept of Lean and tofocus on areas for improvement. Construction organisations should be able to evaluate their Lean implementation efforts in terms of where they are, where they are going and where they would like to be. A thorough examination of such questions will enable an organisation to know whether the implementation of Lean Construction would be valuable.

Chapter Fourteen (14) presents the proposed assessment tools validated and presented according to both the current and desired circumstances of the project. The same validation approach has been presented and conducted for the developed framework used for validating the proposed assessment tool. Chapter Fifteen (15) presents the results of conducting the actual assessment of an ongoing Mega-construction project in KSA (action research) to identify the level of maturity of the Lean Construction method and to verify the developed assessment tool. In addition, it is considered to be the first step in implementing the developed framework through assessment gate No.1.

Chapter Thirteen: PROPOSED ASSESSMENT TOOL

13.1 INTRODUCTION

Prior to a successful Lean implementation, a Lean assessment should be conducted to identify gaps in knowledge that need to be addressed. The Lean implementation assessment consists of all the observed categories of Lean implementation. The researcher believes that Lean assessment should be applied before implementing the Lean Construction method through the proposed developed framework. The researcher considered two tools for conducting Lean assessment, including: (1) The Lean Enterprise Self-Assessment Tool (LESAT); and (2) The Highways Agency Lean Maturity Assessment Toolkit (HALMAT).

13.2 PROPOSED LEAN CONSTRUCTION ASSESSMENT TOOL (LCAT)

The researcher proposes a Lean Construction Assessment Model to evaluate the level of Lean awareness in organisations which can measure the gap between their current state of maturity and the position they want to reach. In Chapter 7, Task 1 the researcher reviewed some of the previous assessment tools and adopted two approaches, LESAT and HALMAT, as guidance and then tailored an assessment tool to be adopted for assessing the level of Lean awareness in construction companies in the KSA. The rationale behind choosing these two tools is that the two approaches are easy to use and will be relevant to the KSA construction industry. Highways England (2012) developed a step-by-step route to completion, and abiding by the following steps is highly recommended.

13.2.1 LEAN CONSTRUCTION ASSESSMENT STEPS

The researcher mainly followed the steps of the assessment tool mentioned in the HALMAT section because, from experience, it is more applicable to construction projects. The road map has been created to implement an actual assessment for the organisation that undertakes the management of the ongoing Mega-construction project (selected action research). The following are the steps that should be abided by and followed by the road map (see Figure 13.1):

Step 1: Decide the limit of the assessment, whether to include a whole organisation, a particular division or a department of an organisation.

Step 2: Determine individuals qualified to participate in the assessment process:

Step 3: Appoint a facilitator

Explanation: A facilitator should have sufficient knowledge of Lean principles so as tobe able to guide participants on interpretation; should be an independent individual; and should not be one of the leaders of the organisation, in order to avoid any conflict of interest.

Step 4: Determine the mission, vision, value and strategic aims of the organisation.

Explanation: The Company's mission, vision, value and strategic aims should be considered in the questions posed to assess the level of company awareness regarding Lean.

Step 5: Hold an initial meeting to set the ground rules of the assessment.

Explanation:(1) Ensure that the participants fully understand the assessment tool as well as the application method; (2) Confirm that they understand the limits of assessment clearly; (3) Arrive at an agreement on the timetable for completion and collation of individual scores; (4) Set a date for the assessment meeting.

Step 6: The assessment form is filled in by selected participants

Step 7: Facilitator gathers results that determine areas of strong agreement

Step 8: Conduct an assessment meeting where consent is given and the facilitator analyses the results.

Step 9: Facilitator determines the level of Lean awareness of the company based on collected scores from the review.

Figure 13.1: Lean Construction Assessment Roadmap

13.2.2 AREAS OF COVERAGE OF THE ASSESSMENT TOOL

The researcher held a brainstorming session before developing the assessment tool questions and determining the key assessment elements with the workers involved in the selected ongoing Mega-Construction project. This session aimed at tackling the main Lean Construction principles as well as the quantitative evaluation of such principles within construction projects through site visits. Attempting to cover all Lean Construction aspects, the researcher chose the following assessment elements based on the reviewed literature and previous assessment tools, as well as key findings from data collected from both the conducted survey and the researcher's experience in KSA. These areas of coverage are verified in the validation process (Chapter 14) and if any other area is suggested by the participants, the research will consider it:

- **Lean policy and strategy:** this element identifies the extent of Lean principles incorporated in the strategic and planning processes of organisations and assesses the company policy deployment in order to determine the company's position in the future.
- **Lean philosophy:** this element identifies the scope of an organisation's target for creating more value for customers and focuses on its key processes to continuously increase it.
- **Lean leadership and structure:** this element indicates how the organisation's leaders are active in encouraging and mentoring the introduction of Lean and examines the companies' degree of structuring their organisations to maximise team working and employee empowerment.
- **Lean principles and drivers:** this element evaluates the organisation's usage of the five principles of Lean and ensures that companies are following the overall organisational strategy and that they are constantly and consistently delivering value to their customers through the constant review of their processes.
- **Eliminating waste and continuous improvement:** this element identifies the organisation's plan for defining and managing the generated waste in order to achieve continuous improvement.
- **Lean techniques and tools:** this element aims at evaluating the usage of the Lean techniques and tools to support the adoption of Lean principles.

- **Delivery of value:** this element identifies the level of value maximisation in the organisation through the analysis of the key processes which deliver end customer value.
- **Built-in quality:** this element identifies whether the organisation avoids quality issues through the quality assurance processes.
- **Process flow:** this element assesses the degree to which processes are being designed to encourage flow and balance resources.
- **Lean impact (barriers and success factors):** this element identifies the organisation's understanding of Lean's impact on its performance and defines the process of assessing the impact of Lean on final project success.

13.2.3 ASSUMPTIONS FOR ASSESSMENT TOOL

The researcher made two assumptions for proposing the assessment tool: 1) LCAT weighting and overall scoring system; 2) evaluation of the outcome of the assessment tool (reading results). The main basis for those two assumptions was an expert's judgment, reviewed literature and the researcher's experience in KSA.

In order for the researcher to develop the tool, a brainstorming session with four of the selected participants, two from top management (the CEO and Project Management Office Director) and another two from site workers (project manager and construction manager) was held to discuss the main Lean Construction principles and how they can be quantitatively evaluated within construction projects in the KSA.

The researcher considered the HALMAT scoring spreadsheet developed by the Highways Agency (2012) as a basis for the first assumption (weighting and overall score system). The questions weights are given tailored upon the company's area of weakness and strengths. Therefore, the researcher and experts during the brainstorming session agreed to weight the twenty (20) questions provided in the assessment tool equally at 5 per cent each and have a minimum score (1) and maximum score (5).

The second assumption is the outcome/results of the assessment tool which will be used to calculate an overall weighted score for the organisation's Lean maturity. This assumption is verified during the validation process of the proposed assessment tool (Chapter Fourteen) in Question no.12 in the survey (02) questions.

LCAT WEIGHTING AND OVERALL SCORING SYSTEM

The adopted maturity levels for the development assessment are based on the approach of Nesensohn et al., (2014).The researcher applied a scoring system based on a 5-point scale for each question. Ratings are in whole numbers only (no decimal ratings). The assessment tool is based on a numerical scoring system on a scale that ranges from 0 to 4, where 0 represents the state of Uncertainty and 4 represents the Challenging state. The researcher used the same maturity levels utilised for the maturity assessment. Table 13.1 identifies the maturity levels used for Lean Construction assessment (Nesensohn et al., 2014):

Table 13.1: Maturity level definitions

Level	Maturity Level	Definition
0	Uncertain	No implementation or action taken to implement the system
1	Awakening	Knowledge about the system is present but there is lack of interest in implementing it
2	Systematic	System is present but lacks concentration and guidance in the implementation
3	Integrated	System is implemented and company is adjusting to the system
4	Challenging	System is implemented and company is reaping the benefits while adjusting to new challenges encountered during the process.

Lean Construction principles were presented in questions applicable to the reality of construction sites. However, the Lean principles included in the assessment tool were split into ten main categories, covered by 20 questions, for applicability reasons. These ten main categories are: 1) Lean policy and strategy; 2) Lean philosophy; 3) Lean leadership and structure; 4) Lean principles and drivers; 5) waste elimination and continuous improvement; 6) Lean techniques and tools; 7) delivery of value; 8) Built-In Quality; 9) process flow; and 10) Lean impact (barriers and success factors). Each of the 20 questions has an equal weighting, with a rating value that ranges from 0 to 4(refer to appendix 8). Table13.2 illustrates the weighted scoring for each section and subsection (questions).

Table 13.2: Weighted scoring system – assumptions

Section	Sub-section	Sub-section Weighting	Section Weighting	Min Score	Max Score
1.0 Lean Policy and Strategy	1.1	5.00%	15%	1.00	5.00
	1.2	5.00%		1.00	5.00
	1.3	5.00%		1.00	5.00
2.0 Lean Philosophy	2.1	5.00%	10%	1.00	5.00
	2.2	5.00%		1.00	5.00
3.0 Lean Leadership and Structure	3.1	5.00%	10%	1.00	5.00
	3.2	5.00%		1.00	5.00
4.0 Lean Principles and Drivers	4.1	5.00%	10%	1.00	5.00
	4.2	5.00%		1.00	5.00
5.0 Eliminating Waste and Continuous Improvement	5.1	5.00%	15%	1.00	5.00
	5.2	5.00%		1.00	5.00
	5.3	5.00%		1.00	5.00
6.0 Lean Techniques and Tools	6.1	5.00%	10%	1.00	5.00
	6.2	5.00%		1.00	5.00
7.0 Delivery of Value	7.1	5.00%	5%	1.00	5.00
8.0 Built-In Quality	8.1	5.00%	5%	1.00	5.00
9.0 Process Flow	9.1	5.00%	5%	1.00	5.00
10.0 Lean Impact (Barriers and Success Factors)	10.1	5.00%	15%	1.00	5.00
	10.2	5.00%		1.00	5.00
	10.3	5.00%		1.00	5.00
Weighting Check		100%	100%	20.00	100.00

Evaluation and outcome of the assessment tool

There are several necessary prerequisites for conducting the application of the LCAT adequately. Project and company information should be gathered beforehand in order to provide time for the assessment, which is conducted through an interview and needs to be well prepared through a site/company visit. In order to reduce bias and to facilitate observation and questioning, site visits and interviews should be conducted with ten or more people. The evaluation model should not be filled out during the site visit and questioning, in order to provide better observation and maintain confidence between the facilitator and interviewee. In order to rate the project or company according to the LCAT, based on a trial that has already been conducted, the researcher asked two of the participants to fill/answer the assessment questions prior to the actual assessment. It has been found that one hour of site visit is considered enough. The results of the assessment are then compared, discussed and merged in order for the interviewers to agree on a final version. For the sake of gaining more experience and a clearer rating notion, the same researchers are advised to apply the LCA-Tool to as many projects as possible. This will also help in minimising bias.

The reading of results is based on the overall score of the ten categories of the assessment. The results are considered to be the company's level of Lean Construction awareness; this is represented as a score between 20 and 100. The researcher has assumed a weighting score system such that the minimum score for each question is 1.0 and the maximum is 5.0, whereby results are based on the overall score of the ten categories of the assessment. It is assumed that the score range represents each level of maturity, as shown in table 10.3.

INITIATION (score range: 20.0 – 30.0): your company urgently needs to improve these aspects

PLANNING (score range: 31.0 – 45.0): your company needs to address the gaps in its knowledge

EXECUTION (score range 46.0 – 60.0): your company has moderate capability and maturity and scope for improvement

MONITORING AND CONTROLLING (score range 61.0 – 75.0): your company has high capability and maturity

CLOSING (score range: 76.0 – 100): your company needs continuous improvement

CHAPTER FOURTEEN: VALIDATION OF ASSESSMENT TOOL

14.1 INTRODUCTION

This chapter presents the validation approach for the proposed assessment tool. In this chapter (Fourteen), the results of validating the proposed assessment tool are presented according to both the current and desired circumstances of the project.

