A FRAMEWORK FOR LEAN IMPLEMENTATION IN INFRASTRUCTURE CONSTRUCTION IN THE UK

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Declaration

This thesis is presented as an original contribution based on Doctorate of Philosophy research at University of Salford, Salford, United Kingdom and has not been previously submitted to meet requirements for an award at any higher education institution under my name or that of any other individuals. To the best of my knowledge and belief, the thesis contains no materials previously published or written by another person except where due reference is made.

……………………………… (Signed)

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Abbreviations

Tools and Techniques	Definition
3Cs	Concern, Cause and Countermeasures
5Ps	Product, Price, Place, Promotion, And People
5S	Sort, Straighten, And Shine, Standardise, Sustain, And Safety
ACA	Association of Consultant Architects
BIM	Building Information Modelling
BRCF)	Benefits Realisation Capture Form
CP	Collaborative Planning
CP5	Control Period 5
CPIF	Cost-Plus Incentive Fee
CPM	Critical Path Method
DfT	The Department for Transport
DMAICT	Define, Measure, Analyse, Improve, Control, and Transfer
ECI	Early contract involvement
EVA	Earned Value Analysis
FMEA	Failure Mode and Effect Analysis
FPIF	Fixed Price Incentive Fee
HA	Highways Agency
HALMAT	Highways Agency Lean Maturity Assessment Tool
HE	Highways England
HELMA	Highways England Lean Maturity Assessment
ICE	Institute of Civil Engineers
IMPV	International Motor Vehicle Program
IPA	Infrastructure and Project Authority
JCT	Joint Contracts Tribunal
JIT	Just-In-Time
KTP	Knowledge Transfer Packs

LC	Lean Construction
LCI	Lean Construction Institute
LCT	Lean Construction Theory
LEA	Lean Enterprise Architecture
LM	Lean Manufacturing
LPDS	Lean Project Delivery System
LPS	Last Planner System
LT	Lean Thinking
LTDP	Lean Thinking Development Plan
LVM	Lean Visual Management
MBO	Management by Objectives
NEC	New Engineering Contracts
NHS	National Health Service
NR	Network Rail
OPR	Owner's Project Requirement
PDCA	Plan – Do – Check – Act
PERT	Program Evaluation Review Technique
PM	Project Management
PPC	Percentage Promised Completed
RIS	Road Investment Strategy
RNC	Reason for Non-Completion
SAS	Statistical Analysis Software
SIPOC	Suppliers, Inputs, Process, Outputs, Customers
SMEs	Small and Medium-sized Enterprises
SPSS	Statistical Package for the Social Sciences
TfL	Transport for London
TFV	Transformation, Flow, Value
TIES	Transport Infrastructure Efficiency Strategy
TIMWOODS	Transport, Inventory, Motion, Waiting, Over production, Over processing, Defect, Skills
TIP	Transforming Infrastructure Performance
TPS	Toyota Production System
TQM	Total Quality Management

TRIZ	Theory of Inventive Problem Solving
UK	United Kingdom
UKICI	United Kingdom Infrastructure Construction Industry
VM	Visual Management
VMS	Visual Management System
VSM	Value Stream Mapping
WORMPIT	Waiting, Over Production, Rejects, Motion, Processing, Inventory, and Transportation

Abstract

The UK government is keen to have a world class modern transport infrastructure operational in the UK that will provide opportunities for regeneration and enable the nation to be competitive in the global market. Modern transport infrastructure is the economic backbone of many first world nations. The UK government has plans to increase spending on infrastructure that will rival any spending in the sector since the 1970s (IPA, 2017). A five-year, £135.3bn investment is planned to be spent on transport infrastructure between 2017 and 2026. The stakes are high, and therefore, there is a need for increased efficiency and effectiveness in the pre, during and post construction process. The industry is now vehemently pushing for the adoption of Lean construction to guide the allocation of resources and the execution of the works on budget, time and at an appropriate quality (IPA, 2017). Lean has brought about many benefits in manufacturing, such as; increased customer engagement, increased customer satisfaction, time and cost savings, and enhanced quality (Aziz et al., 2016). Lean construction, therefore, will bring about an effective system to generate the kind of efficiency savings desired within infrastructure construction. However, for optimum efficiency, the project team and the entire supply-chain must be committed to the Lean process. There has to be a full management buy-in, and commitment. The supply-chain also has to be fully motivated to achieve the desired efficiency targets. Many Lean implementation frameworks have been provided for use in the construction industry, but none have successfully incorporated the necessary elements that will drive motivation and commitment on the part of top management, project teams, and the supply-chain. It is imperative that the Lean initiative is beneficial for everybody involved. Therefore, this research set out to develop a framework to drive motivation and ensure commitment from project stakeholders in Lean implementations within infrastructure construction. Using purposive sampling, semi-structured interviews were conducted with 27 Lean managers and practitioners in the infrastructure sector for which rich and informative responses were received satisfying many of the study's queries on Lean implementation in infrastructure construction. The research found that the nature of contracts determines the level of motivation and commitment given to any Lean initiative. Furthermore, it was found that leadership, aligned with the objectives of the supply-chain and that of the client, including collaborative planning, monitoring and control, performance evaluation, and rewarding and incentivising of good performance make for a successful implementation of Lean within infrastructure projects.

1 CHAPTER ONE| INTRODUCTION

1.1 Introduction

Transport infrastructure is the backbone of economic growth in the UK as it connects people and allows businesses to thrive. The modernisation of its transport infrastructure has become a pivotal keynote strategy of the UK government with investments trebling in 2018 (DfT, 2017). In the fourth quarter of 2017, the government created the Transport Infrastructure Efficiency Taskforce to promote best practice in procurement; this group is responsible for implementing the *Transforming Infrastructure Performance (TIP)* programme and the *Transport Infrastructure Efficiency Strategy (TIES)* (The Construction Index, 2018). The *Transport Infrastructure Efficiency Strategy (TIES)* pledges to boost efficiency and productivity in the construction industry with a focus on offsite construction, prefabrication, and whole-life-costing (DfT, 2017). According to the DfT (2017), the TIES and Construction Sector Deal, "aims to achieve a 33% reduction in whole life costs, a 50% reduction in project time, a 50% reduction in carbon emissions and a 50% reduction in the trade gap from built assets by 2025." To deliver these efficiency targets, the Department for Transport, Highways England, Crossrail, HS2 Ltd, Network Rail, and TfL will rely on the capabilities of digitalisation and Lean manufacturing methods through the support of the construction supply chain. However, the UK construction industry has come under criticism regarding the inefficiencies that are pervasive throughout the construction process. Sir Michael Latham's report, *Constructing the Team* (1994), Sir John Egan's report, *Rethinking Construction* (1998), and Wolstenholme report, *Never Waste a Good Crisis* (2009), have all documented, in detail, the industry's inefficiencies and suggested Lean Construction as a solution the industry can use to move towards for strategic improvement (Koskela, 2000; Koskela et al., 2002).

This chapter of the thesis presents an introduction to the thesis including the background to the research, the scope and limitations of the study, the research problem and justification, the aim and objectives, which are critically presented and argued. The chapter also summarises the study's contribution to knowledge and closes with a structure of the entire thesis. Within this research the term "infrastructure construction" will be synonymous with that of "transport infrastructure construction."

1.2 Background of Lean Manufacturing

Lean Thinking originated from manufacturing, and specifically in the automotive industry. Henry Ford pioneered a Lean production process that integrated work and conveyance, known as the flow process. This process was later adopted and modified by the founders of Toyota (Taiichi Ohno and Kiichiro Toyoda) who then invented the Toyota Production System (TPS). The overall objective of Lean is the elimination of waste in process activities, and the improvement in quality and efficiency. According to Womack and Jones (2003) and Liker (2004), waste in Lean includes overproduction, waiting, transportation, over-processing, inventory, movement, defective products, and waste of unused employee creativity. In succinct terms, Lean is doing more with fewer resources, which leads to better value for the customer. Lean manufacturing involves a relentless effort to eliminate or reduce waste (which is any non-value adding activity), in design, development, production, distribution, and customer service processes (Koskela, 2000; Salem & Zimmer, 2005).

1.3 Lean Implementation in Construction

Koskela (1992) was among the first authors to create a Lean philosophy for the construction industry, better known as Lean Construction. The construction industry is characterised as a fragmented supply chain, that is slow to change with a temporal production system (one-of-a-kind production) that is replete with unforeseen and uncontrolled parameters, that generates waste from the design stage to the production stage (Koskela et al, 2013; Tezel et al, 2017). Latham (1994) and Egan (1998) exposed the inefficiencies and waste generated by the construction industry in the UK and since then, Lean Thinking implementation in the construction process has been advocated by many researchers (Ballard & Howell, 1998; Green & May, 2005; Koskela, 2000, 1992), which drove the proposition of several Lean implementation frameworks to facilitate industry adoption, including prominent examples such as the Transformation, Flow, and Value theory developed by Koskela (1992) and the Last Planner System developed by LPS developed by Ballard (1994). Despite the availability of these frameworks, not only is the industry’s rate of Lean adoption slow, the frameworks do not drive a sustained level of motivation and commitment from the stakeholders to ensure Lean Thinking throughout the project life cycle – from inception to completion.

Koskela integrated three scientific theories of production to produce the transformation, flow, value (TFV) theory of production (Koskela, 2000). Table 1.1 shows the Transformation, Flow, and Value views. Each view focuses on a different aspect of production in order to efficiently and effectively finish a product that adds value to customer experience. Koskela et al. (2002) states:

> *A Lean project delivery system (Lean Construction) is one that is structured, controlled, and improved in the simultaneous pursuit of the three goals of transformation, flow and value.*

Table 1.1: Integrated TFV theory of Production

	Transformation View	**Flow View**	**Value Generation View**
Conceptualisation of Production	As in transformation of inputs into outputs	As a flow of materials composed of transformation, inspection, moving and waiting	As a process where value for the customer is created through the fulfilment of his/her requirements
Main Principle	Getting production realised efficiently	Elimination of waste (non-value adding activities)	Elimination of value loss (achieved value in relation to best possible value)
Methods and Practices	Work break down structure, MRP, organisational responsibility charts	Continuous flow, pull production control, continuous improvement	Methods for requirement capture, quality function deployment
Practical Contribution	Taking care of what has to be done	Making sure that unnecessary things are done as little as possible	Taking care that customer requirements are met in the best possible manner
Suggested Name of Practical Application of The View	Task management	Flow management	Value management

Source: Koskela (2000)

Construction adopted Lean after recognising the success of Lean in the manufacturing industry. Like manufacturing, the construction process involves the sequencing of works to produce a finished product, therefore, Lean adoption and applications was possible. Lean was adopted due to conventional project management (PM) techniques, such as Critical

Path Method (CPM), PERT schedules, Earned Value Analysis (EVA) etc., have proven to be inadequate in eliminating the inefficiencies of the construction industry. According to Koskela et al (2002), project management "practices attempts to manage activities by centrally applied scheduling and to control them using output measures" whilst ignoring the value-creation workflow. Lean Project Delivery, on the other hand, involves the inter-phasing of projects and production systems for the purpose of project control. Hence, it is perfectly transferable to construction projects, including capital projects. Lean has been acknowledged in the construction sector as it significantly improves the efficiency and management of project delivery (Ballard & Howell, 2003; Garrett & Lee, 2011; Paez et al., 2005).

The UK industry saw a significant performance improvement benefit from adopting Lean construction owing to the effective and strategic elimination of waste in the construction process (Sage et al., 2012). A plethora of research has been carried out, which established a new perception and the effective functional implementation of Lean Thinking (LT) within the construction industry (Aziz et al., 2016; Koskela et al., 2002; Picchi, 2004). However, the application of Lean in construction has faced many barriers and challenges, which requires substantial research (Howell, 1999). The construction industry is slow to change, and resistance to Lean implementation is experienced from both construction clients and industry practitioners (Pasquire & Connolly, 2002). If the benefit of Lean is to be realised in construction, the benefits have to be clear, visible, and attainable (Pasquire & Connolly, 2002). In the last 20 years, several Lean implementation frameworks have been proposed in the construction industry (Ballard & Howell, 2003; Chick, 2013; Hines et al., 2004). Their purpose is to serve as roadmaps or guidelines for construction organisations to follow to successfully implement Lean principles in their work processes or production sequence. Some frameworks are plain and generic (Åhlström, 1998; Ballard & Howell, 2003; Beck, 1999; Chick, 2013; Hilbert, 1998; Hines et al., 2004; Mathaisel, 2005; Mostafa et al., 2013; Kowalski, 1996; Shingo, 1989) while others are specific to the construction process (Aziz et al, 2016; Ballard, 2000a; Bassioni, 2004; Harbour, 2012; Kasiramkumar & Indhu, 2016; Pasquire & Gibb, 2002; Wright, 2015) focus on addressing and measuring the benefits that can be achieved from Lean implementation.

1.4 Justification for the Study

In the last decade, the infrastructure and project authority (IPA), the Department for Transport (DfT), alongside transport organisations, such as Highways England (HE), Network Rail (NR), Crossrail, High Speed Two Ltd (HS2 Ltd), and Transport for London, (TfL) have become determined to develop a world class modern transport infrastructure that would be operational in the UK as soon as possible to ensure there is good infrastructure, which opens opportunities for regeneration and new housing development, and enables the nation to be competitive in the international market place. Modern transport infrastructure is the economic backbone of many first world nations. Hence, since 2015, the UK government has increased infrastructure spending by 50% (IPA, 2017). According to the IPA (2017), this increase in transport investment will birth the biggest modernisation of the country's transport network since the 1970s. A five year, £135.3bn investment is planned for spending on transport infrastructure between 2017 and 2026. The stakes are high, and therefore, there is a need for the industry to push for the adoption of Lean construction to guide the allocation and execution of works on budget, time and at the best possible quality (IPA, 2017). Consequently, implementing Lean in transport infrastructure, would deliver better road and rail networks for less money with significantly increased stakeholder benefits, such as increased engagement, customer satisfaction, time, and cost savings, while enhancing quality (Aziz et al., 2016).