The researcher used the same mixed methods that have been conducted for validating the developed framework in order to validate the assessment tool as well. The methods of interview and survey are the methods of data collection of the validation of the assessment tool. The validation approach is carried out in three phases:

D) The first phase was an interview with the participants in order to introduce the proposed assessment tool. Moreover, during the interview, the nine steps of Lean Construction Assessment were explained, as well as the ten areas of coverage of the assessment tool. In addition, the parameters of the proposed weighting and scoring system to determine the desired level of maturity for construction organisations were explained by the researcher. This first step is considered an introduction to the participants before they answer the questions.

E) The second phase was an online survey that included structured questions to get feedback from the participants about the developed assessment tool.

F) The last phase was also an interview in order to discuss their feedback and critically analyse the perceived pros and cons of the proposed assessment tool.

The same 15 professionals in KSA that were used for validating the developed framework are used also to validate the proposed assessment tool. The survey that has been sent to validate the framework uses Section Three (see Appendix 5) to validate the assessment tool, as shown below:

<u>**Section Three: Validation of the proposed Lean Construction Assessment Tool (question 11-15), covering:**</u>

1) Evaluation of the proposed assessment tool in terms of level of coverage of the overall content;

2) Addition of a question to improve the assessment;

3) The applicability of the mentioned assumption described in the structured questions interview;

4) Feedback or confirmation that the proposed Lean Construction Assessment Tool can assess the awareness of Lean within construction organisations/projects;

5) Comment on areas that could be deleted/included/improved.

14.2 DATA ANALYSIS – VALIDATION OF PROPOSED ASSESSMENT TOOL

Question No. 11:
Evaluation of the proposed assessment tool

This question tackles the evaluation of the proposed framework. This question has four sub-questions, as follows: (1) What is your overall opinion of the level of coverage of the proposed Lean assessment tool in terms of its overall content?; (2) What is your opinion of the selected 10 areas provided (Lean policy and strategy, Lean philosophy, etc.) in terms of the level of uptake and understanding?; (3) What is your opinion of the 20 questions provided?; and (4) With what degree of efficiency do the provided maturity levels explain each of the proposed answers? Table 14.1 reviews the results of the four sub-questions, as follows.

Table 14.1: Number of respondents in each rating level

Sub-Questions	Very low	Low	High	Very high	Total
S-Q1	0	1	11	2	14
S-Q2	0	1	11	2	14
S-Q3	1	1	9	3	14
S-Q4	1	4	7	2	14

The majority(93 per cent) of the respondents gave a high rating to the proposed assessment tool; in addition, the respondents agreed with the researcher that the selected 10 areas provided (Lean policy and strategy, Lean philosophy, etc.) are suitable in terms of the level of uptake and understanding. Twelve (12) participants out of fourteen (14) who have answered these questions said that the 20 questions provided are appropriate and effective for assessing the maturity level of Lean Construction. In addition, 65% of the participants accorded a high or very high rating to the degree of efficiency with which the provided maturity levels explained each of the proposed answers. On the other hand, during the second interview, where the researcher asked the other 35% of the respondents for the reason they gave a low rating to the proposed answers, they stated that the proposed assessment tool is adequate to evaluate the maturity level but suggested that the facilitator/researcher should explain each question and answer to the workers before the actual assessment, and this is what the researcher already did in Chapter Eleven.

Question No. 12:
Do you think that the assumption mentioned below is applicable/workable?

The researcher has assumed a weighting score system such that the minimum score for each question is 1.0 and the maximum is 5.0, whereby results are based on the overall score of the ten categories of the assessment. The results are considered to be the company's level of Lean Construction awareness; this is represented as a score between 20 and 100. It is assumed that the score range represents each level of maturity, as follows:

Initiation: (score range: 20.0 – 30.0): your company urgently needs to improve these aspects;

Planning: (score range: 31.0 – 45.0): your company needs to address the gaps in its knowledge;

Execution: (score range: 46.0 – 60.0): your company has moderate capability and maturity and scope for improvement;

Monitoring and controlling: (score range: 61.0 – 75.0): your company has high capability and maturity; and

Closing: (score range: 76.0 – 100): your company needs continuous improvement.

It is important to the researcher to confirm whether the assumption mentioned above is applicable/ workable. Sixty five per cent (65%) of the respondents agreed with the researcher regarding the mentioned assumption. The researcher asked the opinion of the respondents who disagreed with that assumption. Those participants suggested changing the project management life cycle process group to maturity level, mentioned in comment no. 3 in section 10.3.2. The researcher found that the suggestion would be more logical and would provide a solid link between the developed framework and assessment tool. Table 14.2 presents the number of respondents who agreed or disagreed with the researcher's assumption.

Table 14.2: Number of respondents who agreed or disagreed with the mentioned assumption

	Strongly agree	Agree	Can't say	Disagree	Strongly disagree	Total respondents
INITIATION (score 20.0-30.0 "a range"): your company urgently needs to improve these aspects	2	10	0	1	2	15
PLANNING (score 31.0-45.0 "a range"): your company needs to address the gaps in its knowledge	2	8	3	1	1	15
EXECUTION (score 46.0-60.0 "a range"): your company has moderate capability and maturity and scope for improvement	0	8	3	3	1	15
MONITORING AND CONTROLLING (score 61.0-75.0 "a range"): your company has high capability and maturity	2	6	3	1	2	14
CLOSING (score 76.0-100 "a range"): your company needs continuous improvement	3	7	1	2	2	15

Question No. 13:
If you were allowed to add a question to improve the assessment, what would it be?

The researcher asked the respondents if they were allowed to add a question to improve the assessment, what it would be. All of them agreed that the provided questions were sufficient to evaluate the maturity level of Lean Construction and they did not suggest any more questions.

Question No. 14:
The researcher assumes that the proposed Lean Construction Assessment Tool can assess the awareness of Lean with construction organisations/projects. Do you agree?

This question asked the participants whether or not they agreed with the researcher that the proposed Lean Construction Assessment Tool could assess the awareness of Lean within construction organisations/projects. A hundred percent (100%) of the participants agreed that the proposed assessment tool could evaluate the maturity level of Lean (See Figure 14.1).

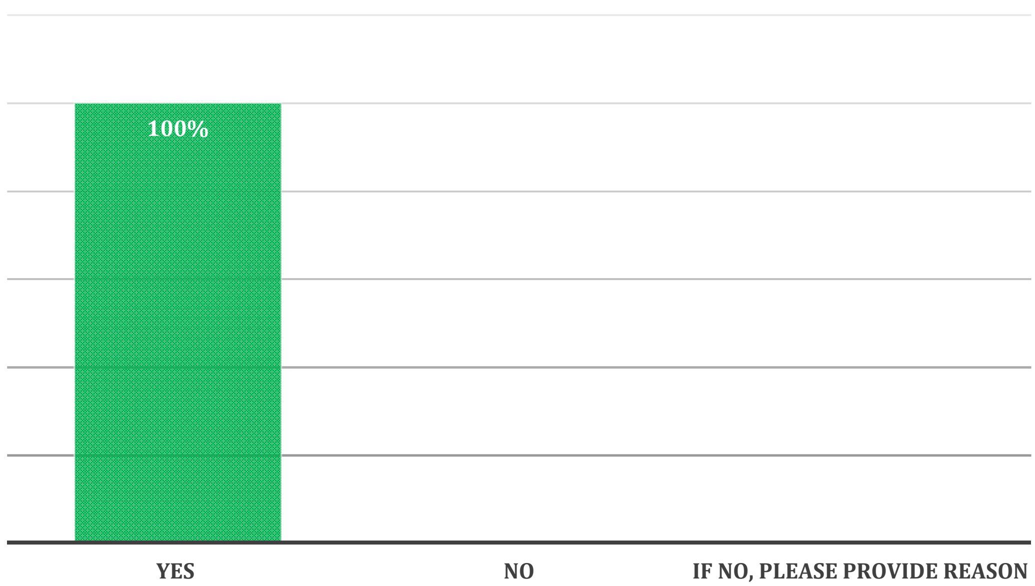

Figure 14.1: Percentage of respondents who agreed that the proposed assessment tool could evaluate the maturity level of Lean

14.3 CONCLUSION OF THE DEVELOPED FRAMEWORK VALIDATION

The validation of the proposed assessment tool was achieved through experts' feedback. Fifteen (15) structured expert interviews were conducted in order to validate the proposed assessment tool. The assessment tool was assessed in terms of general comprehensiveness and level of coverage of its features, as well as the provided 20 questions and proposed answers.

Question No. 15:
Are there any further inputs in the form of suggestions, comments to enhance the proposed Lean Construction Assessment Tool?

The researcher asked the participants to provide further inputs in the form of suggestions and comments to enhance the proposed Lean Construction Assessment Tool. The researcher received only one comment regarding his assumption discussed in question no. 12. At this stage, and after validating the proposed assessment tool, the researcher can confirm that the proposed assessment tool can evaluate the maturity level of Lean within construction companies in KSA. In Chapter Fifteen the researcher will discuss the actual assessment that has been conducted for the organisation managing the selected ongoing Mega-construction project in KSA (action research).

CHAPTER FIFTEEN: CONDUCTED ACTUAL ASSESSMENT

15.1 INTRODUCTION

This chapter presents the assessment tool developed by the researcher based on the reviewed literature (Task 1) and the analysed data from the conducted survey (Task 2). Two different groups have been selected; each group has ten participants for conducting the actual assessment. A basic understanding of the definition of Lean Construction is common among the participants and all of them have a basic knowledge regarding Lean Construction principles. A list of self-assessment questions is presented in Appendix 8 for companies to identify gaps in their Lean implementation efforts, assess the benefits of Lean construction, and focus on areas for improvements. The purpose was to provide a tool for self-assessment of organisations based on Lean Construction principles to achieve continuous improvement of practices.

The actual assessment was conducted in relation to the organisation managing the selected ongoing Mega-construction project in KSA in order to identify the level of maturity of the Lean approach and to review and validate the process of selecting the Lean Construction Assessment Tool. The aim of the assessment approach is to identify the results of the proposed assessment questions, which should clearly reflect the level of Lean awareness of the workers who are involved in the action research.

15.2 ASSESSMENT WORKSHOP

The workshop was the main method of data collection used at this stage of the research. Two workshops have been conducted, one with top management at head office and the other with workers who are involved in the selected ongoing Mega-construction project through a site visit. Twenty (20) key personnel and decision-makers working in the organisation were selected by the researcher to be involved in the action research. These participants were chosen according to the data collected from the conducted survey; the researcher selected different workers in different positions in order to obtain a realistic assessment by evaluating high, medium and low levels of understanding of the Lean Construction method. The first group from the head office included: the CEO, project management office (PMO) director, CEO office manager, senior planning engineer, senior cost engineer, head of civil department, head of electrical department, technical manager, procurement manager, and human resources (HR) manager. The second group of workers involved in the action research consisted of the project manager, construction manager, civil superintendent, mechanical superintendent, electrical superintendent, telecommunications superintendent, quality manager, safety manager, quantity surveyor, and planning manager. Those contributors were selected in order to answer the questions provided in the assessment tool to evaluate the level of Lean Construction maturity in the ongoing Mega-construction project in KSA. Some pictures of the conducted workshop are provided in Appendix 10. Moreover, a sample of a completed form of the actual assessment is shown in Appendix 11.

The researcher created an assessment score sheet (Table 15.1) to collect the answers to all of the questions. A separate section will include questions of a more strategic nature, addressing: 1) the effect of the proposed Lean Construction Assessment Tool on future work opportunities with the construction organisations in KSA; and 2) the linkage between Lean Construction and Risk Management.

The researcher did not feel confident about the validity of the scores, being sure that participants would not display any weaknesses and that they would be guided by management to achieve the highest scores possible. This would lead some participants to maximise scores and defend their stance during assessment.

The researcher took this issue into consideration and thus has developed a proactive step before the official launch of the Lean Assessment Tool. He informed participants, at the beginning of the workshop, that over-inflating a score would confer no advantage and let them know that the assessment of the maturity level would not be reported to the top management and would be used only for this study; the researcher will report the results if all participants agree. Moreover, the assessment results will be confidential, will not be reported to the company's top management and will be used exclusively for study issues.