Although there is an increase in infrastructure investment, the government is pushing the idea of cost savings in all transport organisations. It is therefore imperative that cost saving measures and efficiency models, such as Lean manufacturing principles, are implemented on infrastructure projects. The cost saving benefits of Lean Construction have already materialised with some infrastructure companies; for example, Crossrail opened in 2018, with a £1bn saving. Other companies have made substantial commitments to deliver efficiency savings. Highways England (HE) alone has made a commitment of about £1.2bn of efficiency savings in their Road Investment Strategy (RIS), for the period of 2015-2020 (DfT, 2017; HE, 2017a), and has reported substantial project cost savings of up to £80 million, as a direct result of Lean deployment within its supply-chain, generating a 70% increase in plan reliability and a 30% reduction in project time (Pasquire et al., 2015). Network Rail (NR) has committed to £2.3bn efficiency savings by 2019 with Control Period 5 (CP5); furthermore, in 2016, Transport for London (TfL) committed to £4bn of efficiency savings through a new operating model, improved procurement and renegotiated contracts. To achieve these planned savings, an effective management system needs to be introduced and competently applied on infrastructure projects.

Lean Construction is currently the most effective system to generate these kind of efficiency savings in the infrastructure industry. To achieve this savings target, not only has Lean Construction to be mastered by the project teams of infrastructure Tier 1 construction companies and all the stakeholders, but their entire supply-chain has to be committed to the efficiency target as well. For example, 90% of HE's contract is executed by its supply chain, which means they will generate the efficiency savings. In other words, the cost savings target can be achieved only if there is buy-in, with full commitment on the part of the supply-chain and are fully motivated to achieving the target. Consequently, in 2014, HE committed £5bn to deploy Lean construction principles within its supply chain, and specifically, to develop a collaborative delivery framework to support the supply chain's development in Lean Construction (HE, 2015). The Department for Transport and infrastructure Tier 1 contractors are working closely to deploy Lean Construction principles within their supply chain as there is a lack of Lean competence and/or a lack of staff able to drive the Lean initiative.

The Lean implementation frameworks for infrastructure construction focus on techniques, such as collaborative planning and programming (to be discussed in the next chapter) for successful Lean implementation but fail to incorporate the necessary elements that will drive motivation and commitment on the part of the project teams (client, general contractor and sub-contractors, employees, consultants – architects, engineers, quantity surveyors, Lean practitioners and so on) to implement Lean practices. The frameworks within the literature of Lean infrastructure construction have focused on the implementation of Lean principles and the benefits derived from Lean; however, they have not addressed implementation issues, such as the lack of commitment and motivation. Without buy-in and support from everyone involved in the project, especially the supply chain, the frameworks will fail to realise the benefits from Lean implementation. The benefits of Lean should not be exclusive to the final product (and hence, the client) alone; it should be for all parties involved. In order to attain optimum efficiency, the desires and aspirations of the supply chain as well as other project stakeholders must also be realised.

1.5 Research Aim

The aim of this research is to review how Lean production principles are applied within the UK construction industry with specific focus on UK infrastructure construction identifying current best practice together with the current drivers and barriers to its successful implementation to inform the development of an improved Lean implementation process framework.

1.6 Research Objectives

The following specific objectives have been formulated in order to achieve the aim of this research:

- To critically review Lean Production and Lean Construction practices globally and with specific focus on the UK infrastructure construction industry.
- To evaluate current Lean implementation best practice frameworks that can be applied to processes within the UK infrastructure construction industry.
- To review and evaluate the barriers and challenges, benefits and drivers, and current industry best practice for implementing Lean in the UK infrastructure construction industry.
- To develop a framework for the implementation of Lean in the infrastructure construction industry.
- To present the framework for validation to finalise the framework.

1.7 Scope of the Research

This research focuses on Lean Thinking implementation factors in the UK transport infrastructure construction industry. The research focuses on infrastructure projects undertaken through Lean Construction from inception to completion. This research seeks to develop a framework for Lean implementation in infrastructure construction. In this research, the considered method is limited to respondents' perceptions of Lean Thinking and Lean Construction as well as a robust review of the literature. However, Lean

Construction and Lean Thinking concepts are not considered in isolation, as the theories and business models from other industries influence them. Therefore, this study will introduce other theories and business models that complement Lean.

1.8 Research Overview

The design of this research is of a qualitative approach to satisfy its primary aim and objectives. The researcher commenced with a search of the literature to review the existing studies on Lean Production and Lean Construction worldwide. This led the researcher to gain knowledge of the current condition in the Construction Industry in the UK, identifying the research problems. Furthermore, the researcher established the research aim and objectives. Based on the aim and objectives, a detailed literature review was undertaken to understand the concept of Lean Production and Lean Construction practices globally and with a focus on the UK infrastructure construction industry. The literature review promoted the researcher in ascertaining existing Lean implementation frameworks and obtaining knowledge on challenges, benefits, drivers of Lean implementation in the construction industry. This further led the researcher to use a qualitative approach for collecting and analysing data. The data was gathered from a total of 27 semi-structured interviews with participants selected for their engagement and involvement with Lean Construction. This enabled the researcher to scrutinise the knowledge and experience of professionals who have first-hand experience of Lean Construction in the UK infrastructure construction industry. The interview transcripts were organised and analysed systematically.

The findings from this research were used to develop a framework for Lean Construction implementation in the UK infrastructure construction industry. Finally, the developed framework was validated through interviews with experts. A detailed discussion on the research methodology is provided in Chapter four of this thesis.

1.9 Structure of the Thesis

Chapter 1 highlighted the background of the research, including the justification, research aim and objectives, and contribution to knowledge. The chapter also outlined an overview of the scope of this research, followed by a brief overview of the structure of the thesis. Chapter 2 presents an overview of the literature considerations for this research, which includes a general discussion on Lean principles and techniques, along with the benefits, challenges and barriers of implementation, Lean construction, and specifically Lean within infrastructure Construction. This is followed by a review of Lean Construction approaches, tools and techniques. Chapter 3 provides an overview of the existing Lean implementation frameworks in literature. Chapter 4 gives an outline for the methodology adopted to achieve the aim and objectives of this research that also meets the requirements of the research aims and objectives. The chapter discusses; the research philosophies, approaches, choices, strategies and techniques, sample selection, data collection and analysis. Chapter 5 presents a qualitative analysis and a discussion of the data collected. Chapter 6 provides the framework development, which is followed by Chapter 7, namely the framework validation. Finally, Chapter 8 provides the conclusions and recommendations to the study.

2 CHAPTER TWO| LEAN MANUFACTURING AND LEAN CONSTRUCTION

2.1 Introduction

The UK construction industry has been subject to various strategic improvements over the last couple of decades and particularly since the recession of 2007. Moreover, authors, such as Latham (1994), Egan (1998), Green and May, (2005) and Wolstenholme (2009), have identified 'best practice' to promote true and lasting change in the construction industry, and one such best practice initiative is 'Lean Construction'. In recent years, Lean has garnered widespread popularity in the construction sector, as it has proved very successful in the manufacturing industry. Sage et al. (2012) assert that the implementation of Lean Construction yields substantial increases in performance. Moreover, Lean Manufacturing (LM) is depicted as the process of waste elimination, with emphasis on the whole value stream and pursuit of excellence (Koskela, 2000; Salem & Zimmer, 2005); indeed, Lean principles and Lean Thinking (LT) have been adopted in various fields of the automotive industry and yielded commendable results (Howell & Ballard, 1998).

Although there are contradictions between the manufacturing and construction sectors, the LT approach developed by Koskela (Koskela, 1992; Koskela et al., 2002) provided a fundamental step towards the creation of a Lean philosophy within construction organisations. Koskela's theory of 'transformation, flow, and value' in production seeks to create value to the end-user. Furthermore, the Lean Thinking Development Plan (LTDP) was adapted to the construction industry; its purpose was to improve companies' financial and economic situations, enhance productivity, and improve the delivery of projects to clients whilst gathering capable team workers for project delivery (Alarcon, 1997).

LT applies to the entire supply chain and manages the operations as per the client's requirements and the company's processes and procedures. Egan (1998) affirms that this encourages firms to generate credible business and develop sustainable construction, which can be enhanced by a partnering approach. LT is therefore an effective philosophy as it focuses on the achievement of project excellence and comprises advanced approaches and vigorous implementation methods. Koskela (2002) recommended that, through the adoption of Lean production systems, the manufacturing process demands a review from the perspective of the client. This advocates that employees identify added-value and non-added-value activities in the process; hence, the requirements could be outlined at all stages of a project through the concept of value management (Koskela, 1992).

The construction sector is plagued with supply chain deficiencies, high defect rates, wasted labour and materials, cost overruns, inefficiencies, mistakes, delays and poor communication (Koskela et al., 2002). In recent years, due to waste and a lack of efficiency in the construction sector, the needs of construction enterprises have focused on increasing their performances. Although construction organisations have been adopting innovative procurement strategies within their project processes, management first needs to be improved by generating and sustaining innovative approaches to maximise financial profitability. Thus, LT has been applied to construction projects to examine their design and construction processes. Egan (1998) states that the construction sector can develop by eliminating waste through the adoption of LT; this promotes a robust and uniform range of operational systems to eradicate waste and deliver dynamic sustainable developments, project value and productivity (Koskela, 1992). Ballard et al. (2003) believe that construction production systems can be improved through the application of LT concepts and tools; they affirm that such systems can be designed to specific goals by providing value, reducing waste, increasing throughput, reducing cycle times, reducing supply chain losses, reducing construction costs and shortening project delivery schedules.

This chapter presents a literature review on Lean Thinking in its original production pattern. The main principles of the Lean manufacturing system and Toyota Production System will be explained in detail. Subsequently, the following will be analysed: types of waste, Lean manufacturing techniques, Lean Construction, and the Lean infrastructure practices currently adopted in the infrastructure construction industry. In addition, the value of Lean Construction is explained to provide an understanding of current best practice in the UK industry.

2.2 History of Lean Thinking

Lean thinking (LT) originally came from the automotive manufacturing industry (specifically the Toyota Automotive company, which was the pioneer of Lean) and is perceived as an innovative approach to production management. After World War II, Japanese manufacturers encountered a number of difficulties in the lack of capital, material and people, which gave rise to the foundation of Lean manufacturing systems; this involved the elimination and reduction of waste by minimising working hours, resources, materials and labour. In the mid 1940's Toyota noticed that American auto manufacturers were outproducing their Japanese counterparts to a factor of ten. Japanese business leaders, Shigeo Shingo and Taiichi Ohno, formulated a different, systematic, process-based concept for development, which is now referred to as Toyota Production System (TPS) or Lean Manufacturing (Namrouty & AbuShaaban, 2013). Lean manufacturing was developed by Toyota and guided by Taiichi Ohno to increase the productivity in Toyota, whilst the term 'Lean' was coined by the study group who undertook research on the universal automotive manufacturing to investigate waste elimination within the Toyota Production System (TPS) and to compare it with mass and craft forms of production (Womack et al., 1991). The engineer, Ohno, refocused attention from craft production to employee productivity, and from mass production by machine to the entire manufacturing system. Ohno followed the example of Henry Ford and continued the development of flow-based production management (Howell, 1999). However, Ford had achieved a near limitless demand for a typical product whilst Ohno strived to build cars to client order. Ohno endeavoured to minimise the machine set up time to develop practical targets for the production plan in order to meet clients' needs in a timely manner without creating waste in the operation (Howell, 1999).

TPS was developed and advanced between 1945 and 1970 and has continued to improve worldwide (Liker, 2004). By the 1980s, products in the sector were charged at a lower price, although clients demanded better quality. Hobbs (2004) noted that, whilst some manufacturers started to become more competitive through greater diligence others struggled to survive. Khatri et al. (2011) mentioned that, in order to compete within the industry, American manufacturers had to adapt their traditional mass productions systems to accommodate different variations of TPS as Japanese firms produced, developed and delivered products with 50% less labour effort, finance, time, materials, workspace and total cost (Namrouty & AbuShaaban, 2013).

At first, industry practitioners tried to duplicate the Toyota production process (Gao & Low, 2014) as they believed it was the source of Toyota's competitive edge. This led to many organisations and researchers developing their own production principles. One such variation was Koskela's (1992) 11 principles, which aimed to: reduce the share of non-value-adding activities (also called waste); increase the output value through a systematic consideration of customer requirements; reduce variability; reduce cycle time; simplify the process by minimising the number of steps, parts and linkages; increase the output flexibility; increase the transparency of the process; focus control on the complete process; build continuous improvement into the process; balance flow improvements with conversion improvements; and benchmark. Koskela et al. (2002) asserted that, although Lean is depicted and implemented at a certain level, it is considered a design system. This is due to the manufacturing and production practices that eliminate waste in the process, minimise operation times, and aim to generate maximum value for the client.

Although Gao and Low (2014) argue that these production principles focus on the process rather than the value for the client, Liker (2004) and Womack & Jones (1996) argue that adopting some of the Lean principles can promote enhanced performances. However, focusing on the whole system to provide maximum value to the client is the best approach to assure the maximum benefit. To provide this value, resources are maximised, and waste is eliminated in the production process (Paez et al., 2004).

2.2.1 Value and Waste

At Toyota, eliminating muda (waste) is key to the production system. Liker (2004) and Womack & Jones (2003) understand waste as, "anything that absorbs resources but creates no value".

Koskela's (1992, 2000) 'flow view' of production places the elimination of non-value-adding activities at its core, which leads to the creation of a perfect product (value) to the customer (Hines et al., 2004). Eliminating waste is the main philosophy of the Toyota Production System, for which seven wasteful activities were identified, namely: (1) overproduction, (2) waiting, (3) transportation, (4) over processing, (5) inventory, (6) movement and (7) defective products (Ohno, 1988). These are often referred to under the acronym 'TIMWOOD' (Skhmot, 2017). However, Liker (2004) added one more waste activity, 'the waste of unused employee creativity'; according to Liker (2004), this results in "losing time, ideas, skills, improvements, and learning opportunities by not engaging or listening to employees". Although not at the helm of management decision-making, employees also have ideas and, as they are based on the 'shop floor' operating the system, they can provide helpful inputs on how to improve the production line and eliminate waste. They see the system and can offer ideas on ways to make production faster, cheaper, safer, and more efficient, and thus are significant contributors to Lean. Liker (2004) emphasised that, by capitalising on employees' creativity, companies can eliminate the other seven wastes. The following, is a detailed list of the aforementioned eight TPS wastes:

1. ***Transport*****:** Waste in transportation comprises the excessive movement of tools, inventory, people, equipment or materials. A product's unnecessary movement may result in defects, inessential operations and exhaustion (Skhmot, 2017; Wahab et al., 2013). In the office, the team members who collaborate with one another must often work closely, whilst in the factory, the required products for manufacturing must be easily accessible in the manufacturing site and the double or triple handling of materials must be avoided (Skhmot, 2017). There are some countermeasures to transportation waste, which include the generation of flow among the processes, the creation of a U-shape production line, and the avoidance of over-production in process (WIP) products.