There is likely to be some scepticism at this stage, because few construction organisations are familiar with the field of Lean in KSA. They should also know that the Lean Construction Assessment Tool aims at enabling the organisation and the project to measure and demonstrate continuous improvement in Lean culture and behaviour. On the other hand, the participants knew neither the score ranges nor the desired level of maturity based on the overall score beforehand. The participants were requested only to answer the 20 questions and the facilitator/researcher evaluated the desired maturity level.

There are several prerequisites necessary for the application of the LCA tool. Collection of project and company information should be carried out beforehand because the respondents need to be well prepared before the proposed two workshops. Both the two workshops, the site visit and the head office visit, should be carried out with twenty participants. The researcher chose two different groups to eliminate bias and facilitate observation. During the two workshops, the evaluation tool should be filled out in order to guarantee better observation and provide a better atmosphere of confidence between the facilitator and participants. Each workshop should last as long as one hour so that the organisation and project can be rated according to the LCA Tool.

15.3 WORKSHOP DESIGN FOR DATA COLLECTION

The researcher informed the participants of the assessment workshop one week in advance. Participants were given two sheets: 1) “Proposed 20 questions” (refer to Appendix 8) to provide them with an explanation of the five choices, which were uncertain, awakening, systematic, integrated, and challenging;and 2) “Answer sheet of the structured questions for testing and conducting the Lean assessment tool” (refer to Appendix 9) to allow them to answer all questions easily. During the site and head office visits, the twenty participants answered the workshop questions on their own. At the same time, the researcher/facilitator based the scoring sheet on the HALMAT scoring sheet to collect all the participants’ answers and to estimate the overall score as well as the desired level of maturity.

15.4 EVALUATION AND OUTCOME OF THE ASSESSMENT TOOL

The scores of the twenty questions were calculated according to both the maximum possible rating points and achieved rating points, and the results were shown on a graph. This enhanced the understanding of current strengths and weaknesses underlying the areas covered by the project. The LCR tool is used to classify the results of the 10 areas (mentioned in Task 4, Chapter13 Section 13.2.2) and recommend an easier classification scheme. The researcher added all achieved scores, and then divided the result by the maximum possible score (100 points, based on the 20 questions). This total percentage identified the assessed maturity level. Moreover, the researcher intends to examine the proposed scoring system, and therefore one question has been added to the structured questions of the interview method discussed in Chapter Ten in this task to get feedback from the selected experts for the assumed scoring system.

The researcher examined the selected twenty participants in order to evaluate the maturity level of Lean within the construction organisation managing the selected ongoing Mega-Construction project in KSA. The overall achieved score was 50.20/100 as shown in Table 15.1. It has been observed that both groups achieved a similar score; the first group from the head office got a score of 49.80/100 and the second group from the site got a score of 50.60/100, showing that the actual assessment conducted for the participants who are working in the action research reflected the desired maturity level of the Lean Construction method.

This meant that the desired maturity level for the organisation was conducted at the execution phase (Level 2), firstly as per the researcher's assumption and the experts' validation; and secondly as per the suggestions of some of the interviewees, according to which the desired maturity level was two (Level Two). In addition, the researcher found that the average score for each area was the same as the overall achieved score; around 50/100, except for the last area, Lean impact (barriers and success factors), which got the highest score (around 68/100). This meant that, during the conducted survey (Task 2) and conducted workshops (Task 4), the workers involved in the action research were by then aware of the benefits and barriers of Lean Construction implementation and that they had developed a good understanding of the impact of Lean. On the other hand, the lowest score was 36.50/100 in the area of Lean Leadership and Structure. This score suggested that the level of commitment among senior leaders and management is variable and that there was little coordination between education and training programmes to facilitate the development of Lean capability and culture. Table 15.2 summarises the average score for each area of the proposed assessment tool.

Table 15.1: Score sheet for the actual assessment for both groups

Area of Coverage	Sub-section	Sub-section Weighting	Section Weighting	Min Score	Max Score	Participants																				Assessed	
						First group										Second group											
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total Score	Average Score
1.0 Lean Policy and Strategy	1.1	5.00%	15%	1.00	5.00	1.00	2.00	2.00	2.00	2.00	2.00	5.00	3.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	51.00	2.55
	1.2	5.00%		1.00	5.00	2.00	2.00	2.00	2.00	2.00	1.00	4.00	4.00	2.00	1.00	3.00	1.00	1.00	2.00	1.00	1.00	2.00	1.00	4.00	4.00	42.00	2.10
	1.3	5.00%		1.00	5.00	4.00	2.00	2.00	1.00	1.00	1.00	3.00	3.00	3.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	2.00	2.00	2.00	4.00	41.00	2.05
2.0 Lean Philosophy	2.1	5.00%	10%	1.00	5.00	5.00	2.00	3.00	2.00	3.00	1.00	3.00	4.00	3.00	3.00	2.00	3.00	3.00	3.00	1.00	4.00	4.00	2.00	4.00	3.00	58.00	2.90
	2.2	5.00%		1.00	5.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	3.00	2.00	2.00	2.00	2.00	1.00	1.00	2.00	1.00	2.00	3.00	2.00	4.00	38.00	1.90
3.0 Lean Leadership and Structure	3.1	5.00%	10%	1.00	5.00	3.00	2.00	2.00	1.00	5.00	1.00	4.00	1.00	2.00	2.00	3.00	1.00	3.00	2.00	1.00	2.00	1.00	2.00	3.00	2.00	43.00	2.15
	3.2	5.00%		1.00	5.00	1.00	1.00	2.00	1.00	4.00	1.00	1.00	1.00	1.00	2.00	4.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.00	1.00	30.00	1.50
4.0 Lean Principles and Drivers	4.1	5.00%	10%	1.00	5.00	3.00	2.00	3.00	2.00	3.00	2.00	4.00	3.00	2.00	2.00	3.00	3.00	4.00	2.00	2.00	3.00	2.00	3.00	3.00	2.00	53.00	2.65
	4.2	5.00%		1.00	5.00	2.00	2.00	2.00	2.00	1.00	3.00	2.00	3.00	3.00	2.00	2.00	2.00	2.00	3.00	2.00	2.00	1.00	3.00	2.00	2.00	43.00	2.15
5.0 Eliminating Waste and Continuous Improvement	5.1	5.00%	15%	1.00	5.00	3.00	2.00	3.00	2.00	3.00	1.00	1.00	2.00	2.00	2.00	4.00	2.00	4.00	4.00	2.00	1.00	1.00	3.00	4.00	4.00	50.00	2.50
	5.2	5.00%		1.00	5.00	2.00	2.00	2.00	2.00	4.00	1.00	1.00	2.00	2.00	4.00	4.00	1.00	4.00	2.00	3.00	2.00	1.00	3.00	4.00	4.00	50.00	2.50
	5.3	5.00%		1.00	5.00	3.00	2.00	4.00	2.00	5.00	5.00	5.00	2.00	3.00	5.00	4.00	1.00	2.00	4.00	1.00	2.00	1.00	2.00	5.00	3.00	61.00	3.05
6.0 Lean Techniques and Tools	6.1	5.00%	10%	1.00	5.00	1.00	2.00	2.00	2.00	1.00	2.00	3.00	2.00	2.00	2.00	3.00	1.00	2.00	1.00	2.00	2.00	1.00	1.00	4.00	4.00	40.00	2.00
	6.2	5.00%		1.00	5.00	2.00	1.00	2.00	2.00	1.00	2.00	2.00	2.00	2.00	2.00	4.00	2.00	3.00	3.00	2.00	2.00	1.00	2.00	4.00	5.00	46.00	2.30
7.0 Delivery of Value	7.1	5.00%	5%	1.00	5.00	3.00	1.00	3.00	2.00	2.00	2.00	5.00	2.00	2.00	5.00	3.00	1.00	4.00	2.00	1.00	3.00	2.00	2.00	2.00	2.00	49.00	2.45
8.0 Built In Quality	8.1	5.00%	5%	1.00	5.00	3.00	2.00	4.00	2.00	4.00	1.00	4.00	2.00	3.00	4.00	1.00	2.00	5.00	3.00	1.00	3.00	1.00	2.00	4.00	2.00	53.00	2.65
9.0 Process Flow	9.1	5.00%	5%	1.00	5.00	2.00	2.00	4.00	1.00	3.00	2.00	5.00	2.00	2.00	4.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	2.00	3.00	3.00	53.00	2.65
10.0 Lean Impact (Barriers and Success Factors)	10.1	5.00%	15%	1.00	5.00	4.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	4.00	4.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	2.00	5.00	3.00	59.00	2.95
	10.2	5.00%		1.00	5.00	3.00	5.00	5.00	3.00	4.00	5.00	5.00	3.00	3.00	4.00	4.00	4.00	5.00	4.00	4.00	5.00	3.00	5.00	5.00	4.00	83.00	4.15
	10.3	5.00%		1.00	5.00	2.00	2.00	4.00	2.00	2.00	4.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	4.00	5.00	4.00	3.00	3.00	61.00	3.05
Weighting Check		100%	100%	*20.00*	*100.00*	*50.00*	*40.00*	*56.00*	*36.00*	*54.00*	*41.00*	*64.00*	*50.00*	*49.00*	*58.00*	*60.00*	*40.00*	*54.00*	*51.00*	*39.00*	*46.00*	*37.00*	*48.00*	*69.00*	*62.00*	*1,004.00*	*50.20*
Overall Score															49.80										50.60		50.20

Table 15.2: Average score for each area covered in the assessment tool

Area of Coverage	Average Score/Area
1.0 Lean Policy and Strategy	44.67
2.0 Lean Philosophy	48.00
3.0 Lean Leadership and Structure	36.50
4.0 Lean Principles and Drivers	48.00
5.0 Eliminating Waste and Continuous Improvement	53.67
6.0 Lean Techniques and Tools	43.00
7.0 Delivery of Value	49.00
8.0 Built-In Quality	53.00
9.0 Process Flow	53.00
10.0 Lean Impact (Barriers and Success Factors)	67.67
Average Score	**50.20**

15.5 CONCLUSION OF THE CONDUCTED ACTUAL ASSESSMENT

The researcher believes that the conducted assessment workshops produced limited results because they should have been applied to the greatest possible number of workers in order to broaden the results gained. But the researcher used this assessment tool to achieve the main objective of this research, which is the development of the Lean Construction framework. The LCA tool should also be promoted because it was recommended that it should be applied three or more times to other construction projects of the same organisation. Nevertheless, the researcher would claim that the proposed assessment tool provides a realistic maturity level for the organisation that the actual assessment has been conducted for, but, based on his experience with those participants and this organisation, also believes that the desired score, which is Level Two, does not reflect the existing situation or the knowledge that those participants have regarding the Lean Construction method. In addition, the researcher believes that if this assessment had been conducted for all the workers in this organisation, the overall score would be less than the achieved one. This conclusion is the result of the discussions held between the researcher and professionals in the construction industry.

SUMMARY OF ASSESSMENT TOOL DEVELOPMENT AND VALIDATION

Task Four consists of Chapters 13, 14 and 15 for presenting the proposed assessment tool.

Chapter 13 proposed an assessment tool to allow construction companies in KSA to assess the maturity level of Lean Construction prior to implementing the Lean Construction method through the developed framework and also at the end of each phase (initiation, planning, execution, monitoring and controlling and closing). The nine steps of Lean Construction Assessment and the ten areas of coverage of the assessment tool are provided. The ten areas have twenty questions to help organisations evaluate the level of awareness of the Lean Construction method among their workers. The researcher has assumed a weighting and scoring system to determine the desired level of maturity for construction organisations.

Chapter 14 discussed the results of the validation of the Lean assessment tool process. In addition, in this chapter, all proposed assumptions and ideas have been validated by questioning experts' opinions through an interview conducted with fifteen professionals. The interviewees agreed that the assessment tool mainly covers issues relating to the implementation of Lean Construction. Overall, the participants confirmed that the assessment tool was useful for measuring the awareness and understanding of Lean implementation within construction organisations in KSA. Only one comment was given by the interviewees regarding the researcher's assumption concerning the weighting score system and the results are considered to be the company's level of Lean Construction awareness through initiation, planning, execution, monitoring and controlling and closing. This comment was already considered in the revised developed framework and transformed to Uncertain/level 0, Awakening/level 1, Systematic/level 2, Integrated/level 3 and Challenging/level 4.

Chapter 15 presented the actual assessment that has been conducted to test and verify the proposed assessment tool. Two workshops have been conducted by twenty participants. The actual assessment ended up by confirming that the proposed assessment tool provides a realistic maturity level for the organisation, but it was recommended that it should be applied more than one time to other construction projects of the same organisation.

FINDINGS, RECOMMENDATIONS AND FURTHER WORK

CHAPTER SIXTEEN: CONCLUSIONS, RECOMMENDATIONS AND FURTHER WORK

This chapter presents the main research findings concerning the objectives of this study. It also provides conclusions and recommendations arising from the research findings and further work. This research study consists of four main tasks, and conclusions and recommendations for each task, as presented below:

16.1 TASK 1: A COMPREHENSIVE LITERATURE REVIEW (CHAPTERS 2-7)

There has been much research conducted on the issues associated with construction projects in KSA. Some have focused on the principles of Lean Construction, and others on the procedures of current implemented methods. This research approaches the Lean Construction technique as a new method that, based on the literature review, the analysis of data collected and the investigation into the ongoing Mega-Construction project chosen as an action research, will maximise project value in comparison to other traditional management methods. At this stage of the research, the researcher has found that the main issue in KSA regarding the implementation of a “new” construction method is the lack of a future strategy plan for the construction industry in KSA in terms of managing waste and risks in general.

The researcher proposes applying the Lean Construction method to Mega-Construction projects in the Middle East to provide an appropriate strategy for these issues. It is believed that the traditional implemented strategies can manage the associated construction issues; however, they are not ideal for Mega-projects. These strategies could benefit from an integrated system to increase efficiency. From research performed thus far, the researcher was able to acquire a first impression of how the application of Lean Construction may affect the construction process, and this is based on an action research on the application of Lean Construction to a chosen, ongoing construction Mega-project in the KSA in which he is professionally involved. The researcher will compare it in further research to the current implemented methods to determine whether Lean Construction will add value to the construction industry, supporting his research with figures and potential cost savings.

After studying the literature and gathering the relevant information, the researcher summarised the main findings of this research as follows:

For the construction waste issue, the current applied method, which is Value Engineering, should be enhanced and applied at an earlier stage of the project. In order to do this, the delivery method should theoretically be changed to allow VE to work well. The researcher assumed that, practically, the type of contract will not change, as was shown in the case study. Thus, VE would still be applied throughout the construction phase, as it currently is by most contractors, but with the integration of Lean Construction to increase the efficiency of managing waste. For the behind-schedule issue, the current implemented method is the Critical Path Method (CPM), which is mostly about controlling what is already happening, i.e. "reactive action". But integrating Last Planner (LP) with CPM will allow a more reliable way to plan works and provide a smoother workflow and a more prompt response to construction project variables, i.e. "proactive action". The researcher views the Lean Construction method as an integrated system that enables a view of most common construction issues all at the same time, notwithstanding the separate action taken for solving each of the issues. In the construction industry, any single issue will most likely lead to another. For example, if waste is increased or the project is not finished on time, then the project's cost will be affected.

The review of literature was commenced during the first stage of the study in Task 1. The literature reviewed was in the area of construction issues and implemented methods (Chapter 2), risk management (Chapter 3), the Lean approach in different industries (Chapter 4), Building Information Modeling (BIM) (Chapter 5), Mega-projects (Chapter 6), and Review of Developed Lean frameworks and assessment tools (Chapter 7). This stage reviewed the concept of Lean and other supported areas to achieve the objectives of this research.

16.2 TASK 2: UNDERSTANDING THE EXISTING SITUATION IN KSA (SURVEY) (CHAPTERS 8 AND 9)

In Task 2 the researcher employed mixed research methods (quantitative and qualitative) in order to understand the situation in the KSA. The second stage of this study employed a quantitative approach involving the use of a questionnaire survey (01) presented to construction professionals representing their organisations. At the same time, a qualitative action research (selected ongoing Mega-Construction project in KSA) approach was employed.

The main findings of the conducted survey 01 in Task 2 are presented below:

1. Fifty per cent (50%) of the respondents indicated some knowledge of Lean Construction, while the other fifty per cent have never heard of this philosophy;
2. Sixty-one (61) participants (82 per cent) agreed with the researcher about choosing KSA as an action research location in which to apply the Lean Construction method;
3. Thirty-six (36%) per cent of the respondents believed that the implementation of Lean Construction would add value by 11-20 per cent;
4. The main critical issues associated with the implementation of Lean Construction in Mega-Construction projects in KSA are lack of awareness and lack of knowledge;
5. Sixty five (65) applicants (88 per cent)confirmed that Lean Construction should be applied in Mega-Construction projects in KSA;
6. Lack of guidance and information, skills shortage, lack of experience of its use, client resistance, risk-averse culture, higher costs and higher capital costs are the barriers to the application of Lean Construction in KSA, according to the participants. The order of the above barriers represents the relative weighting; for example, lack of guidance was seen as the most significant barrier and higher capital cost as the least;
7. Sixty-one (61) participants (82 per cent) agreed that risk management should be linked with Lean Construction;
8. It has been suggested that the output of this research provide a framework/guidance, findings from studying the current situation, and recommendations based on the literature review.

16.3 TASK 3: FRAMEWORK DEVELOPMENT AND VALIDATION (CHAPTERS 10, 11, AND 12)

The development of an innovative framework for the application of Lean principles in the construction industry (Objective 1 in 1.1) was achieved and found to be a useful tool for the application of Lean by the majority of participants.

A framework for Lean Construction implementation efforts has been presented, as well as the integration of risk management, named in Task 3 as the developed framework RV01. The proposed framework comprised eight main Lean Construction implementation groups addressing; (1) Lean philosophy, policy and strategy; (2) Lean leadership and structure; (3) Lean principles and drivers; (4) Lean techniques and tools; (5) Risk management; (6) Built-In Quality and process flow; (7) Delivery of value; and (8) Lean impact (barriers and success factors).

In addition, this task focused on the framework, which was refined and validated by means of structured interviews with three (3) academics and twelve (12) practitioners. The researcher carried out two interviews and conducted an online survey. These two methods were used to test and validate the developed framework and assessment tool by interviewing a number of key engineers and academic staff (15 experts in Lean Construction) working on Mega-Construction projects and at universities in KSA. These 15 participants were selected for the study as follows: four by the owner, four by the consultant, and four by the contractor, as well as another three academics choose by the researcher.

The purpose of the first interview was to provide an introduction to the developed framework and assessment tool and to provide an explanation of the structured questions in the online survey (02). The researcher conducted this survey in order to obtain written comments and quantitative data and to provide the participants with more time to evaluate the developed framework and assessment tool. Moreover, the second interview employed an open discussion between the researcher and the 15 participants to discuss their comments and feedback.

Task 3 presented the conducted process of the validation of the framework. The experts interviewed gave positive comments, such as “The proposed framework is comprehensive and integrates risk management with Lean construction, which, if applied, will improve performance in the construction industry, However, the main barrier that will be faced using this framework is the lack of experienced personnel in most of the organisations to implement such a framework". In addition, it is highly recommended to have an effective training programme to help organisations with the appropriate expertise to enable them to implement such a framework. The researcher received three main suggestions regarding the developed framework, presented below:

1. To provide practical examples for each Lean Construction implementation process (nine processes);
2. To add one more process, which is the continuous improvement aspect, to be considered for each maturity level to ensure the improvement of the implementation of the Lean Construction method within construction organisations. Therefore, the nine Lean implementation processes are: (1) Lean philosophy, policy and strategy; (2) Lean leadership and structure; (3) Lean principles and drivers; (4) Lean techniques and tools; (5) Built-in Quality and process flow; (6) Delivery of value; (7) Lean impact (barriers and success factors); (8) Risk management; and (9) Continuous improvement; and
3. Finally, to change the project management life cycle process group (initiation, planning, execution, monitoring and controlling and closing) into maturity levels (Uncertain/level 0, Awakening/level 1, Systematic/level 2, Integrated/level 3 and Challenging/level 4).

All these suggestions have been considered, and consequently the researcher developed a revised framework, named RV02.

16.4 TASK 4: ASSESSMENT TOOL DEVELOPMENT AND VALIDATION (CHAPTERS 13, 14, AND 15)

The fourth and final stage of the study focused on the assessment tool, which was the driver to achieve two of the main objectives of this research.

The development of an assessment tool for measuring the maturity level of Lean Construction within construction organisations in KSA (Objective 2). In addition, to show the extent to which this approach can minimise the risks involved in Mega-Construction projects in developing countries and in the KSA in particular (Objective 3).

Moreover, this task was focused on refining and validating the assessment tool by using the fifteen (15) participants that were used to validate the developed framework by means of structured interviews with three (3) academics and twelve (12) practitioners.

Task 4 presented the conducted process of the validation of the assessment tool. Fifteen participants (100 per cent) agreed that the proposed Lean Construction Assessment Tool could assess the awareness of Lean in construction organisations/projects. In addition, the experts interviewed also gave positive comments on the overall assessment tool, such as "the proposed assessment tool is really well-designed".

In addition, an assessment tool was employed to allow construction companies in KSA to assess the maturity level of Lean Construction prior to implementing the Lean Construction method through the developed framework and also at the end of each phase (initiation, planning, execution, monitoring and controlling and closing). The nine steps of Lean Construction Assessment and the ten areas of coverage of the assessment tool are provided. The ten areas have twenty questions to help organisations evaluate the level of awareness of the Lean Construction method among their workers.

16.5 ACHIEVEMENTS OF THE STUDY

The main achievement of the research is the development of a framework for assessing the efforts to implement Lean and its benefits in construction organisations in KSA, while linking it to risk management. In addition, an assessment tool was proposed to measure the maturity level of Lean within construction organisations in KSA.

The research developed a complete framework for addressing the implementation of the Lean Construction method integrated with risk management. This framework serves as guidance for implementing the Lean Construction method in construction organisations in KSA. The Lean implementation framework is based on the nine processes of the LCFIRM that have been mentioned earlier, where a set of actions (performance activities) is given to use the developed framework.

17.6 ORDER OF APPLICATION OF THE PROPOSED ASSESSMENT TOOL AND LCFIRM FRAMEWORK IN THE CONSTRUCTION INDUSTRY

At the beginning, the researcher intended to develop a framework to facilitate the adoption of Lean Construction within the construction industry in KSA. After investigating all the relevant factors and practices, and while preparing and developing the framework, he observed that there was a gap in knowledge which needed to be considered and measured. The company will need to assess their own gap in knowledge before adopting or applying the developed framework, and the first step in the developed framework (Assessment Gate 1) is to conduct such an assessment. Therefore, the researcher decided to create an assessment tool to be integrated with the developed framework in order to provide the construction company with a tool to evaluate/assess the maturity level of their workers before implementing the developed framework, in order to start from the desired level.

After the framework and assessment tool were developed, the researcher considered reorganising the structure of this research to start with Assessment Tool Development, followed by Framework Development, because this sequence is obviously more applicable in practice. However, the procedure followed by this research was that the researcher started by deeply investigating all aspects of Lean Construction in order to incorporate them into the developed framework. At the same time, he also aimed to identify any gaps in knowledge that needed to be addressed. The researcher then developed the proposed assessment tool after investigating and developing the framework. The purpose of developing the assessment tool was to fill or bridge the gap in knowledge with regard to the developed framework.

In practice, construction companies implementing or using the output of this research should start with the proposed assessment tool and then implement the developed LCFIRM framework. Nevertheless, the researcher has chosen to adhere to the sequence of procedures that he has followed in this research, in order to illustrate the processes that have been conducted in order to achieve the research outcomes.