2. ***Inventory*****:** Most of the time it is difficult to consider excessive inventory as waste. In accounting, inventory is perceived as an asset and suppliers of bulk purchases usually offer discounts. However, having a greater inventory than that required to maintain a continual work flow may cause defects, longer lead times in the manufacturing process, the inefficient allocation of capital, and the concealment of issues (Skhmot, 2017; Wahab et al., 2013). An excess inventory may arise from producing more items than the client requires, overproducing the work in progress (WIP) or over-purchasing. An excessive inventory inhibits the detection of production-related issues as defects have time to accumulate before exposure, which leads to further work to correct the defects. In an office inventory, waste may include clients waiting for a service, files waiting to be dealt with, and the presence of obsolete files or unused records in a database. Manufacturing inventory waste may comprise more finished items than needed, finished items that cannot be sold, damaged machines, and additional materials that take up work space (Skhmot, 2017). The inventory countermeasures comprise: Procuring raw materials only when necessary and in accordance with the required amount, minimising buffers

among the production phases, and developing a queue system to avoid overproduction.

3. ***Motion***: Waste in motion comprises any unnecessary movement of individuals, machinery or equipment, such as lifting, walking, moving, stretching, bending and reaching. Activities that need excessive motion must be restructured to increase employees' work and to improve health and safety standards. In an office, wasted motion may include reaching to obtain materials, seeking files, walking, sifting through an inventory to identify the required items, double data entry and unnecessary mouse clicking (Skhmot, 2017; Wahab et al., 2013). Manufacturing motion waste may comprise repetitive movements that do not add value to the client; the modification of components after installation; and the reach for materials. Various countermeasures for motion include a well-organised workplace, the positioning of equipment close to the production line, and the placement of materials at an ergonomic location to minimise straining and stretching.

4. ***Waiting*:** Waiting waste is categorised into two groups, namely: people waiting on material or equipment, and idle equipment. A wait period usually occurs due to unevenness in the production line and may result in excessive inventory (Skhmot, 2017; Wahab et al., 2013). In the office, waste might mean waiting for a computer to install software, inefficient meetings, waiting for e-mail responses, or waiting for files to be reviewed. Within manufacturing, waste could include waiting for the arrival of materials, inadequate equipment, and waiting for formal instructions to commence manufacturing (Skhmot, 2017). Various countermeasures for waiting include planning processes to ensure a continual flow; levelling out the workload with standardised work instructions; and developing flexible multi-talented employees who are able to promptly meet the client's requirements.

5. ***Overproduction*:** Overproduction arises when manufacturing an item or a component prior to the client's request. It may seem practical to produce more products than requested when there is an idle worker or equipment time (Skhmot, 2017; Wahab et al., 2013); however, producing items only when required, the 'Just in Case' approach causes many issues, such as averting a steady work flow, increasing storage costs, hiding defects inside the WIP, creating excessive lead-

times, and generating unnecessary capital expenditure to fund production processes (Skhmot, 2017). Furthermore, overproduction may result in an increase in the production of products beyond the client's needs. In the office, overproduction may mean excessive copies, writing reports that no one reads, providing a service before the client is ready and providing unnecessary information (Skhmot, 2017). Manufacturing overproduction may generate more products than requested through a 'push production system', or producing items in higher batch sizes than required. The countermeasures for overproduction are: Using a 'Takt Time' to ensure that the proportion of manufacturing among stations are uniform; reducing setup times to enable manufacturing in small batches or a single-piece flow; using a pull or 'Kanban' system to control the WIP amount.

6. ***Over-processing***: Over-processing involves doing more work, adding more components or acquiring more phases in a service or product than the client needs (Skhmot, 2017; Wahab et al., 2013). In the office, over-processing may mean developing detailed reports beyond those required; using inessential tasks during the procurement phase; producing more documentation than needed; using double data entry, or extra steps in a workflow. In manufacturing, this may involve the utilisation of high-quality equipment beyond requirements; the use of higher capacity components than necessary; the production of excess and over-engineering of a solution; the modification of components following installation, and the acquisition of more functional products than required (Skhmot, 2017). Over-processing can be countered by comprehending the work requirements from the client's perspective. Therefore, it is crucial to determine the client's requirements prior to commencing a project or work, produce a product or provide a service based on the client's expectations and quality standards, and produce only the amount required.

7. ***Defects*:** Defects refer to a product that is not fit for purpose, which leads to rework or scrap. These outcomes are wasteful due to the additional costs incurred in the operation; hence, the client receives no value (Skhmot, 2017; Wahab et al., 2013). The countermeasures for defects are: identifying and focusing on the most recurrent defects, designing a process to identify irregularities, not passing any defective items along the production phase, redesigning the process to prevent any potential

defects, and standardising the work to ensure a steady and defect-free manufacturing process (Skhmot, 2017).

8. ***Skills*****:** Although this was not part of the Toyota Production System (TPS), several researchers acknowledged the eighth waste, namely the waste of an individual's potential (Skhmot, 2017; Wahab et al., 2013). This is also referred to as the waste of non-utilised people's skill and ingenuity that arises when companies separate employees from management. In some companies, the role of management entails planning, controlling organising, and changing the production process, while the role of employees is to merely follow orders and perform the planned work. However, the processes cannot be improved without engaging the expertise and knowledge of the frontline employee; often, employees undertaking the production work can detect issues and generate solutions. In the office, unused skill may comprise inadequate training, a lack of motivation, positioning workers in roles below their expertise and skills, and not considering employee feedback (Skhmot, 2017). In manufacturing, this waste may occur when workers are not trained properly or do not know how to successfully operate equipment, when they are not provided with the right tools for the work, and when they are not incentivised to create ideas to improve their work.

Lean Manufacturing was coined by Womack et al. (1990) to define the application of the essential ideas in the Toyota Production System. It was based on their analysis of the automotive industry in Japan and other countries. In general, the adoption of Lean Manufacturing principles is fragmented (Johansen *et al.* 2002; Santos et al., 2006). Furthermore, Womack and Jones (1990) state that waste reduction and increased productivity can only be achieved through the implementation of Lean Manufacturing principles with a broader examination of LT (Rother & Shook, 2000; Womack & Jones, 1996;). Womack and Jones (1990) moved from the car industry to broadly analyse manufacturing, and developed the five Lean production principles, called Lean Thinking. These comprise the following: Precisely specify the value through the specific product; identify the value stream for each product; make the value flow without interruption; let the customer pull value from the producer and pursue perfection.

Value: The project brief and specifications need to be examined from the client's point of view to demonstrate value. Womack et al. (1990) asserted that the activities that do not add value to the process must be ascertained as waste and avoided to deliver successful projects. This requires the design team, construction team and other stakeholders to collaborate effectively throughout the project; this advocates the clear and efficient establishment of employer requirements, which then results in enhanced productivity. Picchi and Granja (2004) state that examining design and construction strategies can help to identify the best-suited method to run a project. This helps to overcome operational problems and eliminate waste.

Value Stream: An important element of waste reduction through the adoption of Lean is the appropriate specification and depiction of project value streams. The principal objective is to develop an advanced process map in order to eradicate non-value-added activities. The process development map includes key activities and milestones for a project. Liker (2004) affirms that value stream mapping advocates that project members understand and develop effective processes and procedures within the business by focusing on the elimination of non-value-added activities.

Flow: This is considered to be one of the focal aspects of LC for the elimination of waste. Successful results can be achieved by flowing value with zero disruption, waste elimination, the reduction of lead times and the practical modification to manufacturing compartments. Koskela (2000) posits that developing a continuous operational flow is vital due to the lack of process standardisation and the fragmentation of the industry. Latham (1994) states that process flow must be successfully managed as a whole, demonstrating a continual flow through the synchronisation of all phases to ensure maximum benefit. Furthermore, Katayama and Bennett (1996) state that a process flow can be sustained by adopting a partnership approach with the supply chain to create a production flow within the allocated time and budget.

Pull: Construction-based activities need to be undertaken in order to mitigate project risks and eradicate uncertainties in the process. Companies are expected to ascertain the employer's requirements at the early stages of the project in order to successfully deliver the projects. Picchi and Granja (2004) state that a project team must be aware that each activity has an impact on the subsequent stages of the project.

Perfection: An excellent performance can be achieved through continual improvement. The successful implementation of Lean Manufacturing requires perfection in the manufacturing process. Picchi & Granja (2004) claim that this could be achieved by using experienced staff who are able to contribute by improving project processes and creating efficiency savings.

Womack and Jones' five approaches demonstrate that the optimisation flow of value towards the client is a guiding approach (Bertelsen & Koskela, 2003). Approaches two to four focus on this, while the first and last can be seen as broad aims. These approaches have developed from an ordered context with a well-known product and client base, a manufacturing process that is precisely described, and an effective supply chain. This is a common situation for production, and these strategies have been successful in enhancing productivity in various manufacturing companies (Bertelsen & Koskela, 2005).

2.3 Toyota Production System

The creation of the Toyota Production System (TPS) and Toyota House (see Figure 2.1) provided a representation of Toyota's outlook in a structured system of production (Liker, 2004). The house is a collection of seven themes (with Lean tools and techniques), showing the foundation, pillars, and roof of the system that are combined for sustained continuous improvement (Liker, 2004). These themes are: Best quality – lowest cost – shortest lead time; best safety – high morale; Just–In–Time (Womack & Jones, 2003); people and teamwork; Jidoka (or in-station quality); continuous improvement, and waste reduction.

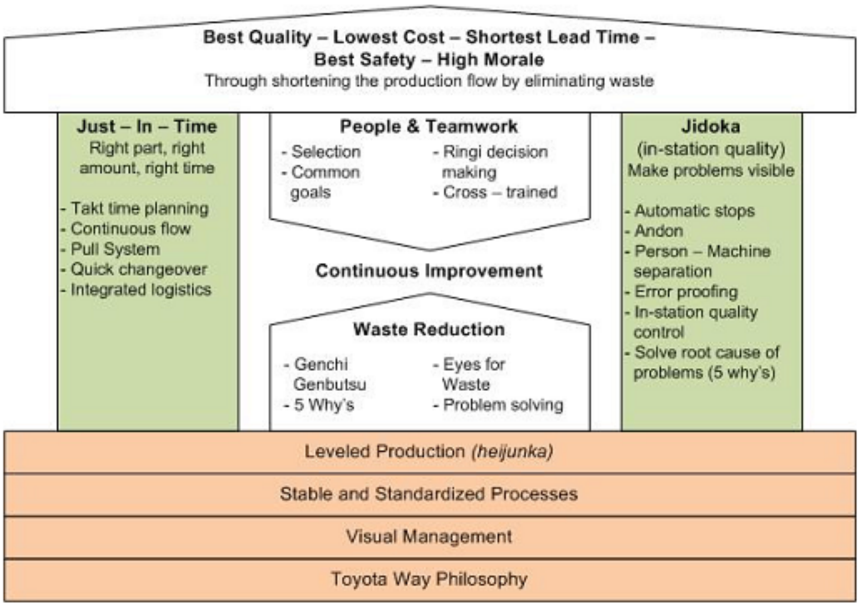


Figure 2.1: The Toyota Production System (Liker, 2004)

Furthermore, Liker (2004) produced 14 Lean Thinking principles and identified where each lies within Toyota House. He grouped these principles into four categories, namely; philosophy; process; people and partners, and problem solving. Table 2.1 shows the 14 principles while Figure 2.4 shows where each principle lies within the Toyota Production System.

Table 2.1: Principles of Toyota Production System

Toyota terms	"4 P" Categories	14 Principles
Challenge	**Philosophy** (Long-term Thinking)	**Principle 1.** Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals
Kaizen	**Process** (Eliminate Waste)	**Principle 2.** Create continuous process flow to bring problems to the surface **Principle 3.** Use pull systems to avoid overproduction **Principle 4.** Level out the workload (heijunka). (Work like the tortoise, not the hare.) **Principle 5.** Build a culture of stopping to fix problems, to get quality right the first time **Principle 6.** Standardized tasks are the foundation for continuous improvement and employee empowerment **Principle 7.** Use visual control so no problems are hidden **Principle 8.** Use only reliable, thoroughly tested technology that serves your people and processes
Kaizen; Respect and Teamwork	**People and Partners** (Respect, Challenges, and Grow Them)	**Principle 9.** Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others **Principle 10.** Develop exceptional people and teams who follow your company's philosophy **Principle 11.** Respect your extended network of partners and suppliers by challenging them and helping them improve
Kaizen; Genchi Genbutsu	**Problem Solving** (Continuous Improvement and Learning)	**Principle 12.** Go and see for yourself to thoroughly understand the situation (genchi genbutsu) **Principle 13.** Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly (nemawashi) **Principle 14.** Become a learning organization through relentless reflection (hansei) and continuous improvement (kaizen)

2.3.1 Pillars

Just- In -Time (JIT)

Toyota production pioneered Just-In-Time with the aim of operating with zero inventory and supply resources that are only accessed when needed (Womack & Jones, 2003). JIT enables effective production with sufficient quality and quantity to ensure products are produced at the right time (Tommelein & Li, 1997). *Principle 2* refers to the redesign of the project process to achieve continuous flow and added value. With this flow, materials and information can be transferred efficiently, whilst generating an uninterrupted flow that promotes continuous development (Liker, 2004).

Just-in-Time utilises three different techniques; first, the Kanban system is utilised for waste reduction. This is based on backward requests that flow through digital signals, cards, and baskets (Chaoiya et al. 2000). Second, production levelling ensures that fluctuations in demand maintain the right sequence of products in minimum batches (Miltenburg, 2002). Third, minimising the setup activities reduces the activities through downtime; therefore, alterations do not interfere with the minimum batches (Salem et al., 2006). Planned activities are promoted by Single-Minute Exchange Devices (SMED), which should minimise the exchange of different products.