16.7 LIMITATIONS OF THE LCFIRM FRAMEWORK AND LCAT

The research attempted to cover all aspects related to the Lean Construction method in the developed framework; however, the limitations of the developed framework can be summarised as follows: 1) The framework acts as a guidance that explains the process of Lean Construction implementation, but does not guarantee the success of construction organisations in KSA. In order to implement the developed framework, the construction organisation needs to adopt the appropriate policy strategy, and thus 2) the researcher did not consider quality and cultural factors, which may be a critical barrier to successful Lean implementation; 3) The researcher validated the developed framework only with professionals working in KSA and involved in infrastructure projects; this approach may be different for another country or another type of project. In addition, 4) the use of equal weights for the question in the proposed assessment tool might vary according to the preference of the user.

16.8 RECOMMENDATIONS AND FURTHER WORK

Further research should be conducted to compare the current traditional methods for dealing with construction waste, behind schedule and project over budget with the Lean Construction techniques.

Regarding the proposed assessment tool, the researcher believes that in order to evaluate it, it should be applied to the greatest possible number of employees in the same organisation in order to obtain a realistic maturity level. In addition, the researcher thinks that in order to evaluate the proposed assessment tool, it should be evaluated by more than one construction organisation, ideally at least three, in order to produce broader results and feedback. This recommendation is the result of discussions held between the researcher and professionals in the construction industry.

As a recommendation for academics and suggestions for future work, further study can be carried out to improve the evaluation of the weights, developing a user graphical interface programme that allows the use of the tool and calculations automatically. In addition, agent-based modelling can be used to model the interactions between the parties in the framework implementation.

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APPENDICES

APPENDIX 1: ETHICAL APPROVAL

University of Salford MANCHESTER

Research, Innovation and Academic Engagement Ethical Approval Panel

Research Centres Support Team
G0.3 Joule House
University of Salford
M5 4WT

T +44(0)161 295 5278

www.salford.ac.uk/

16 November 2015

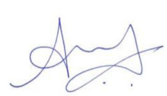
Dear Ahmed,

RE: ETHICS APPLICATION CST 15/48 – Lean Construction as an innovative approach for minimising risks of Mega-Construction projects in developing countries

Based on the information you provided, I am pleased to inform you that your application CST 15/48 has been approved.

If there are any changes to the project and/ or its methodology, please inform the Panel as soon as possible by contacting S&T-ResearchEthics@salford.ac.uk

Yours sincerely,



Prof Mohammed Arif
Chair of the Science & Technology Research Ethics Panel
Professor of Sustainability and Process Management,
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APPENDIX 2: QUESTIONNAIRE SURVEY (01)

University of Salford MANCHESTER

Lean Construction as an innovative approach for minimising risks of Mega-Construction projects in the Kingdom of Saudi Arabia

The principles of Lean Construction

The principles of Lean Construction derive from those of Lean Production, which was developed in the 1960s by Engineer Ohno, whose philosophy was the continuous reduction of waste in all its forms.

The definition of Lean Construction is "a philosophy based on the Lean manufacturing principles. It mainly focuses on the management and improvement of the construction process in order to profitably deliver what the customer needs. Lean Construction, as a philosophy, can be pursued through a number of different approaches" (Constructing Excellence, 2004).

The most important principles are as follows (Constructing Excellence, 2004):

1. Waste elimination.

2. Precise specification of value according to the ultimate customer.

3. Clear identification of the process, delivering what the customer values and eliminating all non-value-adding steps.

4. Don’t make anything until a customer needs it, and then make it quickly.

5. Continuous improvement.

The research focuses on developing an innovative framework to facilitate the use of Lean Construction as an approach for minimising risks of Mega Construction projects in developing countries. The results of the survey will be used in the analysis of the research topic and as a basis for a more successful Lean implementation in KSA.

1

University of Salford MANCHESTER

Lean Construction as an innovative approach for minimising risks of Mega-Construction projects in the Kingdom of Saudi Arabia

Instructions

Dear respondent,

My name is Ahmed Mohamed currently residing in Saudi Arabia. I am a PhD candidate at the University of Salford in the United Kingdom. By profession, I am a Planning and Cost Control Manager at M. M. Al-Harbi Contracting Company. To partially fulfil the requirements of my doctorate, I am conducting a survey to collect data from participants who are working in Saudi Arabia.

In this survey, you will be asked to complete a questionnaire pertaining to the impact of the implementation of the Lean Construction method within your organisation. It will take approximately 5 minutes to complete.

The results of this survey will be shared upon request. These results may help you to evaluate the Lean Construction within your organization and to make strategic decisions relevant to this subject.

The survey is designed to maintain your anonymity and your participation in this survey is completely voluntary. Your survey responses will be kept confidential, and data from this research will be reported only collectively. There are no foreseeable risks associated with this empirical data collection.

If you have questions at any time about the survey or the procedures, you may contact me (Ahmed Mohamed) by emailing me at: A.H.Mohamed@edu.salford.ac.uk.

Thank you very much for your time and support. If you agree to take part in this survey, please fill out the attached form.

Regards,

Ahmed Helmy Mohamed

MSc, BSc, PSP, PME, CPM

2

1. Disclaimer:

By taking part in this survey, the participant agrees to be contacted by the researcher and the University of Salford only if required. The outcome of survey will not be shared with a third party and all findings will be destroyed once the research is deemed complete.

If the participant is in agreement in above statement, he/she should provide their company email for contacting purposes.

Name (Optional) [ ]

Company (Optional) [ ]

Email Address [ ]

2. Title:

[ ]

3. Number of years of experience in the construction industry:

- ◯ < 5 Years
- ◯ 5 to 10 Years
- ◯ 10 to 15 Years
- ◯ > 15 Years

4. Your organisation type:

- ◯ Policy Maker/Government Official
- ◯ Constructor
- ◯ Developer
- ◯ Architect/Engineer
- ◯ Product Manufacturer/Supplier

5. The researcher has chosen a project in the Kingdom of Saudi Arabia as an action research to apply the Lean Construction method. Do you think the lessons learnt from projects in this country can be used as a guide for other countries in the Middle East?

- ◯ Yes
- ◯ No

Please provide a reason for either answer

[ ]

3

6. Have you heard about the Lean philosophy or the Toyota Production System's (TPS) philosophy?

- ◯ Yes
- ◯ No

7. Do you know of any construction company in KSA that applies Lean Construction?

- ◯ Yes
- ◯ No

8. Number of projects applying Lean Construction you have worked on:

- ◯ None
- ◯ 1-3 Projects
- ◯ 4-6 Projects
- ◯ 7-9 Projects
- ◯ > 10 Projects

9. As per your experience in KSA, provide a percentage of the workers that you think are aware of the concept of Lean Construction in KSA:

- ◯ 0%
- ◯ 1-5%
- ◯ 6-10%
- ◯ 11-20%
- ◯ >20%

10. In your opinion, what are the methods that should be implemented to increase awareness of Lean Construction in KSA?

- ☐ Training
- ☐ Motivation
- ☐ Clear instruction
- ☐ Other (please specify)

4

11. Do you think that if Lean Construction were applied in KSA and, specifically, at your company, it would add value?

- ◯ Yes
- ◯ No

12. If Lean Construction is applied at your company, by what percentage do you think it will add value in general?

- ◯ 5-10%
- ◯ 11-20%
- ◯ 21-30%
- ◯ >30%

13. If Lean Construction is applied at your company, by what percentage do you think costs will be reduced?

- ◯ 5-10%
- ◯ 11-20%
- ◯ 21-30%
- ◯ >30%

14. If Lean Construction is applied at your company, by what percentage do you think waste will be reduced?

- ◯ 5-10%
- ◯ 11-20%
- ◯ 21-30%
- ◯ >30%

15. What are the benefits/impact of implementing lean construction in Mega-Construction projects in KSA?

- ☐ Cost reduction
- ☐ Eliminate waste
- ☐ Maximise value
- ☐ All of the above

16. If your organisation has applied Lean Construction, what was the motivation?

[ ]

17. What was the level of satisfaction with the implementation of Lean Construction in your organisation?

[ ]

18. Do you think that Lean Construction needs to be applied to Mega-construction projects in KSA?

- ○ Yes
- ○ No

19. What are the critical issues associated with the implementation of Lean Construction in Mega-Construction projects in KSA?

- ☐ Lack of awareness
- ☐ Cost added
- ☐ Lack of Knowledge
- ☐ Other (please specify)

[ ]

20. What are the barriers to the implementation of lean construction in KSA?

	Strongly Agree	Agree	Can't Say	Disagree	Strongly Disagree
More expensive	○	○	○	○	○
Higher capital cost	○	○	○	○	○
Client resistance	○	○	○	○	○
Lack of guidance and information	○	○	○	○	○
No experience of its use	○	○	○	○	○
Risk averse culture	○	○	○	○	○
Skills shortage	○	○	○	○	○

21. What percentage do you think is the level of use of lean tools and techniques/principles for maximising project value?

- ◯ 5-10%
- ◯ 11-20%
- ◯ 21-30%
- ◯ >30%

22. Do you know any tool/software that will help companies to implement Lean Construction?

- ◯ Yes
- ◯ No
- ◯ Other (please specify)

23. In your view how do Lean Construction techniques compare to conventional methods?

	Significantly more	More	Same	Less	Significantly less
Flexibility in design	◯	◯	◯	◯	◯
Equipment Usage	◯	◯	◯	◯	◯
Rework and site problems	◯	◯	◯	◯	◯
Speed of Construction	◯	◯	◯	◯	◯
Quality	◯	◯	◯	◯	◯
Safety	◯	◯	◯	◯	◯

24. What types of information is available on Lean Construction techniques in KSA?

	Widely Available	Scarcely Available	Not available
Literature Review	◯	◯	◯
Successful case studies/best practices	◯	◯	◯
Technical research reports	◯	◯	◯
Government and legislative sources	◯	◯	◯
General web resources	◯	◯	◯

25. Are there links between Lean Construction and Risk Management?

- ○ Yes
- ○ No

If so, what are they?

[ ]

26. Do you think that Risk Management should be linked to Lean Construction?

- ○ Yes
- ○ No

Please provide a reason for either answer

[ ]

27. What are the benefits of integrating Risk Management and Lean Construction?

[ ]

28. In which way would you prefer to implement Lean Construction?

- ☐ Theoretically, by increasing worker awareness
- ☐ Practically, by applying specific tools
- ☐ Other (please specify)

[ ]

29. What type of output would you prefer to get from the research?

- ☐ Recommendation based on literature review
- ☐ Framework/guidance
- ☐ Findings from studying the current situation
- ☐ Statistics data

30. Comments or Suggestions:

[ ]

APPENDIX 3: EXAMPLE OF COMPLETED SURVEY (01) BY ONE RESPONDENT

Lean Construction as an innovative approach for minimising risks of Mega-Construction projects in the Kingdom of Saudi Arabia — SurveyMonkey

#27

COMPLETE

Collector: Web Link 1 (Web Link)
Started: Tuesday, November 24, 2015 8:09:15 AM
Last Modified: Tuesday, November 24, 2015 8:43:11 AM
Time Spent: 00:33:55
IP Address: 37.126.65.70

PAGE 2: Instructions

Q1: **Disclaimer:By taking part in this survey, the participant agrees to be contacted by the researcher and the University of Salford only if required. The outcome of survey will not be shared with a third party and all findings will be destroyed once the research is deemed complete.If the participant is in agreement in above statement, he/she should provide their company email for contacting purposes.**

Name (Optional)	Hossam Gomoah
Company (Optional)	MMAH
Email Address	hossam.gomoah@gmail.com

Q2: **Title:**	General Manager
Q3: **Number of years of experience in the construction industry:**	> 15 Years
Q4: **Your organisation type:**	Constructor
Q5: **The researcher has chosen a project in the Kingdom of Saudi Arabia as an action research to apply the Lean Construction method. Do you think the lessons learnt from projects in this country can be used as a guide for other countries in the Middle East?**	Yes, Please provide a reason for either answer Kingdom of Saudi Arabia is having a various of mega projects that can be repeated in other countries in addition to different the different nationalities working in kingdom which represents their countries' experiences in this field.
Q6: **Have you heard about the Lean philosophy or the Toyota Production System's (TPS) philosophy?**	Yes
Q7: **Do you know of any construction company in KSA that applies Lean Construction?**	No
Q8: **Number of projects applying Lean Construction you have worked on:**	None
Q9: **As per your experience in KSA, provide a percentage of the workers that you think are aware of the concept of Lean Construction in KSA:**	1-5%
Q10: **In your opinion, what are the methods that should be implemented to increase awareness of Lean Construction in KSA?**	Training, Clear instruction
Q11: **Do you think that if Lean Construction were applied in KSA and, specifically, at your company, it would add value?**	Yes