Autonomation is the prevention of defects, and a substitute for the traditional quality control originally promoted by a functional management system that promotes quality and cost in a company (Ho & Fung, 1994). Autonomous control inhibits the flow of defective systems in the process. The visual assessment *(Poka-yoke)* of components advocates this control level, continuing the transformation from traditional autonomation that does not allow for direct intervention in the process (Shingo, 1985). It is important for companies to retain flexible employees to fulfil their labour needs with a fluctuating level of demand for their products (Salem et al., 2006). A multifunctional layout design and standard operations promote flexible labour (Yang & Peters, 1998). The positions can be rotated in the production line with a flexible machine set-up.

Takt time is a standard continuous flow that aims to make one part at a time to the speed of the client's requirements. It can be utilised to set the manufacturing rate by alerting employees when their work is behind or ahead (Liker, 2004). JIT practice is also adopted through a 'pull' system so that products are pulled when they are needed. This is produced on time and in the right quantity and quality to minimise the inventory. *Principle 3* is to use *'Pull' systems to avoid overproduction;* it provides clients with a manufacturing process that is based on their needs. The replenishment of materials is the key principle of just-in-time; furthermore, understanding the customer's needs reduces overproduction and workload. To track overproduction, the customer's daily programme is monitored, (Liker, 2004). Kanban is the fundamental part of JIT that ascertains the need for replenishment or the order of inventories; hence, it is an effective operational tool (Liker, 2004).

Jidoka

Jidoka is the second pillar of Toyota that assures quality through the manufacturing line by ascertaining deficiencies and fixing them to reduce waste (Womack & Jones, 1996). Principle 5 is to build a culture of stopping to fix problems, to get quality right the first time. The latest quality improvement methods drive the client's value proposition. Liker (2004) posits that a visual method is adopted to alert and empower team members and managers to detect issues. The idea of stopping and decelerating to ensure the right quality first time increases long term productivity. Jidoka is also referred to as autonomation equipment endowed with human intelligence to pause itself if there is an issue. Liker (2002) affirms that this avoids the passing of issues down the line, which is more efficient and cost effective than analysing and fixing issues at later stages (Liker, 2004).

Moreover, Pegels (1984) noted that, when there is an issue, quality can be enhanced quickly to meet the customer's requirements. However, the adoption of technology needs to support the company's operations. *Principle 8* is to use only reliable, thoroughly tested technology that serves your people and processes. Technology should be adopted to assist individuals and not replace them. The latest technology cannot be relied on and it does not promote standardisation that jeopardises the flow. It is therefore better to use a proven technique rather than adopt untested technology. A new technology should only be adopted after it is analysed and validated. If the technology conflicts with a company's outlook, it should be rejected or modified (Liker, 2004).

Another model of Jidoka is the 'person-machine', which ensures quality and impedes the over-dependence on individuals; this involves the segregation of teams from 'person machines' to facilitate the use of multiple processes. An error-proofing 'andon' signal only appears when a problem occurs; however, if people ignore the signs, the defects will continue to occur (Patel et al., 2001). Therefore, machines must be shut down automatically with error proofing. In-station quality control refers to the aversion of quality issues, so they do not go beyond the station in which they arise (Liker, 2004). Moreover, looking at the root cause of an issue can help to avoid the problem. The 5Whys technique continually seeks deeper roots to resolve the original problem (Liker, 2004).

People and Teamwork

In Toyota Manufacturing, people are the core of the production line, whilst computers transfer information, as noted under *Principle 8*, namely use only reliable, thoroughly tested technology or process (Liker, 2004). Toyota adopts the Ringi decision-making approach to resolve an issue and eliminate waste. The purpose of this approach is to take decisions with the involvement of stakeholders by considering all options by consensus. This is as referred to as *Principle 13*, which is to make decisions slowly by consensus, thoroughly consider all options and implement decisions rapidly. Rather than focusing on a single approach, every potential strategy must be considered; once a strategy has been chosen, the plan can be conducted instantaneously and carefully (Liker, 2004). A process called Nemawashi provides a potential solution to analyse the issues; it does this by obtaining the opinions from individuals from different backgrounds to agree a project strategy. Even though such a process is time consuming, it can promote decision-making and agree an effective project phase (Liker, 2004).

In Toyota, the mechanisms are designed to encourage employees to bring value to the processes because they are the ones coordinating and carrying out projects. Toyota makes a commitment by empowering employees and monitoring their works. Thus, *Principle 10* is to develop exceptional people and teams who follow your company's philosophy. Creating a vigorous and steady approach is vital for organisations to share their ideas and values (Liker, 2004). Remarkable individuals are trained to perform in an inclusive culture where they are expected to work efficiently to achieve continual improvement and effective results. Moreover, increased efficiency and quality can be accomplished through the use of cross-functional teams that essentially increase the flow (Liker, 2004). It is therefore imperative to continuously educate and encourage staff to work collaboratively for organisational development.

Principle 9 is to grow leaders who thoroughly understand the work, live the philosophy, and teach it to others. TPS does not promote the hiring of executives as managers should understand the Toyota philosophy and transfer their knowledge to other individuals in the team to enable staff to grow with the organisation’s culture. The supply chain is a crucial element of the production line, and therefore improvements can only be made via the supply chain. *Principle 11* is to respect your extended network of partners and suppliers by challenging them and helping them improve; indeed, respecting colleagues and the supply chain is imperative for success. Liker (2004) further posits that a company's development and growth can be achieved by regularly encouraging exterior business partners to offer challenging ideas that demonstrate their value to the business.

Waste Reduction

The fundamental purpose of Lean Manufacturing is to eliminate waste from processes. There is a need for process improvement in projects; however, Koskela (2000) stresses that the West avoids process improvement and instead embraces operational management. According to Koskela (2000), when there is a waste, value is not added to completed products. Therefore, waste elimination is the one of the main flow elements. In the transformational form of manufacturing, both transformation and non-transformation activities are unnecessary for the flow. This helps companies ascertain the activities that need eliminating. According to Gilbreths (1992), non-transformational activities include delay, transfer and inspection; however, Ohno strived to develop a model to map value added activities whilst eliminating non-value-added activities.

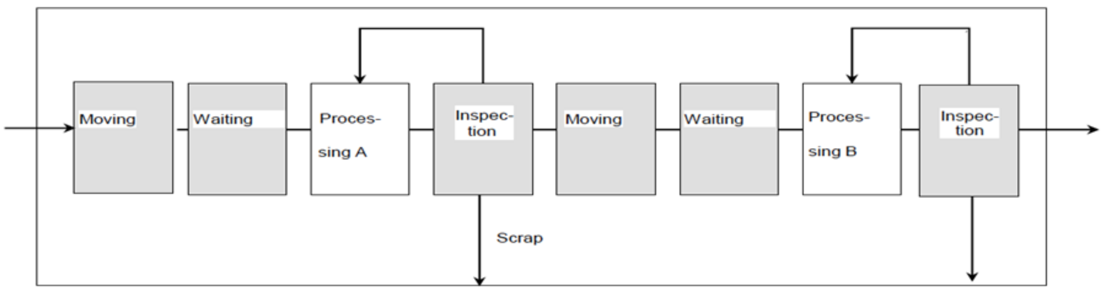


Figure 2.2: Production as Flow Process: Shaded-Non-Value-Added Activities (Koskela, 2000)

Koskela (2000) mentions that both added value and non-added value activities are included in the manufacturing process. The manufacturing process can be improved by minimising non-added value activities; moreover, Lean principles aim to eliminate waste by continually improving processes whilst treating employees with respect. Womack and Jones (2003) refer to waste (Muda), as an activity that integrates sources while creating non-added value activities. Waste elimination is the fundamental purpose of TPS and can be achieved by adopting the various techniques previously outlined. Liker (2004) states that, in order to thoroughly understand the issues, processes must be seen in person. This enables individuals to effectively analyse them so that the root cause can be determined to resolve the issue. This is referred to under *Principle 12, namely to go and see for yourself to thoroughly understand the situation (genchi genbutsu).* Personal observation and data verification on sources are vital to resolve any issues in the company. Rather than relying on theoretical data obtained by computers, personal observations should be the main method by which to evaluate and verify information. Hence, managers and directors should observe processes in person to properly understand the circumstances, which will then lead to enhanced processes (Liker, 2004).

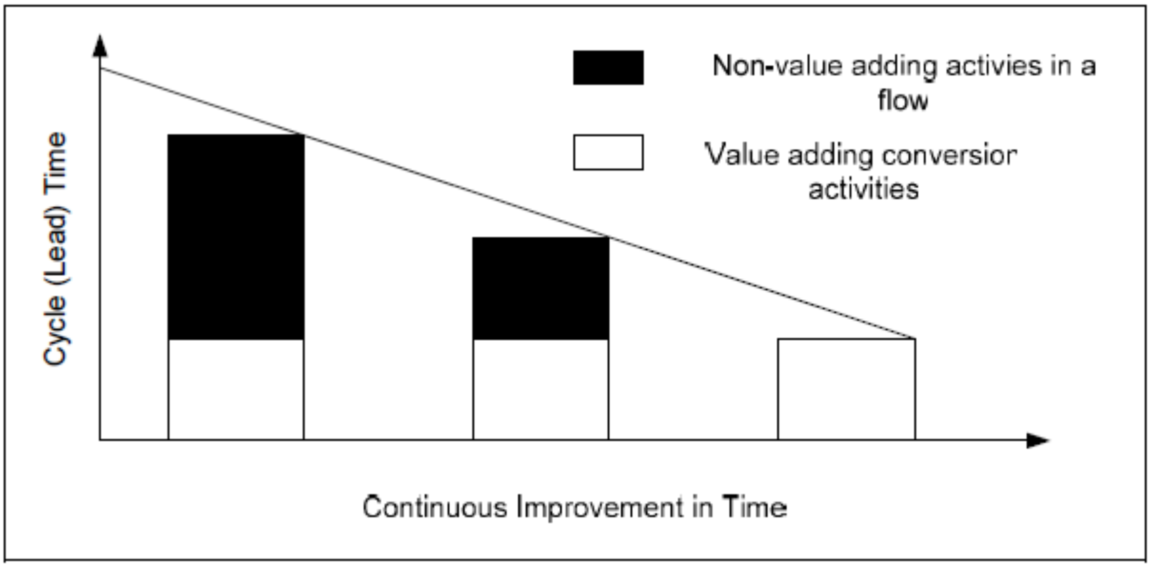


Figure 2.3: The Reduction of Non-Value Adding Activities (Koskela, 1992)

Continuous Improvement

A company tends to continuously seek methods to develop further and increase their profit in the industry (Imai, 1986; Nicholas, 1998; Ross, 2003). Lean principles enforce this continuous improvement, as indicated by *Principle 14*, which is to become a learning organisation through relentless reflection and continuous improvement (Liker, 2004). Effectively managing processes will lead to successful outcomes, and this can be achieved by monitoring and standardising processes; for example, evaluating issues and suggesting preventative countermeasures (Imai, 1986; Nicholas, 1998; Ross, 2003). Liker (2004) states that empowering team members and considering different views are crucial for the resolution of these issues.

Once a process has been established, continuous improvement strategies are adopted to ascertain the root cause of inefficiencies; from this, effective countermeasures are implemented. Project plans should be conducted with zero inventories so that wasted time and sources become visible to everyone; thus, employees are required to adopt continuous improvement to eliminate waste in a process (Liker, 2004; Ross, 2003). Furthermore, the information in an organisation must be protected by growing stable teams. Once the operation has been concluded, Hansei (reflection) is implemented during the key milestones to ascertain the defects in the process and to develop countermeasures to resolve similar issues (Liker, 2004). Liker (2004) further stated that learning by standardising the most useful methods is more efficient than inventing a new concept with a different leader.

Visual Management

According to Liker (2004), not noticing issues is a dysfunction that persists until such hidden problems arise. Lean Thinking relies on visual control for waste elimination, and this is referred to under *Principle 7, namely to use visual control, so no problems are hidden.* Simple visual control systems are adopted to enable teams to immediately ascertain problems, whether the circumstances are normal or divergent. Liker (2004) further noted that the use of computers must be avoided when they start to distract staff within the workplace. To advocate a pull and flow, basic visual methods are planned in the office where reports are condensed into a single document. Thus, the '5S technique' is used to promote the elimination of waste; these 5S are outlined below (standing for seiri, seiton, seiketsu, and shitsuke in Japanese):

- *Sort - sort through items and keep only what is needed while disposing of what is not;*
- *Straighten (orderliness) – there is a place for everything and everything has its place;*
- *Shine (cleanliness) – the cleaning process often acts as a form of inspection that exposes abnormal and pre-failure conditions that could hurt quality or cause machine failure;*

- *Standardise (create rules) - develop systems and procedures to maintain and monitor the first three Ss;*
- *Sustain (self-discipline) – maintain a stabilised workplace as an ongoing process of continuous improvement.*

The 5S help to create a continuous process to develop the workplace; for example, a visual control system can be utilised as a communication technique in an office. This determines the standard adopted to carry out the work, and helps to readily identify any deviation. Moreover, the visual control systems essentially focuses on improving the flow; for example, the *Kanban* card is used to signal previous processes to improve production while the *Andon* cord is used to signal deviations from the standard (Liker, 2004).

Stable and Standardised Processes

Various processes are frequently replicated, which may lead to operational issues; therefore, Liker (2004) affirms that setting a norm for these processes is imperative to achieve an aim. Thus, *Principle 6* involves standardised tasks, which are the foundation for continuous improvement and employee empowerment. Stable and repeatable methods are used to maintain a common timing, output and process probability, which is the basis of pull and flow. By standardising the latest methods, the accumulated information of a project is acquired (Liker, 2004). The norm should not be perceived as the only method suitable for an activity as it is a phase to stabilise and enhance a process (Ford, 1988). A standardised activity advocates an increase in the product quality; however, quality can only be managed and sustained when it is based upon the norm. Once the deviations from the norm arise, the quality is controlled in an operation to fix or stop it, as reinforced by *Principle 5*, namely to build a culture of stopping to fix problems, to get quality right the first time (Liker, 2004).

Levelled Production (Heijunka)

Liker (2004) posits that, due to changes in the client's requirements, such as fluctuations in demand, companies that meet these requirements are prone to hidden problems, longer lead times, overproduction, and low performances. Nevertheless, levelled production advocates the standardising of processes, as referred to by *Principle 4*, which is to level out the workload (Heijunka). However, Liker (2004) further asserts that reducing waste is merely one-third of the Lean equation, and that reducing staff and equipment overload and eliminating uncertainty in the production phase is also crucial. Levelling out the workload of an activity and production is perceived as the start/finish approach of managing projects in batches. This approach is common for companies. Levelling out the workload promotes uniformity in an organisation, which is vital for flow and the eliminating overload in an operation (Womack & Jones, 1996).

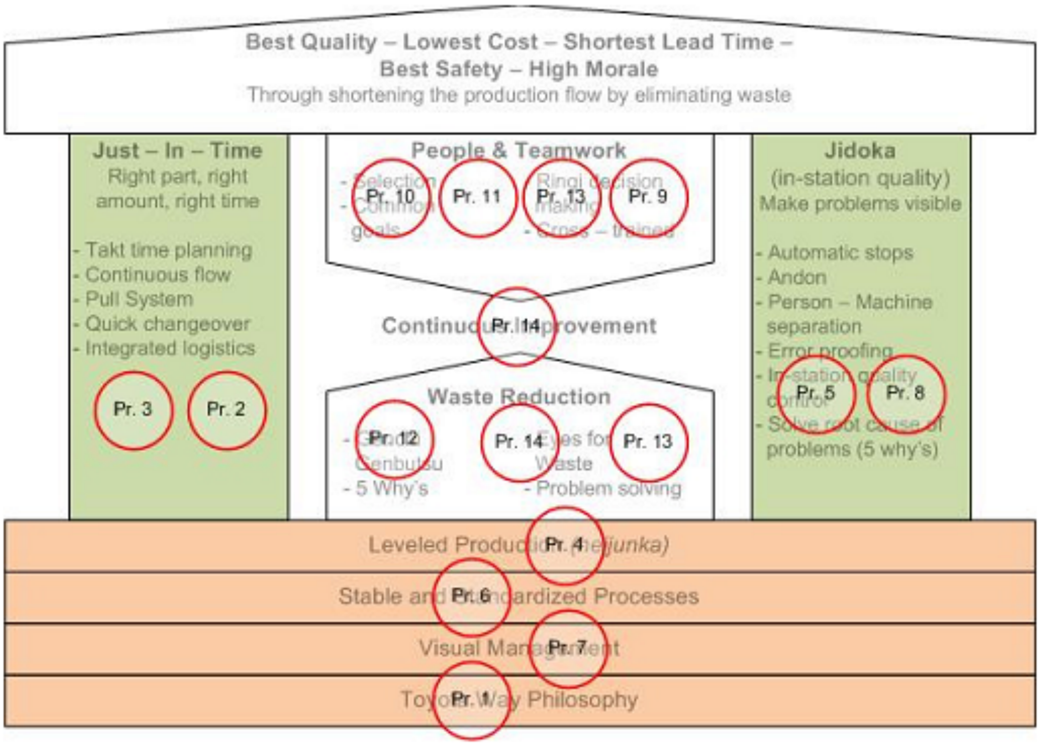


Figure 2.4: Liker (2004) 14 Principles placed within Toyota Production System

Both TPS and Womack and Jones' (2003) Lean principles have recently been validated in operations management literature (Slack & Lewis, 2011). Nevertheless, there is still substantial scope for their implementation in practice; these are now clearly articulated and tested principles, which have spread beyond their conventional manufacturing roots (e.g. Womack & Jones, 1994). Hence, their adoption must be discussed by demonstrating that construction is an approach to production similar to manufacturing. Both TPS and Womack and Jones' Lean principles demonstrate that the techniques initiated and developed in the automotive manufacturing industry can be adopted within construction. Despite fragmentation in the construction industry, the outcome of implementing Lean is both encouraging and effective (Ballard & Howell, 2003; Koskela, 2000; Santos, 1999).

2.3.2 Liker's 13 Tips for Transitioning a Firm to a Lean Enterprise

There are several firms run by skilled and experienced lean leaders who have successfully brought cultural change. It is envisaged that the transformation can be achieved in many ways (Liker, 2004). Below outlines Liker's 13 general tips on what works in transitioning a firm to a Lean enterprise:

- *Start with action in the technical system; follow quickly with cultural change.* Many firms attempting a lean transformation focus on the process layer of the 4P model which is perceived as a suitable approach, since the technical systems of lean drive the Toyota Way approach, i.e. surfacing issues that the staff need to learn how to resolve. However, the technical and social systems of TPS are linked; if a firm intends to change the culture. It also requires growing lean leaders who can drive this cultural change. The most effective way of developing this is by improving the firm's fundamental value stream, reinforced by committed leaders who promote cultural change. Leaders needs to participate in the transformation of shop floor and value stream mapping in order to learn to see waste (Liker, 2004).

- *Learn by doing first and training second.* Prior to commencing making radical changes, the employees should be informed of the structure of training sessions. The Toyota Way focuses on learning by doing. In the initial phases of lean transformation there needs to be 20% training and informing and 80% doing. The most effective training is followed straight after by doing or doing followed by immediate training. The Toyota way to training is to challenge employees with difficult tasks and enable them to resolve the issues (Liker, 2004).

- *Start with value stream pilots to demonstrate lean as a system and provide a go see model.* In the value stream, a model is generated in a value stream defined by a product family. This means, applying the entire system of techniques so that other staff in this company can go and see lean in practice without needing to go to another firm. The go-and-see model line needs a great focus with a significant resources and management attention for success and object lesson in management commitment (Liker, 2004).

- *Use value stream mapping to develop future state visions and help learn to see.* Value stream mapping is a technique to show in diagram form the information and material flow. Value stream mapping generates a language and tool for the team to select a particular process, identify waste, develop a lean approach and implement it with that specific process. The mapping must be adopted merely to particular product unit, which will be instantly transformed (Liker, 2004).

- *Use kaizen workshops to teach and make rapid changes.* The *kaizen* workshop enables teams to make changes within a week rather than months. Choosing the correct individuals for the team is crucial, as is allocating time for those people and supporting them. However, there should be other workshops alongside kaizen workshops to acquire optimum efficiency. Kaizen workshops are best utilised as one technique to adopt particular developments led by a future state value stream map.

- *Organise around value streams.* Many organisations organise management by function or process. Managers are responsible for stages in the process of generating value for the customers and no one is accountable for the value stream. An individual who has leadership skills and a good comprehension of the process and product should be accountable for the process of generating value for the customer.

- *Make it mandatory.* If lean transformation is only considered as a voluntary activity, it will not happen, hence lean needs to be made mandatory with consequences for not buying into it.

- *A crisis may prompt a lean movement, but may not be necessary to turn a company around.* Senior management needs to proactively champion improvement and Lean leadership must be focused on long-term learning.

- *Be opportunistic in identifying opportunities for big financial impacts.* Toyota looks at improving processes, which in turn leads to improved financial outcomes. Nevertheless, if a firm does not have confidence in Lean Thinking, it is specifically crucial to acquire significant wins by making successes visible and by choosing the correct product group to focus on.

- *Realign metrics with a value stream perspective.* Toyota utilise metrics differently in comparison with many firms as they use that metrics as a tool for continual improvement. In the vast majority of firms, managers use metrics for short-term cost control rather than value delivery.

- *Build on your company's roots to develop your own way.* Liker (2004) posits, A firm can use some of the principles from the Toyota Way, however these principles need to be translated into a company's language to fit into the business. Therefore, a firm should build on its heritage to ascertain what it stands for (Liker, 2004).

- *Hire or develop lean leaders and develop a succession system.* Leaders needs to fully comprehend and have a confidence in the firm's system. Every leader should thoroughly comprehend the work and know how teams can be involved. If the executives do not drive the transformation, it will not happen (Liker, 2004).

- *Use experts for teaching and getting quick results.* Sensei is a Japanese word that refers to a lecturer who is expert in a particular area. A firm needs a sensei for technical assistance and change management advice when an approach is being tried for the first time. The sensei assists in facilitating the transformation, getting quick outcomes, and keeping the momentum developing. However, a competent sensei should also get lean knowledge into the firm. This can be achieved either by recruiting specialists with at least five years lean experience or by recruiting external consultant specialists. A specialist can commence the process quickly by training through action, however to build a lean learning firm, it is important to develop internal improvement expertise, senior executives and team leaders who are bought into Lean Thinking and able to spread Lean in the organisation (Liker, 2004).

2.4 The Construction Industry in the UK

The UK Construction Industry (UKCI) has been perceived as extremely inefficient. Many construction schemes have inefficiencies in terms of certainty of time, cost, and quality measures. Construction professionals have proposed a revolution in various fields of the sector's conventional methods (Banwell, 1964; Egan, 2004; Latham, 1994). Moreover, Folwell et al. (2012) mentioned that, in 2012, the UK Construction Industry highlighted the following problematic statistics: time certainty was calculated at 34% (these involved schemes, as a whole, completed on or before the planned completion date); cost predictability was identified at 61% (this involved the final project cost at or below the predicted cost); and 2.7% was calculated for sector profitability.

Latham (1994) and Egan (1998) asserted that the UK construction industry (UKCI) needs improvements in various fields. Latham identified the fragmentation of the industry and its resistance to change as hindrances to project processes. The fragmentation leads to a lack of communication among teams, which results in inefficiencies and poor operational performances (Anumba, 2000). There are different ways in which fragmentation arises; for example, works can be allocated randomly based on a plan of work, or alternatively, works could be structured in different ways where experts may not be engaged or collaborate with the supply chain. Thus, Egan (2004) and Mossman (2009) posit that, in order to minimise fragmentation issues, collaboration and communication among team members must be enhanced.

Construction industry clients having increasing expectations; however issues with underperformance can lead to inadequate project delivery and hence dissatisfied clients. (Santos et al., 2000). Research has demonstrated that the main barriers to enhancing industry wide performance are fragmented processes and confrontational relationships, which cause inefficiencies at several stages of the construction process. To address this issue, Egan (2004) and Latham (1994) underlined two approaches: firstly, client focus and secondly, integrating the team within the process development. The emphasis needs to shift from silo based individual responsibilities and duties to the complete project requirements.

Many firms and employers are often reluctant to the change their approach to business. This is due to the unique and specific integration of the organisation's structure with their philosophy. Nonetheless, it is known that innovation in an organisational structure can enable companies to develop processes, and increase their efficiency and effectiveness at the project and operational levels. Thus, it is noted in the literature that construction professionals should encourage teams to adopt such changes (including Lean) to promote the effective delivery of projects.

2.5 The Challenges of Implementing Lean Thinking in the Construction Industry

An extensive survey of Lean application processes indicates several factors that either hinder or support the implementation of Lean Thinking throughout construction projects (Karlsson & Ahlstrom, 1996). The factors that affect the application of LT are discussed in the following sections.

2.5.1 Fragmentation

The application of LT has been successful in various sectors where employees work as a team. Fragmentation in construction companies may result from a lack of communication between working groups. This could have an impact on the project performance and its relative processes (Anumba, 2000). Fragmentation within the sector arises in many ways; for example, tasks are dispersed haphazardly in compliance with the business; the work might also be formed in different ways, and experts are not associated with the supply chain. Thus, according to Egan (2002), the development of unified team members would help to moderate issues associated with such divisions (Mossman, 2009). Many problems can arise when a firm is fragmented, such as not meeting the customer's needs, and a lack of collaboration and communication between team workers. Furthermore, the lack of coordination causes inadequacy in project processes such as overproduction and delay (Amor & Anumba, 1999).

2.5.2 Resistance to Change

Although many firms and employees are reluctant to change, such shifts can benefit companies in the longer term. Thus, Lean Construction specialists are expected to manage and encourage teams to adopt these changes to the project processes in order to ensure successful completion (Song & Liang, 2011). Many organisations fail at the beginning as they lack the necessary understanding of the needs and advantages related to change; for example, the superintendent and foremen involved in a project may be sceptical about the impact and benefits of such changes (Song & Liang, 2011). To apply a Lean philosophy to project processes, changes to conventional applications are almost inevitable, and unfortunately these innovations often face resistance (Bove & Hede, 2001). Moreover, resistance to change is considered a crucial factor in the failure of several development enterprises.

2.5.3 Management

In order for new business methods to be successful, the senior management needs to introduce them in detail (Mossman, 2009). The implementation of LT can be accomplished with managers' commitment to the operation of an effective process. It is also important to provide sufficient support and resources to manage changes deriving from practice. Nonetheless, a range of barriers associated with poor management is identified within the existing research reviewed by Alarcon et al. (2002) and Common et al. (2000). Delays in decision making, a lack of senior management presence, insufficient design depiction, postponements in delivering products, the lack of materials, inadequate time for modifications, inappropriate procurement methods, longer working hours and a lack of client and supply chain contribution are seen as the major barriers to the implementation of LT in the construction industry (Suresh et al., 2010).

2.5.4 Economic Situation

The implementation of new methods, such as LT, needs sufficient funds to support employees and provide the necessary labour and materials; this also can help LC specialists appropriately guide managers and team workers. The customer's payment for the project activities is an important element of financial support, and embodied in the firm's capability to spend on innovative techniques, including Lean production, which requires considerable funding. Financial support is the core element of change and its lack results in delays to a project's completion. The inadequacy of financial support may discourage organisations and employees from implementing LT in their project processes (Mossman, 2009; Suresh et al., 2010). There have been many attempts by organisations, academics and researchers to raise awareness of, provide management for, and knowledge on LT. Nevertheless, educational problems persist as the key barriers to the full-scale application of LT. It is suggested that, the basis of LT may hinder the construction industry's comprehensive commitment (Suresh et al., 2010). According to some academics, the problems in education are associated with a range of barriers, such as inadequate technical skills, a lack of understanding of LT, a lack of training, insufficient disclosures to application requirements, and a lack of knowledge transferral in the company (Alarcon et al., 2002; Mossman, 2009). The inadequate transparency of LT and uncertainty in theory and practice hold companies back from applying a Lean manufacturing philosophy (Petterson, 2009). Organisational education is supported by LT for which managers and team workers need to be trained to develop awareness so that new strategies can be executed successfully (McGill & Slocum, 1993).

2.5.5 Cultural Issues

Based on the studies carried out by Alarcon et al. (2004) and Mossman (2009), numerous factors are classified and considered impediments to LT practice in the construction industry. In particular, the behaviour of individuals is a major factor (Howell, 1999), whilst others include: a lack of clarity, limited collaboration, insufficient management, resistance to cultural change, an inadequate understanding of the customer's needs, misconceptions about LT implementation, divergent theories concerning complex perception (Suresh et al., 2010).