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Q12: **If Lean Construction is applied at your company, by what percentage do you think it will add value in general?**	11-20%
Q13: **If Lean Construction is applied at your company, by what percentage do you think costs will be reduced?**	11-20%
Q14: **If Lean Construction is applied at your company, by what percentage do you think waste will be reduced?**	>30%
Q15: **What are the benefits/impact of implementing lean construction in Mega-Construction projects in KSA?**	All of the above
Q16: **If your organisation has applied Lean Construction, what was the motivation?**	N/A
Q17: **What was the level of satisfaction with the implementation of Lean Construction in your organisation?**	N/A
Q18: **Do you think that Lean Construction needs to be applied to Mega-construction projects in KSA?**	Yes
Q19: **What are the critical issues associated with the implementation of Lean Construction in Mega-Construction projects in KSA?**	Lack of awareness, Lack of Knowledge

Q20: **What are the barriers to the implementation of lean construction in KSA?**

More expensive	Agree
Higher capital cost	Disagree
Client resistance	Disagree
Lack of guidance and information	Agree
No experience of its use	Strongly Agree
Risk averse culture	Agree
Skills shortage	Disagree

Q21: **What percentage do you think is the level of use of lean tools and techniques/principles for maximising project value?**	5-10%
Q22: **Do you know any tool/software that will help companies to implement Lean Construction?**	No

Q23: **In your view how do Lean Construction techniques compare to conventional methods?**

Flexibility in design	Same
Equipment Usage	Significantly less
Rework and site problems	Significantly less
Speed of Construction	Significantly more
Quality	More
Safety	More

Q24: **What types of information is available on Lean Construction techniques in KSA?**

Literature Review	Not available
Successful case studies/best practices	Not available
Technical research reports	Not available
Government and legislative sources	Not available
General web resources	Scarcely Available

Q25: **Are there links between Lean Construction and Risk Management?**	Yes
Q26: **Do you think that Risk Management should be linked to Lean Construction?**	Yes, Please provide a reason for either answer To use it as a tool to minimize risks and increase value
Q27: **What are the benefits of integrating Risk Management and Lean Construction?**	Minimizing project's risks , reducing waste & costs and increasing value thereafter
Q28: **In which way would you prefer to implement Lean Construction?**	Practically, by applying specific tools
Q29: **What type of output would you prefer to get from the research?**	Framework/guidance, Findings from studying the current situation, Statistics data
Q30: **Comments or Suggestions:**	To provide more comparisons and guidance for more awareness of lean construction.

APPENDIX 4: DEVELOPED FRAMEWORK RV01 – MATRIX FORMAT

The proposed Lean Construction Framework Integrated Integrated with Risk Management [LCFIRM]-Rev01

Lean Construction Implementation Processes	ASSESSMENT GATE	PHASE ONE Initiating Process Group	ASSESSMENT GATE	PHASE TWO Planning Process group	ASSESSMENT GATE	PHASE THREE Executing Process Group	ASSESSMENT GATE	PHASE FOUR Monitoring and Controlling Process Group	ASSESSMENT GATE	PHASE FIVE Closing Process Group	CLOSED GATE
Lean Philosophy, policy and strategy		Adopt the appropriate policy and strategy to be aligned to the organisational strategy plans and philosophy		Select project, team and leader to implement Lean Construction		Follow policy and strategy that have been set		Ensure that the policy and strategy are aligned to the project objectives and organisational strategy goals and philosophy		Solicit feedback from the stakeholder regarding the settled policy and strategy	
Lean leadership and structure		Identify the stakeholders and their expectations regarding the implementation of Lean Construction		Make sure all senior leaders and management are committed to and support the implementation of Lean Construction		Provide leadership, guidance and recognition of positive actions by management		Make sure the adoption of a Lean leadership philosophy is apparent at meetings at all levels throughout the organisation		Create lesson learned	
Lean principles and drivers!		Clearly define the five principles of Lean Thinking !		Create a plan of how to implement the five principles of Lean Thinking !		Ensure that you are driving towards the overall organisational strategy by a constant review of your processes!		Ensure that Lean principles are constantly and consistently delivering value to the customer!		Create user feedback !	
Lean techniques and tools!		Understand Lean Construction tools and their benefits!		Identify Lean Construction practices and methods in order to achieve successful Lean implementation !		Use the Lean Construction tools suitable for your project/organisation and ensure that they will maximise project value !		Measure and evaluate the performance of the project by using Lean Construction tools and compare them to the traditional methods!		Summarise lesson learned!	

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Lean Construction Implementation Processes	ASSESSMENT GATE	*PHASE ONE* Initiating Process Group	ASSESSMENT GATE	*PHASE TWO* Planning Process group	ASSESSMENT GATE	*PHASE THREE* Executing Process Group	ASSESSMENT GATE	*PHASE FOUR* Monitoring and Controlling Process Group	ASSESSMENT GATE	*PHASE FIVE* Closing Process Group	CLOSED GATE
Built-in Quality and process flow		Determine quality processes, standards, and metrics		Create performance measurement plan		Follow processes which are adapted and integrated to complement flow		Perform quality control		Continue collecting user comments for continuous improvement	
Delivery of value		Identify key value steams of major end customers and projects		Ensure performance levels of key processes are understood and initial value stream analysis is under way to identify and deliver improvement to end customer value		Analyse the principle of value stream(s), allowing the identification of critical interaction		Measure Value Stream performance management		Streamline the system using lesson learned	
Lean impact (barriers and success factors)!		Create measurable objectives!		Develop implementation plan and timeline!		Analyse resources or budget for implementing Lean!		Assess the degree to which processes are being designed to encourage flow and balance resources!		Implement new strategies collected from feedback, which can add value and improvement to the system!	
Risk management!		Create risk management plan!		Perform risk analysis and risk response plan!		Perform risk reassessment and audit and update Risk Register!		Control risks and update risk register!		Summarise user feedback!	

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APPENDIX 5: STRUCTURED QUESTIONS FOR VALIDATING AND CONDUCTING THE LEAN ASSESSMENT TOOL – SURVEY 02

Structured Questions for Validating the Lean Construction Framework and Assessment Tool

1. A- Respondent information

Purpose of the interviews:

The interview seeks to validate the developed Lean Construction framework and proposed Lean Construction Assessment Tool, evaluate the benefits of Lean implementation and assess the level of awareness of Lean within construction firms.

The structure of the interview questions consists of three sections:
A- Respondent information [1-4]
B- Validation of the Developed framework [5-10]
C- Validation of the proposed Lean Construction Assessment Tool [11-15]

1. Job title:

☐

2. Background:

☐ Academic

☐ Industrial

☐ Both

3. Organisation:

☐

4. Area of proficiency (if academic staff):

☐

1

Structured Questions for Validating the Lean Construction Framework and Assessment Tool

2. B- Validation of the developed framework

5. Evaluation of the proposed framework:

	Very low	Low	High	Very high
What is your overall rating of the proposed framework in terms of its overall content?	○	○	○	○
What is your overall opinion of the level of understanding of the proposed framework?	○	○	○	○
What is your opinion of the selected 8 (Lean Construction Implementation groups) areas provided (Lean policy and strategy, Lean philosophy, etc) in terms of the level of coverage and understanding?	○	○	○	○
In your view, how would you describe the level of coherence in terms of the overall logic of the process (e.g. flow of necessary steps to be taken in implementing Lean Construction method?)	○	○	○	○

6. Would you recommend the framework for use within the construction companies?

- ☐ Yes
- ☐ No
- ☐ Please provide reasons for both answers

7. Which of the obstacles/barriers mentioned below could the proposed framework overcome?

- ☐ Client resistance
- ☐ Higher capital cost
- ☐ More expensive
- ☐ Risk averse culture
- ☐ Skills shortage
- ☐ No experience of its purpose
- ☐ Lack of guidance and information
- ☐ All of the above
- ☐ None of the above

8. Do you think the developed framework will add value to construction projects?

	Strongly Agree	Agree	Can't Say	Disagree	Strongly Disagree
Cost reduction	○	○	○	○	○
Waste elimination	○	○	○	○	○
Maximisation of value	○	○	○	○	○
Flexibility in design	○	○	○	○	○
Rework and site problems	○	○	○	○	○
Speed of Construction	○	○	○	○	○
Quality	○	○	○	○	○
Safety	○	○	○	○	○

9. Do you think the proposed framework is easy to use/implement for construction projects?

- ☐ Yes
- ☐ No
- ☐ If No, please provide reason

10. Please provide a brief comment and your constructive criticism on the framework provided.

Structured Questions for Validating the Lean Construction Framework and Assessment Tool

3. C- Validation of the proposed Lean Construction Assessment Tool

11. Evaluation of the proposed assessment tool:

	Very low	Low	High	Very high
What is your overall opinion of the level of coverage of the proposed Lean assessment tool in terms of its overall content?	○	○	○	○
What is your opinion of the selected 10 areas provided (Lean policy and strategy, Lean philosophy, etc) in terms of the level of uptake and understanding?	○	○	○	○
What is your opinion of the 20 questions provided?	○	○	○	○
With what degree of efficiency do the provided maturity levels explain each of the proposed answers?	○	○	○	○

12. Do you think that the assumption mentioned below is applicable/workable?

The researcher has assumed a weighting score system such that the minimum score for each question is 1.0 and the maximum is 5.0 whereby results are based on the overall score of the ten categories of the assessment. The results are considered to be the company's level of Lean Construction awareness; this is represented as a score between 20 and 100. It is assumed that the score range represents each level of maturity.

	Strongly Agree	Agree	Can't Say	Disagree	Strongly Disagree
INITIATION (score range: 20.0 - 30.0): your company urgently needs to improve these aspects	◯	◯	◯	◯	◯
Please provide reasons for your answer					
PLANNING (score range: 31.0 - 45.0): your company needs to address the gaps in its knowledge	◯	◯	◯	◯	◯
Please provide reasons for your answer					
EXECUTION (score range: 46.0 - 60.0): your company has moderate capability and maturity and scope for improvement	◯	◯	◯	◯	◯
Please provide reasons for your answer					
MONITORING AND CONTROLLING (score range: 61.0 - 75.0): your company has high capability and maturity	◯	◯	◯	◯	◯
Please provide reasons for your answer					
CLOSING (score range: 76.0 - 100): your company needs continuous improvement	◯	◯	◯	◯	◯
Please provide reasons for your answer					

13. If you were allowed to add a question to improve the assessment, what would it be?

14. The researcher assumed that the proposed Lean Construction Assessment Tool can assess the awareness of Lean with construction organisations/projects. Do you agree?

- Yes
- No
- If no, please provide a reason.

15. Are there any further inputs in the form of suggestions, comments to enhance the proposed Lean Construction Assessment Tool?

APPENDIX 6: EXAMPLE OF COMPLETED SHEET FROM SURVEY 02

Structured Questions for Validating the Lean Construction Framework and Assessment Tool — SurveyMonkey

#15

COMPLETE

Collector: Web Link 1 (Web Link)
Started: Tuesday, June 28, 2016 4:20:16 AM
Last Modified: Sunday, July 17, 2016 4:06:06 AM
Time Spent: Over a week
IP Address: 197.41.157.194

PAGE 1: A- Respondent information

Q1: **Job title:**	Professor
Q2: **Background:**	Academic
Q3: **Organisation:**	Mansoura University
Q4: **Area of proficiency (if academic staff):**	Construction Management

PAGE 2: B- Validation of the developed framework

Q5: **Evaluation of the proposed framework:**

What is your overall ratingof the proposed framework in terms of its overall content?	High
What is your overall opinion of the level of understanding of the proposed framework?	High
What is your opinion of the selected 8(Lean Construction Implementation groups) areas provided (Lean policy and strategy, Lean philosophy, etc) in terms of the level of coverage and understanding?	High
In your view, how would you describe the level of coherence in terms of the overall logic of the process (e.g. flow of necessary steps to be taken in implementing LeanConstruction method?)	Very high

Q6: **Would you recommend the framework for use within the construction companies?**

Yes,

Please provide reasons for both answers
The frame work if used is expected to improve the industry in terms of reducing risks and minimizing waste and accordingly minimizing time and cost.

Q7: **Which of the obstacles/barriers mentioned below could the proposed framework overcome?**

Skills shortage, No experience of its purpose ,

Lack of guidance and information

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Q8: Do you thinkthe developed framework will add value to construction projects?

Cost reduction	Strongly Agree
Waste elimination	Strongly Agree
Maximisation of value	Agree
Flexibility in design	Agree
Rework and site problems	Agree
Speed of Construction	Agree
Quality	Agree
Safety	Strongly Agree

Q9: **Do you think the proposed framework is easy to use/implement for construction projects?**	Yes
Q10: **Please provide a brief comment and your constructive criticism on the framework provided.**	The proposed framework is comprehensive and integrates risk management with lean construction which if applied will improve the performance in the construction industry, However, the main barrier that will be faced using this framework is the lack of experienced personnel in most of the organizations to implement such framework. As such, it is highly recommended to have an effective training program to help organizations having the appropriate expertise to enable them implementing such framework.

PAGE 3: C- Validation of the proposed Lean Construction Assessment Tool

Q11: Evaluation of the proposed assessment tool:

What is your overall opinion of the level of coverageof the proposed Lean assessment tool in terms of its overall content?	Very high
What is your opinion of the selected 10 areas provided (Lean policy and strategy,Lean philosophy, etc) in terms of the level of uptake and understanding?	Very high
What is your opinion of the 20 questions provided?	High
With what degree of efficiency do the provided maturity levels explain each of the proposed answers?	Very high

Q12: **Do you think that the assumption mentioned below is applicable/workable?The researcher has assumed a weighting score system such that the minimum score for each question is 1.0 and the maximum is 5.0 whereby results are based on the overall score of the ten categories of the assessment. The results are considered to be the company's level of Lean Construction awareness; this is represented as a score between 20 and 100. It is assumed that the score range represents each level of maturity.**

INITIATION (score range: 20.0 - 30.0): your company urgently needs to improve these aspects	Disagree
Comment:	It is not clear for me why do you use a scale range from 20-30 in this stage and this scale range is changed from stage to stage? Why do not you use a separate scale for each stage from 0-100 as you are measuring the company maturity level of the company? My question in another format, why do you link the maturity level with the project phases, namely "Initiating, executing, etc"?
PLANNING (score range: 31.0 - 45.0): your company needs to address the gaps in its knowledge	Disagree
Comment:	Same as before
EXECUTION (score range: 46.0 - 60.0): your company has moderate capability and maturity and scope for improvement	Disagree
Comment:	Same as before
MONITORING AND CONTROLLING (score range: 61.0 - 75.0): your company has high capability and maturity	Disagree
Comment:	Same as before
CLOSING (score range: 76.0 - 100): your company needs continuous improvement	Disagree
Comment:	Same as before

Q13: **If you wereallowed to add a question to improve the assessment, what would it be?**	The questions are comprehensive.
Q14: **The researcher assumed that the proposed Lean Construction Assessment Tool can assess the awareness of Lean with construction organisations/projects. Do you agree?**	Yes
Q15: **Are there any further inputs in the form of suggestions, comments to enhance the proposed Lean Construction Assessment Tool?**	the proposed framework a assessment tool are really well designed, however, i am bit confused of assessing the maturity level as I described in my question above in 12? This might need some clarification.

APPENDIX 7: DEVELOPED FRAMEWORK RV02 – MATRIX FORMAT

The proposed Lean Construction Framework Integrated with Risk Management [LCFIRM]-Rev02

Lean Construction Implementation Processes	ASSESSMENT GATE	*LEVEL 0* UNCERTAIN	ASSESSMENT GATE	*LEVEL 1* AWAKENING	ASSESSMENT GATE	*LEVEL 2* SYSTEMATIC	ASSESSMENT GATE	*LEVEL 3* INTEGRATED	ASSESSMENT GATE	*LEVEL 4* CHALLENGING	CLOSING PHASE / NEW STRATEGY GATE
Lean Philosophy, policy and strategy		Adopt the appropriate policy and strategy to be aligned to the organisational strategy plans and philosophy		Select project, team and leader to implement Lean Construction		Follow policy and strategy that have been set		Ensure that the policy and strategy are aligned to the project objectives and organisational strategy goals and philosophy		Make sure strategic and business plans are clear; operational and commercial targets to be realised through Lean activity in order to achieve growth and profitability and improve market position	
Lean leadership and structure		Identify the stakeholders and their expectations regarding the implementation of Lean Construction		Make sure all senior leaders and management are committed to and support the implementation of Lean Construction		Provide leadership, guidance and recognition of positive actions by management		Make sure the adoption of a Lean leadership philosophy is apparent at meetings at all levels throughout the organisation		Make certain that senior leaders and management mentor and foster Lean champions internally and throughout the supply chain	
Lean principles and drivers!		Clearly define the five principles of Lean Thinking !		Create a plan of how to implement the five principles of Lean Thinking !		Ensure that you are driving towards the overall organisational strategy by a constant review of your processes!		Ensure that Lean principles are constantly and consistently delivering value to the customer!		Take action necessary for Lean policies and process-based orientation to be aligned across the overall organisation processes.!	
Lean techniques and tools!		Understand Lean Construction tools and their benefits!		Identify Lean Construction practices and methods in order to achieve successful Lean implementation !		Use the Lean Construction tools suitable for your project/organisation and ensure that they will maximise project value !		Measure and evaluate the performance of the project by using Lean Construction tools and compare them to the traditional methods!		Use professional Lean tools for planning all activities-not just design and construction. All team members, including subcontractors, require planning and commitments to be based on Lean tools!	

Lean Construction Implementation Processes	ASSESSMENT GATE	*LEVEL 0* UNCERTAIN	ASSESSMENT GATE	*LEVEL 1* AWAKENING	ASSESSMENT GATE	*LEVEL 2* SYSTEMATIC	ASSESSMENT GATE	*LEVEL 3* INTEGRATED	ASSESSMENT GATE	*LEVEL 4* CHALLENGING	CLOSING PHASE / NEW STRATEGY GATE
Built-in Quality and process flow		Determine quality processes, standards, and metrics		Create performance measurement plan		Follow processes which are adapted and integrated to complement flow		Perform quality control		Undertake Standardised Work and 5S throughout the site	
Delivery of value		Identify key value steams of major end customers and projects		Ensure performance levels of key processes are understood and initial value stream analysis is under way to identify and deliver improvement to end customer value		Analyse the principle of value stream(s), allowing the identification of critical interaction		Measure Value Stream performance management		Continually improve process flow throughout all value streams (internal and through the supply chain), in time with actual demand, with distance travelled and inventory/buffer levels minimised	
Lean impact (barriers and success factors)!		Create measurable objectives!		Develop implementation plan and timeline!		Analyse resources or budget for implementing Lean!		Assess the degree to which processes are being designed to encourage flow and balance resources!		Ensure that cost savings, waste elimination and value maximisation are more efficient with the application of Lean Constructions than with that of conventional methods!	
Risk management!		Create risk management plan!		Perform risk analysis and risk response plan!		Perform risk reassessment and audit and update Risk Register!		Control risks and update risk register!		Implement and follow Risk Analysis and Management for Project (RAMP)!	
Continuous Improvement		Solicit feedback from the stakeholder regarding the settled policy and strategy		Create lesson learned		Create user feedback		Summarise lesson learned		Implement new strategies collected from feedback, which can add value and improvement to the system	

APPENDIX 8: PROPOSED ASSESSMENT TOOL

Lean Construction Assessment Tool

Maturity Level	*Uncertain* Level 0	*Awakening* Level 1	*Systematic* Level 2	*Integrated* Level 3	*Challenging* Level 4
1) Lean policy and strategy					
1.1 Does the organisation have integrated Lean Construction principles as part of the strategic plan?	Lean is not considered to be appropriate for achieving business performance improvement within the organisation.	Lean is recognised as appropriate for lower levels of the organisation.	The potential benefits of the widespread use of Lean are recognised and understood by the senior management team.	The development of Lean is incorporated as an integral part of the business strategy and its supply chain management.	Strategic and business plans include clear operational and commercial targets to be realised through Lean activity in order to achieve growth and profitability and improved market position.
1.2 Does the organisation demonstrate a long-term plan for adopting the deployment of an effective Lean Construction process?	There has been little evidence of a formal approach to business performance improvement or the training of staff in Lean methodologies.	The organisation has endorsed a business improvement approach but its methodology is not clearly defined and deployment is inconsistent.	A business improvement approach with a clear operating methodology has been adopted and formalised within the business management and quality systems.	All teams throughout the organisation currently operate an effective suite of Quality Cost and Delivery (QCD) performance measures and local targets.	All team throughout the supply chain currently operate a disciplined, effective Quality Cost and Delivery (QCD) performance management system to secure delivery of local performance targets and understanding of how these targets relate to top-level business aspirations.
1.3 Does the organisation have clear Lean policy deployment?	There is no policy integrated with the overall organisation policy.	The organisation understands Lean policy deployment, but it is not clearly defined.	The Lean policy has been adopted and defined in organisation policy but it is not followed properly.	All the teams understand Lean policy and it is a part of overall organisation policy.	The Lean management process aligns both vertically and horizontally with the organisation's functions and activities and with its strategic objectives.

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Maturity Level	*Uncertain* Level 0	*Awakening* Level 1	*Systematic* Level 2	*Integrated* Level 3	*Challenging* Level 4
2) Lean philosophy					
2.1 Does the organisation have the ultimate goal of providing perfect value to the customer through a perfect value creation process that has zero waste?	The method of identifying what the customer considers to be of value is unstructured and informal.	There is a structured process for defining value applied to selected customers.	There is a well-defined process for identifying how the organisation can best contribute to customer satisfaction.	The definition of customer value is well understood and is a major influence on the direction of the business and strategic plans.	Competitiveness is enhanced as customer value drives become a significant driving force throughout the supply chain.
2.2 Does the organisation have a management philosophy based on the Toyota Production System?	TPS is not considered in the organisation policy.	A few participants understand TPS and how to implement it.	Some supervisors use TPS, but on an ad hoc basis.	TPS is starting to be used as a basis for organisation management policy.	All participants understand and use TPS. Training and knowledge of the relevant management philosophy is necessary before any work is begun.
3) Lean leadership and structure					
3.1Do all senior leaders and management within the organisation willingly embrace the concept of Lean and support a transition to Lean culture?	Level of commitment among senior leaders and management is variable – some endorse Lean, while others may actively resist it.	All senior leaders and management are committed to implementing Lean principles.	Senior leaders and management are championing the transformation to Lean within the organisation.	Senior leaders and management personally and visibly lead the transition to Lean. Adopting a Lean leadership philosophy is apparent at meetings at all levels of the organisation.	Senior leaders and management mentor and foster Lean champions internally and throughout the supply chain.
3.2 Has the personnel department (HR) taken appropriate steps to ensure that suitable Lean skills are available within the organisation?	There is little coordination between education and training programmes to facilitate the development of Lean capability and culture.	Education and training is made available, covering basic Lean awareness and some operational improvement tools and techniques to support the organisation's planned Lean projects.	An education and training programme has been designed and deployed covering Lean leadership, use of the organisation's Lean Approach and the basic improvement tools and techniques to support the organisation's strategy for Lean transformation.	Education and training at all levels, and in the supply chain, is periodically reviewed against the current gap between actual and target performance measures, and developed to improve alignment to, and effectiveness in, supporting the organisation's business.	Education and training links directly with strategic plans, with budget and scope determined directly by business performance improvement needs.