The construction industry tends to have a conservative and change-resistant image (Davis & Songer, 2009), which the adoption of LC challenges. The concept of Lean is new to many contractors, and its application needs a change of mindset and the consideration of current theories (Howell & Ballard, 1998). To encourage this change, there needs to be a focus on training in LC, the improvement of Lean theories and practice, and the demonstration of Lean principles and their advantages through the sharing of case studies (e.g. Salem et al., 2005). Another obstacle to the implementation of LT is the lack of efficient application techniques to promote LC practice. Its slow adoption might not be due to the 'shortage theories' but instead attributable to a lack of knowledge of the fundamental application process and techniques that promote its application (Song & Liang, 2011). LC has a different perspective for the management of operations (Ballard, 2000a), and existing techniques based on conventional management philosophy might either discover their application in the LC environment or need updating for Lean practice.

2.6 Lean Construction

The achievement of Lean practice in manufacturing and the opportunities emerging from its implementation are two of the fundamental incentives for its deployment in construction (Egan, 1998). Lean was initially adopted in the construction sector several years after its success had been proven in the manufacturing industry (Gao & Low, 2014). Various authors have endeavoured to offer an account of the Lean Construction (LC) concepts. One of the earliest contributions was Koskela's (1992) report on the potential of a new production philosophy in the construction sector. Koskela (2000) later integrated three new concepts on the construction process (discussed earlier in Chapter 2), which laid the foundations of Lean Construction. Koskela et al. (2002) defined LC in simple terms as a method of designing production systems to minimise wasted effort, time and materials so as to achieve the maximum possible value.

The Lean Construction Institute (LCI) defines LC as a management-based production system to project delivery, which is predominantly beneficial for high-speed, complex and ambiguous projects (Ballard, 2000b). The depiction of LC by Koskela et al. (2002) implies that it endeavours to achieve the same objectives as Lean Production by focusing on the elimination and reduction of waste and the maximising of value. LCI depiction, on the other hand, indicates that engineering approaches in manufacturing can be directly adopted within construction (Gao & Low, 2014). In addition to Koskela's (1992, 2000) concepts, a different understanding of the LC systems is highlighted in Figure 2.5 (Koskela et al., 2002; Winch, 2006). Such opinion discusses the adoption of Lean manufacturing systems within the construction industry (Gao & Low, 2014). Last Planner (LP) is the foremost approach adopted by construction from manufacturing and applied to the management and planning of construction processes (Ballard 2000; Howell & Ballard, 1998). LP aims to create a consistent work-flow by developing a dynamic project team, comprising firms that are influenced by this approach and collaboratively developing a stage plan for the operational phase (Gao & Low, 2014). This is considered a social process, involving discussions with the workman on site, and scheduling to ensure that operations are not waiting for staff and that the staff are not waiting for operations.

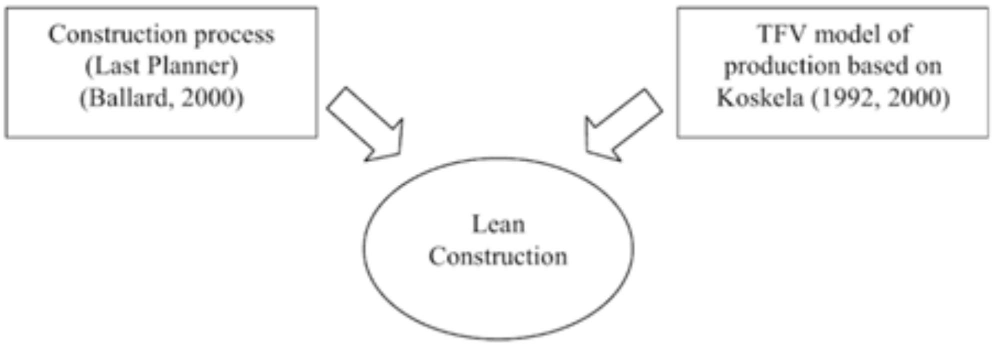


Figure 2.5: Two Core Interpretations of Lean Construction (Gao & Low, 2014)

Green and May (2005) have observed the coexistence of disparate perceptions of LC and have highlighted that the interpretation of LC may be perceived as: a range of methods, a debate, a 'sociotechnical paradigm', or a cultural commodity. The Egan report (Egan, 1998) has been accountable for popularising the 'Lean' brand among construction professionals within the UK (Green & May 2005), who principally perceive Lean Thinking (value, value stream, flow, pull, and perfection) as a range of methods, which could be directly adopted on construction projects. Due to the increase in awareness of LC the study has incorporated almost every construction phase that adopts Lean principles. Emmitt et al. (2007) posit that, "the term Lean Construction tends to be interpreted quite widely, ranging from a term to include design and construction activities to very narrow interpretations related to specific production functions and/or application of tools by contractors."

Furthermore, the term comprises a set of project types including industrialised housing (Dentz & Blanford, 2005), high-end buildings (Sacks & Goldin 2007), pre-fabricated projects (Low & Chan 1997), and refurbishment projects (Bryde & Schulmeister 2012). It has also been extended to incorporate project fields including project briefs at the design stages (Ballard et al., 2003), simulation and supply-chain mapping (Tommelein, 1998), and construction operations on site (Picchi & Granja, 2004; Salem et al., 2006). LC brings opportunities to the construction industry. Although its accomplishments in construction have not been as noticeable as the automotive manufacturing industry, the results seem promising (Gao & Low, 2014).

Notwithstanding, Jorgensen (1994) states that, through its transformation from manufacturing to construction, the process losses seem to be associated with the critical characteristics and the challenges encompassed within its implementation. Lean is considered to be interpretive and as such, there is no communal depiction or perception of what is meant by Lean, Lean production, or Lean Construction. The emphasis has been principally placed on planning and management, production system design, and application. Jorgensen (2006) noted that the neglect of broader views on Lean has raised significant issues. It has also been noted that there is a need to consider a return to various other features of the philosophy, such as whole-life value, and identifying waste and entire-life value.

Mueller and Strzelczak (2015) suggest that adopting empirical evidence from the Western manufacturing systems sector within which the targeted effects are mostly cost savings, and increases in production and utilisation create negative side effects (such as unplanned increased costs, quality issues, and customer dissatisfaction). Mueller and Strzelczak (2015) further noted that, as an administrative technique, the monitoring system could help to avoid such impacts; specifically, its adoption could support the application of a multi-perspective assessment of Lean management implementations.

Green and May (2005) state that the prevailing publications on LC tend to be prescriptive with little acknowledgement of the social and political nature of the diffusion procedure. The current view of production engineering frequently assumes that companies are unique bodies, wherein each party strives to achieve a mutual aim of enhanced performance and increased productivity. An alternative view considers the dissemination of LC across debated pluralistic fields; various performers mobilise diverse themes to fit their own localised political agendas, and numerous LC themes continually compete for attention amongst alternative management systems. Therefore, the conception and performance of LC varies across different arenas and stages; moreover, it frequently produces disparate indications from those foreseen. Nevertheless, these types of localised LC performance are designed and constructed by the prevailing economic and social systems over which management have limited influence (Green & May, 2005). Thus, ‘Leanness’ may be conceptualised as the need for structural flexibility that includes outsourcing, downsizing and restructuring. Moreover, on this basis, the UK construction industry (UKCI) can be perceived as having initiated Leaner ways of performing from the mid-1970s, long before the language of LT became prevalent. Semi-structured interviews with construction professionals provide empirical support for the perception that LC is a multifaceted notion that defies world-wide depiction.

Eklund and Berglund (2007) suggest that Lean Production was launched within various organisations in the early 1990s. Critics perceived the concept as a solution to the complex working conditions of Taylorism, whereas others vigorously criticised it as 'Mean Production' (Liker 2004; Stewart & Garrahan 1995). The focal critique was that working conditions were onerous, and there was a high risk of stress-associated and/or musculoskeletal illnesses. Other proponents considered that there was no a discrepancy between Lean Production and Taylorism. By the late 1990s, Lean Production appeared to be out dated in Sweden. These early developments aimed to replicate the Japanese concepts, but resulted in complications due to disparities between the different adopting cultures (Friel, 2005; Seppälä & Klemola, 2004).

Nevertheless, in the early 2000's construction professionals started to show new interest in Lean. Eklund and Berglund (2007) confirmed that several Swedish organisations had been experimenting with the deployment of Lean and considered it a governing production system in the industrial rhetoric. Firms such as British Telecoms and Scania established their own form of Lean, called the British Telecoms' Production System and Scania Production System respectively. Such concepts, to a great extent, combined Scandinavian traditional design concepts with Japanese manufacturing concepts. Seppälä and Klemola (2004) mentioned that similar approaches were adopted Finland, where sociotechnical methods were combined with Lean.

Nevertheless, Lean Construction theory has been applied to develop construction processes, planning practices, and project delivery processes (Ballard, 2000b). The practical value of LC theory has been proven through several examples (Song & Liang, 2011). For instance, Salem et al. (2005) assessed the efficiency of construction methods that comprised Last Planner, improved visualisations, first-run studies, and daily huddle meetings, and their research demonstrated that these methods brought about effective results. Lean Construction theory has been developed as a strategy to improve project processes and to add value in the construction industry. The deployment of LC theory has demonstrated that the application of Lean principles to construction brings significant advantages, despite the view that LC implementation techniques are not advanced (Ansell et al., 2007).

In their research into seven Chilean construction companies, Alarcon and Diethelm (2001) envisaged that the issues with LC implementation could be overcome by using a community arrangement for construction management. Process and manufacturing design could be standardised for conventional products although nonconventional products need to be standardised at the planning phase (Ansell et al., 2007). However, this is usually limited due to fragmentation in the construction industry; therefore, construction projects utilise process mapping to accomplish an interconnected community that, in theory, helps to develop systems.

2.6.1 Waste in the Construction Industry

In recent years, there has been a significant interest in LT amongst construction professionals in the industry. Long delivery times and considerable waste in the construction process has led developers to search for more efficient production systems that will enhance process dependability, decrease the overall lead period and increase quality. Nevertheless, the construction industry provides an analogy to manufacturing, although a high level of mobility hampers the direct replacement of the Lean model and methods (Yu et al., 2009). In cooperation with a local developer, a methodical strategy on the basis of value stream mapping can be generated to analyse existing processes and develop a Lean production model. The model consists of four features that are: synchronised first-in-first-out lane-based flow; production levelling to a pacemaker; developed work reliability, and work restructuring.

A new production model, Value Stream Mapping (VSM), which Toyota considers material and information flow mapping, is a frequently used method for Lean scheduling. This model encourages Lean specialists to consider flow rather than thinking of isolated waste and to apply Lean system thinking rather than specific practices (Yu et al., 2009). Research into the implementation of VSM within construction has either concentrated on the macroprocess level, e.g. the supply chain (Arbulu & Tommelein, 2002; Fontanini & Pichi, 2004), and project delivery (Mastroianni & Abdelhamid, 2003), or on particular activities, e.g. masonry (Pasqualini & Zawislak, 2005) and components manufacturing (Alves et al., 2005). However, to date there is no report that demonstrates the application of VSM to construction process development.

However, a construction project represents a distinctive design, framework and specifications; it should be structured accordingly based on a distinctive construction process (value stream) (Yu et al., 2009). VSM needs steady management integrated with effective performance in the methodical data collection and analysis, plus the main application team assembly, a working process transformation, and Lean training. However, practitioners are reluctant to invest such efforts into develop a process that can be repeated.

Moreover, in terms of sustainability, waste reduction efforts from a Lean perspective appear to have environmental impacts of differing natures (e.g., negative, positive, or neutral) and magnitudes (e.g., negligible or significant) (Song & Liang, 2011). Lapinski et al. (2006) affirm that, if a contractor's perception of Lean is limited to merely increasing financial performance, such a 'narrow' outlook may not have positive environmental outcomes.

Institutional Waste in the Construction Industry

It is broadly acknowledged that there is significant waste in the end-to-end design, construction and facility management stages. Studies have shown that waste prolongs construction time by 50%; it understood to be anything that does not add value for the end-user, which mainly involves process waste with some physical waste. Alongside the aforementioned categorisations the `making-do` waste (Koskela, 2004) also comprises this group. Making do is the main waste in construction (Koskela et al., 2013), whilst Viana et al. (2012) identified three main types, namely: Construction material waste (physical waste), Non-value-adding activities (process waste) and Specific sorts of waste (such as accidents and rework).

A study of waste in construction has demonstrated that that one model is not common to the area of construction management and economics (Koskela & Ballard, 2012). The results have shown that waste is restricted in comparison with different subjects in construction, and several investigations have concentrated on the causes rather than the *root* causes.

Moreover, LC community members have conducted research into non-added value activities and process waste (Viena et al., 2012).

Waste at the project level

Last planner is a Lean, production-based project planning system, which combines a multiple-level planning framework including look-ahead planning, master planning and weekly work scheduling to develop work flow reliability (Ballard, 2000a). Master planning determines a project's performance policy and work packages. Operations are monitored for their readiness by assessing the possible effect of engineering, contracts, resources, and prerequisite tasks on work performance (Choo, 2003). Such examination minimises unevenness in the work flow and shields downstream processes from upstream ambiguities (Song & Liang, 2011). Furthermore, look-ahead planning advocates a pull system that pulls upstream material and off-site work to match the progress on site (Tommelein, 1998).

Zhang et al. (2005) proposed a management strategy in relation to waste, which concerned all contributors in a project comprising labour, information, material, equipment, work space, and time, as potential sources of waste. Ballard (2001) stated that mobility was the basis of waste in construction and that steady-flow production can enhance work flow reliability, and as such cycle times in housing construction could be reduced. Bashford et al. (2003), on the other hand, affirmed that the strategy only had a minor effect on the housing construction period; however, it could notably minimise work flow mobility.

Waste at operation level

Research in the industry has demonstrated that 30%-35% of construction costs are waste and do not add value for the customers (Forsberg & Saukkoriipi, 2007). Furthermore, Koskela (1992) and Mastroianni and Abdelhamid (2003) mentioned that waste in construction operations comprise over-production; over-processing, delays and waiting; double handling of materials; excess inventory; unnecessary movement of equipment and people and rework.

2.6.2 The Development of Lean Construction

> *'Lean Construction is a new paradigm challenging traditional thinking about construction and project management'* (Ballard & Howell, 2008).

Since the introduction of LT to the construction industry (Koskela, 1992), both academia and industry have endeavoured to develop Lean Construction. On the basis of Lean manufacturing, Koskela (1992) evolved 11 principles of flow process design and development for construction; these principles are currently applied to academic Lean Construction literature (Low & Teo, 2005). Moreover, Bowen and Youngdahl (1998) presented cases of process-based services that implement Lean techniques, which is significant as construction has both service and production system features. Nevertheless, Lean construction poses challenges as it is often centred on project-based production (Salem et al., 2006), although socio-technological contexts are applicable to Lean Construction (Niepce & Molleman, 1998) as the mixture of people and technical components enable effective outcomes (Moore, 2002; Salem et al., 2006). Nevertheless, in practical terms, it is important to ascertain the set of practices that can be implemented to succeed effective outcomes for construction projects.

Bertelsen and Koskela (2005) identify that LT principles develop from a condition with a prominent product and client focus; this involves an accurately depicted production process, and a well-organised supply chain, which better relates to manufacturing than construction. Hence, Koskela (2004) contended that LT principles are restricted to the transformation of mass production and are not applicable for the characteristics of production in construction. These principles are only slogans, which focus on the work flow in production (Bjornfot, 2006). Thus, it is postulated that construction needs to move beyond LT to develop a construction manufacturing theory of its own (Bertelsen & Koskela, 2005; Koskela, 2004). However, Green and May (2005) emphasised the irony in moving beyond LT before anyone has been able to depict what Lean is in reality.

In acknowledging the lack of LT in construction, Koskela (2000) introduced the Transformation-Flow-Value (TFV) theory of construction production. Since its introduction, TFV theory has been the main focus for the execution of research into Lean Construction (Ballard, 2001; Bertelsen, 2003; Bertelsen & Koskela, 2003; Rischmoller et al., 2006). TFV theory promotes the implementation of LT principles in construction management (Winch, 2006). According to Koskela (2000), construction is carried out by transforming inputs into outputs, where information flows through added value and non-added value actions, and value for the client is the ultimate aim.

However, Ballard and Howell, (2003) stated that the principal thrust in LC for managing construction project processes is the Lean Project Delivery System (LPDS). In contrast to conventional construction processes, the LPDS considers construction stages as interconnected. LPDS is well established in the Lean Manufacturing system; defining the project stage of the LPDS is akin to the distribution stage of Lean Manufacturing, for example extensively identifying the requirements for production by precisely comprehending and converting the client's needs into product specifications (Freire & Alarcón, 2002). Accordingly, Lean design focuses on the same target as a product development in Lean Manufacturing; for example, producing products with specifications that fully meet the client's needs.

On the basis of LC development, there are two important perspectives that should be taken into account. The first considers construction as manufacturing with the aim of adopting Lean principles within construction through flow process design methods. From this perspective, the LPDS brings about new Lean concepts to the construction processes. In the second perspective, LT in construction is represented by the aim to develop the principles of LT to construction by the TFV production model (Bjornfot & Stehn, 2007). It has been acknowledged that both these views have promoted the development of LT practices in the construction sector.

Lean Construction techniques have been analysed and improved by two different research streams. Howell and Ballard (1998) initiated the practical stream, which noted that typically 50% of the assignments in a weekly plan are realised on site. Furthermore, the innovative strategy, Last Planner System was created for production control (Ballard, 2000); while Last Planner focuses on production development and control production system design methods have also been improved (Ballard et al., 2001). Moreover, several new techniques for design management and other sides of construction have been developed (Bertelsen & Koskela 2002; Bertelsen et al., 2002).

The hypothetical stream began with Koskela's (1992) study of the implementation of a new manufacturing approach to construction, and relates to the understanding of common methods of operational management (Bertelsen & Koskela, 2005). Furthermore, the validity of these methods has been analysed within the production context of construction (dos Santos, 1999). Koskela (2000) discussed the techniques and provided a theoretical explanation for the methods on the basis of recent theories in operation management. Whilst the study principally addressed the production system, research on the management system mainly focused on the project management context (Howell & Koskela 2000; Koskela & Howell, 2002a, 2002b) and the underlying techniques of LPS. Moreover, they also underlined problems in complicated systems such as construction (Bertelsen, 2003).

The essence of the new manufacturing philosophy categorises views into two groups, namely flows and conversions. Although in every activity money is expended and time is consumed, conversion actions add value to the transforming information to a manufacturing good. Thus, the development of non-added value flow actions (inspection, moving, waiting) must mainly focus on their reduction and elimination, while conversion actions must be more productive (Alarcon, 1997). Both views need to be taken into account in planning, control and development. In contrast, conventional management principles have either tended to focus only on conversions or considered every activity as an added-value conversion (Alarcon, 1997).

Formosa et al. (1998) recommended that value stream analysis reduces non-added value activities, and demands significant effort to obtain client needs, stabilise activities with a high mobility, eliminate cycle periods, and simplify the process, improve the transparency of the process to its contributors, focus on the accomplishment of design phases before starting the subsequent steps, and describe and control performance measures through the design process (Tribelsky & Sacks, 2011). Due to conventional management principles, flow processes have not been monitored or developed in methodical design, whilst conversion activities have led to complex flow processes, the development of non-added value actions, and the elimination of output value (Alarcon, 1997).

2.6.3 Collaborative Planning and Collaborative Programming

Customer satisfaction is the main objective of Collaborative Planning and Collaborative Programming; this is captured through increased transparency amongst project stakeholders so that the project is completed on time, and at the right cost and quality. Collaborative Planning is the process of developing a reliable construction programme early in the business case preparation, by directly involving everyone in the project team as well as the client. This allows them to plan the project and debate its intricacies until a consensus is reached from the start to the end of all activities (Ballard, 2000; Mossman, 2013). The process is essential to the harmony of the project team; it builds trust, and creates an atmosphere where the project details are fully understood by every member of the project (Anderson et al., 2011; Pasquire et al., 2015).

Ballard (2000, cited in Pasquire et al., 2015) reiterates the importance of Collaborative Planning, which allows all project stakeholders to make collective decisions and identify the "best opportunities to be used in addressing the problem under consideration." Whilst many contractors believe that they are already planning their projects 'collaboratively', namely that the main planner consults with each supplier separately, this is not Collaborative Planning. Instead, CP is "about contractors and sub-contractors working together to improve productivity, reduce time and cost"; it ultimately improves project completion reliability (HE, 2017b). Collaborative Planning, also known as Collaborative Programming, or phase scheduling must be executed with transparency in order to achieve optimal completion time, curb delays, eliminate non-value adding activities, eliminate waste from re-work, improve communication, and reduce conflict. This is because, at weekly collaborative planning sessions, team members would have the opportunity to discuss requirements, hone responsibilities, allocate resources, set the start and finish times of activities to the agreement of all members, and set weekly targets and accountability measures.

Traditionally, collaborative programming has not always been undertaken on projects due to the adversarial nature of construction procurement, which was driven by the JCT forms contract. Many argue that might have been the main reason for many construction project failures (Howell & Ballard, 1998). A partnering procurement methodology is now advocated by most construction professionals, especially the government, which is driven by the NEC forms of contract, because it allows collaborative working and makes collaborative programming possible (Zaghloul & Hartman, 2003). Figure 2.6 shows that collaborative planning has three elements: production control, collaborative mapping, and process improvement.

Figure 2.6: Elements of collaborative planning

Highway England defines the three CP elements as:

- Production Control – enabling better productivity through effective resource and information management
- Collaborative mapping – Better planning through creation of process-based look ahead programmes
- Process improvement – through the implementation and adoption of Continuous Improvement tools

2.6.3.1 Production Control

Production control is synonymous with the Just-In-Time (JIT) delivery system. It is the means by which a project team manages information, labour, and materials in order to achieve an efficient delivery (HE, 2017). Moreover, it is a process by which materials are brought to site when needed, in the right quantity and quality, without building-up an inventory on site. Here, the team meets daily (or weekly) in design teams to hold production meetings and create collaborative work plans in order to: commit to tasks and be measured on successful reliable task completion, understand dependencies with other team members, and capture reasons for not achieving the agreed tasks for the purpose of future learning and improvement (similar to a feedback loop). Production control consists of four key tools; work planning, make ready, standard processes, and data analysis.

- *Work planning*: the team creates work plans to focus on reliable promises by using the Plan, Do, Check, and Act (PDCA) cycle (see Figure 2.7). This enables the measurement of learning throughout (HE, 2017). The PDCA cycle represents a scientific process where a modification is proposed (plan) and implemented (do); measurement data are recorded and assessed (check); and the change is either adopted or rejected (act) based on whether the proposed change actually reduces waste and adds value.

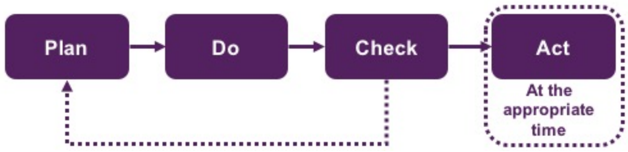


Figure 2.7: Work Planning (HE, 2017)

- *Make Ready*: the aim is to remove constraints to planned activities before the particular work can start (Pasquire et al., 2015). Teams are facilitated in meetings to map and agree the enabling activities required in order to remove task blockers and maintain production. Tasks are made ready when all inputs (materials, labour, plant, and controls specification) are in place and matched to the present circumstances on the construction site; thus, task constraints are removed (Ballard, 2000). According to Koskela (2000), unless tasks are made ready, non-value added activities can easily creep into the construction process. Therefore, it is essential that only sound activities (from which constraints have been collaboratively removed by all members involved) are added to the weekly work plan for execution (Mossman, 2013).
- *Standard processes*: the majority of highways construction activities are repetitive and so an opportunity exists to standardise the steps and understand the constraints and enablers.
- *Data analysis*: the production control measurement and learning generate robust performance data that can be analysed to show areas in which to improve performance. Mossman (2014) asserts that the evaluation process enables project team members to remain committed to the overall project objective. The following

are types of analysis undertaken: the reliability of the percentage plan completed, or the percentage of activities completed to the activities planned (Pasquire et al., 2015); the reasons analysis, which shows categories detailing why tasks are not complete; and a root cause analysis which establishes the underlying cause(s) for incompletion. The results of these analyses are used for process improvements.

2.6.3.2 Collaborative Mapping or Look- Ahead planning

Derived from Lean practices, collaborative mapping or look-ahead planning aims to eliminate construction waste, including rework, over processing, idle times and delays, over-processing, rework, and unnecessary transportation (Ballard, 2000). By making prerequisites ready and checking for the presence of essential resources, look-ahead planning also ensures that tasks broken down to an operational level could, in fact, be carried out as scheduled (Ballard, 1997; Hamzeh, 2011, Hamzeh et al., 2012). Pasquire et al. (2015) state that the objective of collaborative mapping is for members of different companies to work together to create a three to six week, short-medium term plan, to agree sequence of work (or a look-ahead plan), and to identify and understand the enablers and constraints to ensure success. On the other hand, according to HE (2017a), collaborative mapping should be undertaken regularly on a rolling programme every 4 to 10 weeks, depending on the type of work. The frequency of meetings and look-ahead planning may be different from project to project, but it is important that both are undertaken.

Sometimes the best approach to collaborative mapping is to work backwards from the milestone, tracing every step, whilst measuring, learning and recording for knowledge transfer. The team uses colour coded post-it notes produced by discipline/team members for each step to identify who does what; this helps to build the commitment of members to the plan, as well as encourage trust and transparency. In the process, they capture constraints/enablers on the map, so that team members are clear and aligned on the look-ahead plan. Collaborative mapping allows for members of the project team, from the project brief stage, to: buy-in and agree on the project milestones; identify interdependent and overlapping tasks and develop and offer with solutions to sequencing issues; clarify front-end requirements early, and assign responsibility to, and promote accountability amongst stakeholders. According to HE (2017b), the process will ultimately:

- reduce programme duration,

- Improve collaboration, transparency and understanding,
- Better integrate suppliers,
- Reduce time and cost,
- Allow side agreements to be clearly understood and captured.

Furthermore, Mossman (2014) and Ballard (2000) affirmed that, the traditional method of procuring construction projects fails to remove constraints from planned activities; therefore, unforeseen and unwanted non-value activities tend to appear in the construction phase. It is essential that non-value adding activities are removed from the beginning by eliminating constraints early on so that only sound activities are registered for execution in the weekly work plan (Pasquire et al., 2015). Koskela (2004) also outlines some of the benefits of the look-ahead plan. They are as follows:

- The plan ensures that there is a smooth flow between planned activities;
- It matches the planned activities to the current realities on site i.e. available materials, labour and resources;
- It ensures that only sound activities that have been made ready are executed and completed as planned;
- It collates similar-activities for group execution;
- It encourages the group planning of activities.

The development of Lean methods and look-ahead planning, serve as an operational means for more practical scheduling. Look-ahead planning breaks down and adjusts the master plan; it then develops the work to the subsequent phase to optimise the detailed level processes on the basis of existing real resources and the completion of prerequisites.

2.6.3.3 Process improvement

The main purpose of process improvement is to identify issues with existing processes and to provide improvements by those undertaking the work on site without the need for interventions from senior management. Data analysis within the process control helps to identify problems and their associated baseline in order to make improvements. After problems in the process have been identified, the project team sets out the main objectives of the improvement. The team adopts the improvement objective as a focus for creating the right and most suitable solutions to the problem. Furthermore, the project team makes use of a variety of Lean tools to generate process improvements. They include, but are not limited to, Blitz, DMAICT from Sig Sigma, Total Quality Management, and Agile Management (Ogunbiyi, 2014).

1. **Blitzes: –** Blitz, according to HE (2017b) involves people 'on the shop floor' or on site. This entails the people actually undertaking the work having a short 'one-off brainstorming event' that "focuses on productivity improvement and the identification of long-term waste reduction." The process can take several days of workshops attended by all participants in the process involved in the improvement. They are brought together to examine the process and offer ideas for rapid improvement.

2. **DMAICT**: **–** Define, Measure, Analyse, Improve, Control and Transfer (DMAICT), is the model upon which the Sig Sigma technique is built. The Sig Sigma methodology is concerned with process improvements through the reduction of variations. It is viewed by many as a powerful, statistics-based continuous improvement methodology that aims to achieve business process improvements through (1) understanding customer needs, (2) analysing factual data, and (3) re-inventing business processes (Ogunbiyi, 2014; Van Seaton, 2010). On the construction site, DMAICT is a tool used over longer period and involving the entire team in the process to identify the problem and implement long-lasting solutions. According to Bicheno (2004) and HE (2017b), the process of DMAICT helps the project team to:

    - Define the problem,
    - Measure performance,
    - Analyse the data for improvement opportunities,
    - Determine and implement solutions,
    - Maintain and control associated improvements, and
    - Transfer improvements.