Maturity Level	*Uncertain* Level 0	*Awakening* Level 1	*Systematic* Level 2	*Integrated* Level 3	*Challenging* Level 4
4) Lean principles and drives					
4.1 Have the organisation and its policies and processes been revised to promote, encourage and support Lean behaviour?	The organisation does not include Lean principles and processes in the overall organisation policy.	Initial efforts are under way to identify Lean principles and understand their full implications.	Partially deployed Lean processes are aligned with the organisation's processes.	Extensive Lean processes are implement across the organisation.	Lean policies and process-based orientation are aligned across the overall organisation processes. Team structure, skills and resource levels, processes, performance measures and targets are derived directly from value stream requirements.
4.2 What is the percentage of the organisation workers who are aware of the concept of Lean Construction and its principles?	0%	1-5%	6-10%	11-15%	>20%
5) Eliminating waste and continuous improvement					
5.1 Does the organisation use processes for eliminating waste?	Few participants understand waste or know how to identify and eliminate it.	The types of waste are sometimes taught to team members, some waste control/management processes are conducted.	Waste is eliminated in significant areas, and stories are spread about Lean processes which have been achieved.	Waste reduction is an ongoing part of work. New and current projects can demonstrate waste reduction and elimination in various areas.	All participants practise waste elimination and prevention in project activities.
5.2 Has the organisation defined waste and its various types?	No	Yes, but only material waste is considered.	Waste is identified and the produced waste is managed randomly.	Waste is identified and managed according to the organisation plan.	Savings and efficiencies are obvious from ongoing and integrated work to eliminate waste.
5.3 Is there a central information area showing up-to-date KPIs that can be used to drive continuous improvement?	Some awareness of KPIs and continuous improvement.	Some connection with continuous improvement and improving processes.	Connects continuous improvement with improving internal processes.	Connects continuous improvement with all process improvements.	Effective KPIs criteria for managing all the organisation projects in order to lead continuous improvement.

Maturity Level	*Uncertain* Level 0	*Awakening* Level 1	*Systematic* Level 2	*Integrated* Level 3	*Challenging* Level 4
6) Lean techniques and tools					
6.1Does the organisation apply Lean tools?	Lack of knowledge regarding Lean tools.	Some limited knowledge or practice of Lean tools.	Some team members have participated in the use of Lean tools.	Make Work Ready Schedules and Weekly Work Plans are the focus of weekly work planning meetings. Lean tools are integrated in organisational process assessments. All participants utilise Lean tools during the project's life cycle.	Team and management professionally use Lean tools for planning all activities – not just design and construction. All team members, including subcontractors, require planning and commitments to be based on Lean tools.
6.2What level of use in percentage terms is there of Lean tools and techniques/principles for maximising project value?	0%	5-10%	11-20%	21-30%	>30%
7) Delivery of value					
7.1Is the performance of the organisation's key value streams evaluated and is improvement of this performance actively managed?	There is little understanding of the need to map and analyse the organisation's main processes and business streams.	The performance levels of key processes are understood and initial value stream analysis is under way to identify, prioritise and deliver improvement to end customer value.	The relative extent to which each key value stream influences the delivery of customer value and economic performance for the organisation is understood	Depth and breadth of knowledge of value stream analysis and supporting processes exposes interdependencies across the organisation. Value stream mapping is used tactically to address performance improvement opportunities.	The ongoing performance of value streams and their interdependencies is evaluated and managed across the organisation and its supply chains.
8) Built-in quality					
8.1Do the organisation projects have processes for implementing Built-in Quality?	Some employees on site have a basic understanding of Built-in Quality.	Employees have some knowledge of Built-in Quality and good Supervisors are using Standardised Work and 5S.	Several areas on site have good work practices, such as Standardised Work, 5S and boundary samples, so workers can tell what the required specification for the job is.	All crews have a good understanding of Built-in Quality and are working to minimise rework.	Receiving Inspection does sample testing on robust parts delivered. Standardised Work and 5S are undertaken throughout the site.

Maturity Level	*Uncertain* Level 0	*Awakening* Level 1	*Systematic* Level 2	*Integrated* Level 3	*Challenging* Level 4
9) Process flow					
9.1 Are processes planned and designed along value streams, aligning demand to customer pull with flow and minimum waste in all aspects of delivery, design, construction, and maintenance?	Flow between processes is disjointed. Individual processes are rarely adapted to suit flow, and inventory/buffer levels are periodically changed.	A few key processes are aligned for flow and stability is improved to reduce inventory/buffer levels. Individual activity processes are partially adapted to suit flow.	Key processes within value streams are ordered to enhance flow and reduce inventory/buffer levels.	A majority of internal, and a few external, processes are adapted to enhance value stream flow and minimise distance travelled, inventory/buffer levels or time delay. Most processes are adapted and integrated to complement flow.	Process flow throughout all value streams (internal and through the supply chain) is continuous, in time with actual demand, with distance travelled and inventory/buffer levels minimised.
10) Lean impact [barriers and success factors]					
10.1 Does the organisation understand the benefits of implementing the Lean Construction method?	No	Yes but it is not the organisation's budget	The benefits of applying Lean Construction are understood and initial value stream analysis is under way to identify, prioritise and deliver improvement to end customer value.	Depth and breadth of knowledge of the Lean Construction method and supporting processes reveals interdependencies across the organisation.	The Lean Construction method is used effectively to deliver step changes in performance as opportunities are identified.
10.2 In your view, how do Lean Construction techniques compare to conventional methods?	Conventional methods serve projects more than Lean.	Same	Lean construction is better than conventional methods, but Lean is more costly.	Savings and efficiencies are quantifiable by applying Lean.	Cost savings and waste elimination and value maximisations are more efficient with the application of Lean Construction than with that of conventional methods.
10.3 What is the extent of the barriers hindering the implementation of Lean Construction in the organisation?	Extremely high	High	Medium	Low	None

APPENDIX 9: ANSWER SHEET FOR ACTUAL ASSESSMENT

Lean Construction Assessment Tool - Actual Assessment

Introduction

Dear participants,

This workshop is being carried out to investigate the extent of the awareness of Lean Construction method among construction workers in your project and organization. The results of the assessment model will be used in the analysis of the Lean Construction implementation and as a basis for a more successful lean implementation in KSA. Please answer the questions freely.

1. Name (Optional)

2. Position

3. Lean Construction Assessment Model

	Uncertain	Awakening	Systematic	Integrated	Challenging
1.1 Does the company have integrated Lean Construction principles as part of the strategic plan?	○	○	○	○	○
1.2 Does your organisation demonstrate a long term plan for adopting the deployment of an effective Lean Construction process?	○	○	○	○	○
1.3 Does your company have a clear Lean policy deployment?	○	○	○	○	○
2.1 Does your company have the ultimate goal of providing perfect value to the customer through a perfect value creation process that has zero waste?	○	○	○	○	○
2.2 Does your company have a management philosophy based on the "Toyota Production System"?	○	○	○	○	○

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	Uncertain	Awakening	Systematic	Integrated	Challenging
3.1 Do all senior leaders and management within the organisation willingly embrace the concept of Lean and support a transition to Lean culture?	○	○	○	○	○
3.2 Has the personnel department taken appropriate steps to ensure that suitable Lean skills are available within the organisation?	○	○	○	○	○
4.1 Have the organisation and its policies and processes been revised to promote, encourage and support Lean behaviour?	○	○	○	○	○
4.2 What is the percentage of your company workers who are aware of the concept of Lean Construction and its principles?	○	○	○	○	○
5.1 Does your company use processes for eliminating waste?	○	○	○	○	○
5.2 Has your company defined waste and its various types?	○	○	○	○	○
5.3 Is there a central information area showing up-to-date KPIs that can be used to drive continuous improvement?	○	○	○	○	○
6.1 Does your company apply Lean tools?	○	○	○	○	○
6.2 What level of use in percentage terms is there of Lean tools and techniques/principles for maximising project value?	○	○	○	○	○
7.1 Is the performance of the organisation's key value streams evaluated and is improvement of this performance actively managed?	○	○	○	○	○

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	Uncertain	Awakening	Systematic	Integrated	Challenging
8.1 Do your company projects have processes for implementing Built-in Quality?	○	○	○	○	○
9.1 Are processes planned and designed along value streams, aligning demand to customer pull with flow and minimum waste in all aspects of delivery, design, construction, and maintenance?	○	○	○	○	○
10.1 Does your company understand the benefits of implementing the Lean Construction method?	○	○	○	○	○
10.2 In your view, how do Lean Construction techniques compare to conventional methods?	○	○	○	○	○
10.3 What is the extent of the barriers hindering the implementation of Lean Construction in your company?	○	○	○	○	○

4. Comments or Suggestions:

APPENDIX 10: PICTURES OF THE CONDUCTED WORKSHOP

APPENDIX 11: SAMPLE OF COMPLETED FORM OF THE ACTUAL ASSESSMENT

Lean Construction Assessment Tool - Actual Assessment

Introduction

Dear participants,

This workshop is being carried out to investigate the extent of the awareness of Lean Construction method among construction workers in your project and organization. The results of the assessment model will be used in the analysis of the Lean Construction implementation and as a basis for a more successful lean implementation in KSA. Please answer the questions freely.

1. Name (Optional)

GALAL SAMEIR

2. Position

PROJECT MANAGER

3. Lean Construction Assessment Model

	Uncertain	Awakening	Systematic	Integrated	Challenging
1.1 Does the company have integrated Lean Construction principles as part of the strategic plan?	○	○	●	○	○
1.2 Does your organisation demonstrate a long term plan for adopting the deployment of an effective Lean Construction process?	○	○	●	○	○
1.3 Does your company have a clear Lean policy deployment?	○	●	○	○	○
2.1 Does your company have the ultimate goal of providing perfect value to the customer through a perfect value creation process that has zero waste?	○	●	○	○	○
2.2 Does your company have a management philosophy based on the "Toyota Production System"?	○	●	○	○	○

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	Uncertain	Awakening	Systematic	Integrated	Challenging
3.1 Do all senior leaders and management within the organisation willingly embrace the concept of Lean and support a transition to Lean culture?	○	○	●	○	○
3.2 Has the personnel department taken appropriate steps to ensure that suitable Lean skills are available within the organisation?	○	○	○	●	○
4.1 Have the organisation and its policies and processes been revised to promote, encourage and support Lean behaviour?	○	○	●	○	○
4.2 What is the percentage of your company workers who are aware of the concept of Lean Construction and its principles?	○	●	○	○	○
5.1 Does your company use processes for eliminating waste?	○	○	○	●	○
5.2 Has your company defined waste and its various types?	○	○	○	●	○
5.3 Is there a central information area showing up-to-date KPIs that can be used to drive continuous improvement?	○	○	○	●	○
6.1 Does your company apply Lean tools?	○	○	●	○	○
6.2 What level of use in percentage terms is there of Lean tools and techniques/principles for maximising project value?	○	○	○	●	○
7.1 Is the performance of the organisation's key value streams evaluated and is improvement of this performance actively managed?	○	○	●	○	○

	Uncertain	Awakening	Systematic	Integrated	Challenging
8.1 Do your company projects have processes for implementing Built-in Quality?	●	○	○	○	○
9.1 Are processes planned and designed along value streams, aligning demand to customer pull with flow and minimum waste in all aspects of delivery, design, construction, and maintenance?	○	○	●	○	○
10.1 Does your company understand the benefits of implementing the Lean Construction method?	○	○	●	○	○
10.2 In your view, how do Lean Construction techniques compare to conventional methods?	○	○	○	●	○
10.3 What is the extent of the barriers hindering the implementation of Lean Construction in your company?	○	○	●	○	○

4. Comments or Suggestions:

1. IT IS NATURAL FOR ANY NEW PHILOSOPHY TO HAVE INITIAL REJECTION AND SIDE EFFECT. THEREFORE, TRAININGS & GOVERNED RULES IS REQUIRED TO ENSURE SUCCESS.

2- THE RESEARCHER HAVE TO MENTION THE COMPARISON BETWEEN LEAN CONSTRUCTION METHOD AND OTHER TRADITIONAL METHOD.