    Define: - the project team is tasked with identifying the problem that requires a solution in order to meet the customer's needs. Therefore, it is critically important to understand the customer's needs, which can be achieved through value stream mapping. Listening to the voice of the customer and understanding the problem enables the team to optimally structure organisational processes (Ogunbiyi, 2014). The nature of the problem must be stated clearly and its scope, and potential constraints. The project team must also define the resource requirements, while top management must provide adequate support and the necessary approval to actualise the solutions (Shankar, 2009).

Measure: - after the problem has been defined, and measuring information about the process (problem) through process maps, a risk analysis, and a process capability analysis, leads to a thorough or greater understanding of the problem (Shankar, 2009).

Analyse: - the root cause of the problem is analysed using a cause and effect or Ishikawa diagram; from this, solutions are generated to meet and correct the defect (Ogunbiyi, 2014).

Improve: - after the best course of action to correct the problem has been identified, the work must be carried out. The earlier this is undertaken the quicker can the company begin to see improvements in the overall process and ensure customer satisfaction (Ogunbiyi, 2014; Shankar, 2009).

Control: - involves the proactive continuous improvement and measurement of processes so that complacency does not emerge, and the problem recurs, or another develops. Therefore, the project team is always looking to control and improve the process (Ogunbiyi, 2014).

Transfer: - this involves recording, storing and transferring learning from previous and current projects into future ones. In other words, it is imperative that solutions to problems, techniques and tools are developed, that new improvements are learnt, and are not only taught to protégés, but also kept for future reference when faced with similar problems in the future.

Lean and Six Sigma are not the same but share the general purpose of waste elimination, and process improvement; a comparison is shown in Table 2.2. Lean Six Sigma requires a level of competence in Lean, total quality management, and constraints theory in order to bring about the desired business improvement in terms of improved quality, the reduction of time and cost, the elimination of waste, and the incorporation of innovation

(Ogunbiyi, 2014). Therefore, the term 'Lean Six Sigma' has emerged and was defined by ASQ (2018) as:

> *… a fact-based, data-driven philosophy of improvement that values defect prevention over defect detection. It drives customer satisfaction and bottom-line results by reducing variation, waste, and cycle time, while promoting the use of work standardisation and flow, thereby creating a competitive advantage. It applies anywhere variation and waste exist, and every employee should be involved.*

Table 2.2: Difference between Lean and Six Sigma

Area	Lean	Six sigma
Objectives	Reduce waste, improve value	Reduce variation Shift distribution inside customer requirements
Framework	5 principles (not always followed)	DMAIC (always followed)
Improvement	Many small improvements, a few low Kaizens. Everywhere, simultaneous	A small number of large projects One at a time.
Typical goals	Cost, quality, delivery, and lead time. Financial often not quantified	Improved sigma level (attempt six sigma 3.4 DPMO). Money saving
People involved in improvement	Team led by (perhaps) lean expert. Often wide involvement on different levels.	Black belts supported by green belts
Time horizon	Long term. Continuous, but also short term kaizen	Short term. Project bt project.
Tools	Often simple but complex to integrate	Sometimes complex statistical.
Typical early steps	Map the value stream	Collect data on process variation.
Impact	Can be large, system-wide	Individual projects may have large savings
Problem root causes	Via 5 why's (weak)	Via e.g. Design-Of-Experiments (strong).

Source: Bicheno (2004)

3. **5WHYs: –** 5Whys is one of the simplest and most useful tools for root cause analysis. This is used at the 'Analyse' phase of DMAICT, and simply involves asking the question 'why' until the fundamental reason for a failure is disclosed. The 5Whys technique works like an onion; with each 'why' question, a symptomatic layer is peeled away, which may lead to another 'why' question and another layer being peeled away until the root cause of the problem is determined. However, the problem is first formalised and understood properly by the team, so that they focus only on the problem

when answering the why questions. In practice, more or less ‘why’ questions can be asked before the root cause of the problem is disclosed. The 5Whys technique can be used as part of Fishbone diagram (Ishikawa or cause and effect diagram), where the project team explores all potential or real causes of a problem. The 5Whys technique is then used to drill down to the root causes once all inputs are established on the fishbone diagram (iSixSigma, 2018).

4. **5S process**: – the 5S process is an organisational technique and integral part of a Lean initiative that helps companies standardise their activities in a systematic way in order to eliminate or reduce waste. Thus, 5S stands for: sort, set in order or straighten, shine, standardise and systemise or sustain. According to Ogunbiyi (2014), the 5S process stipulates that there is ‘a place for everything’ and that activities should be organised as such. It is a form of housekeeping that is used to sort materials and tools according to their usefulness, or according to when they are needed on site. These are set out in order, cleaned up to ensure they are in a perfect condition, and finally, the process is standardised and systemised to ensure both system control and improvements (Spoore, 2003) so that the desired results can be repeatedly achieved. The 5S process implementation leads to continuous improvement, increased productivity, improved set-up times, increased machine uptime, improved lead-times, increased space (JIT), an improved quality, an improved team atmosphere, and reduced cycle times (Ogunbiyi, 2014).

2.6.4 How to Run Collaborative Planning Meetings

The first and most important factor is the team leader’s ability to create a relaxed environment where everyone feels comfortable to give their input without fear of criticism or intimidation. The team leader, usually an experienced person in Lean or Six Sigma, facilitates the group to create the parameters upon which the meetings will be conducted. These parameters or ground rules should be designed to elicit the best from every member at the meeting, and facilitate engagement, debate and negotiation that leads to a consensus on the process steps. The space should encourage communication and brainstorming, and be open enough to allow people to pace around if needed. Moreover, a large blank board is needed to encourage post-it notes and sticker paper for inputs, and refreshments should also be provided.

During the session, the team leader should direct the conversation and keep the focus on the main issues for which the solutions are to be developed. They must set out a target objective or a milestone for the team on which to focus their efforts. The team should agree on the sequence of works whilst outlining the enablers and constraints for each step in the sequence. After this, collaborative mapping takes place where the team walks backwards from the milestone and inserts colour coded post-it notes, by discipline/team member for each step (HE, 2017). Finally, the production control sessions are held when the stage progress and commitment can be agreed; depending on the size of the project or work, four to ten-week intervals are recommended.

Highways England’s collaborative planning technique has been deployed on various construction sites; this has reduced programme durations and ensured that issues are raised early and resolved by the team at the lowest and most practical level. Collaborative Planning, Lean visual Management, 5Ss, and other Lean techniques improve communication and increase engagement. The Collaborative Planning process provides data capture, which means that the team have a clear understanding of their performance and capture the reasons for non-performance in order to reduce such factors. Collaborative Planning is also applied to the design processes to increase the reliability of design programmes.

HE wants to see its suppliers embed a Lean approach within their businesses in order to become more efficient. Therefore, the organisation has developed HALMAT (Highways Agency Lean Maturity Assessment Tool) to assess the companies in its supply-chain by identifying the areas in which they need to improve. In fact, HE’s Board has agreed to use the HALMAT tool as part of their supplier selection process in order to achieve improved efficiencies within their supply chain. In using HALMAT to assess companies, HE looks for evidence of the deployment of Lean techniques, which includes Lean Visual Management and Collaborative Planning together with other Lean techniques, such as 5Ss and Lean Six Sigma. In other words, HE would not work with a supplier who does not show Lean capability and competence. In construction, Collaborative Planning began in the 1980s through the works of Ballard and Howell (Pasquire et al., 2015). They developed the Last Planner System (discussed in 2.6.7), upon which collaborative planning is rolled out and executed.

2.6.5 Visual Management in Collaborative Integrated Planning and Control

Visual Management (VM) is a crucial method in the application of Lean Production. It emphasises the significance of easy-to-understand visual tools for knowledge sharing in the organisation (Liker, 2003). Koskela (2000) asserts that this can be succeeded by making the main procedure flows visible and easy to comprehend from the beginning to the end, through organisational and physical means, dimensions, and public data display. These visual tools may have a significant impact on the mitigation of engineer-to-order production system complexity. Nevertheless, an overload of data might prevent employees from performing their required activities. According to Galsworth (1997), data should be pulled as required, precisely when and where required. Hence the data must be up-to-date and immediately accessible; it needs to be as physically near as possible to the operation to see the differentiation (Galsworth, 2005).

VM promotes the accomplishment of transparency by sharing the most valuable data and eliminating data obstacles within a specific place of work (Koskela, 1992; Tezel et al., 2017). It is an orientation towards visual control in production, quality and workplace organisation (Greif, 1991). Signs, symbols, sounds, colours and odour not only transfer data but also limit reactions to variable levels (Tezel et al., 2017). This may be perceived as a norm for implementation from which deviations are immediately recognisable (Koskela, 1992).

The need for the latest procedural data increases when flexible outputs are required, as alterations in product specifications and staff tasks need specific and direct dissemination (Formosa et al., 2002). Kurtz and Snowden (2003) state that improved techniques that share the correct data diminishes the complexity within production systems, even in complex and unforeseeable production sectors. When there is transparency in the process, the key data source is the process itself; this breaks the common hierarchical framework of order giving (Greif, 1989). Thus, the data sharing method may have an impact on the management of production. Among the rate of non-added value activities and data deficits there is a vigorous connection to the place of work (Formos et al., 2011). Rather than executing added-value activities, individuals usually spend time wandering, searching, or waiting for the techniques, equipment, and data required to perform their job (Galsworth, 1997).

The application of VM could also bring advantages to the planning and control system, through enabling accessible data production in an opportunistic way where the plan will be improved by planning observations and decisions. For Johnston and Brennan (1996), such a method could be perceived as a system of 'management-as-organising' where operatives can learn from production. According to these academics, this conflicts with the ordinarily adjusted *management-as-planning* method where managers set objectives prior to the start of the project and their control is limited to monitoring the operation processes against a schedule. Johnston and Brennan, (1996) further note that adopting the *management-as-organising* method is difficult, as managers are unable to enable direct links among operational procedures and objectives.

Instead, the adoption of VM techniques enhance the ability to process data and reduce the feedback time to take action. Therefore, control could be incorporated within performance, and visual tools may fundamentally promote the application of the management-as-organising method in ambiguous production conditions.

2.6.5.1 Visual Management and Transparency

The principle of transparency is a vital method to resolve issues regarding communication failure amongst the main team members involved in the production process or stages. It also helps to increase collaboration. Therefore, the production process should be made transparent in order to ensure control, and to make the operational main flow understandable and visible to every employee, from start to finish (Stalk & Hout, 1989). Koskela (1992) suggests that this process could be noticeable through organisational or physical means, such as public data display and measurements.

Santos et al. (1998) and Galsworth (1997) suggest that, in the case of physical procedures, operations (for example, production control and planning) also rely on valuable communication, although non-added value activities can reduce, and the administration of production teams can increase. Nevertheless, making the production process more transparent means going further than data transmission through photos, charts and panels. For example, the display of a proposed plan of work on an office wall does not reflect planning transparency, since the consent of team members to such plans is usually inadequate or does not exist (Grief, 1991). However, technological resolution within the community interface might propose a prolonged visibility and play a bigger role in the visual system (Grief, 1991; Galsworth, 1997); for example, through the use of Gamification and VM.

According to Galsworth (1997), a visual system is perceived as set of visual strategies, which are deliberately planned to immediately share data. The use of VM could change the conventional, and often insufficient, method used by several builders. For instance, by adopting a weekly plan of work, the application of graphics and visual components may encourage greater transparency, the simplification of work, the generation of shared possession, and management and facilitation by facts.

2.6.5.2 Lean Visual Management

HE has deployed Lean VM techniques in construction, maintenance, design and office environments. Some contractors have now seen the benefit of the technique and introduced it to other client sites. As they are not geographically based in the same place, the HE Lean team run a weekly Lean VM meeting by computer and telephone. Thus, remote working is not a barrier to the application of Lean VM, which concerns communication and enabling teams to deliver performance improvements over time. A Lean practitioner, or a person trained in Lean Six Sigma, should ideally facilitate Lean Visual Management (LVM) sessions. LVM consists of Visual Displays, Stand-up Meetings, and continuous Performance Improvement by measuring, monitoring and reviewing team performances (HA, 2010). The same parameters that guide Collaborative Planning sessions also drive LVM meetings. These parameters encourage transparency, debate and negotiations without intimidation or coercion so as to ensure the best inputs from the group. Figure 2.8 shows the three elements of Lean Visual Management:

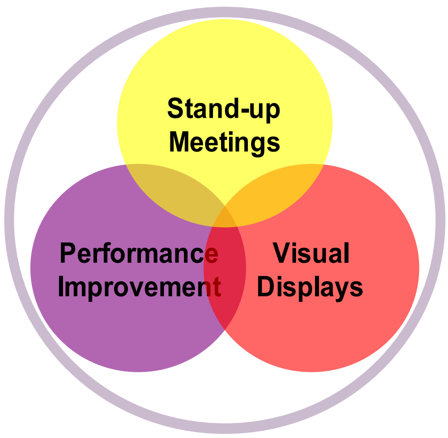


Figure 2.8: Three elements of Lean Visual Management (HA, 2010)

- **Visual displays: -** are large central communication points focused on up to date team specific information and continuous improvement activities (HA, 2010); these are used in stand-up meetings for team interaction. There is dynamic information and also regularly reported information. Visual display boards must not be confused with notice boards; visual displays are central communication points and a place where improvement activity takes place. A visual display covers three key areas: people on site that includes schedules and responsibilities, performance information, and continuous improvement (HA, 2010). It is important to choose the right performance measures to achieve improvement. In addition, Visual Display boards must be close to the team's working area, and regularly updated so that the most up to date information is readily available.

- **Stand up meetings**: - these are short duration meetings (usually 10 to 15 minutes) where team members stand around a visual display board (see Figure 2.9). A stand-up meeting is meant to "review the previous day's performance, plan the current day's workload, identify obstacles to progress, and discuss areas of underperformance and subsequent improvement actions" (HA, 2010). Stand-up meetings are usually held daily at the start of a shift or during a morning break. Discussions based on the project design can be held weekly and usually last for slightly longer than the discussions based on back office activities, which can be conducted daily.

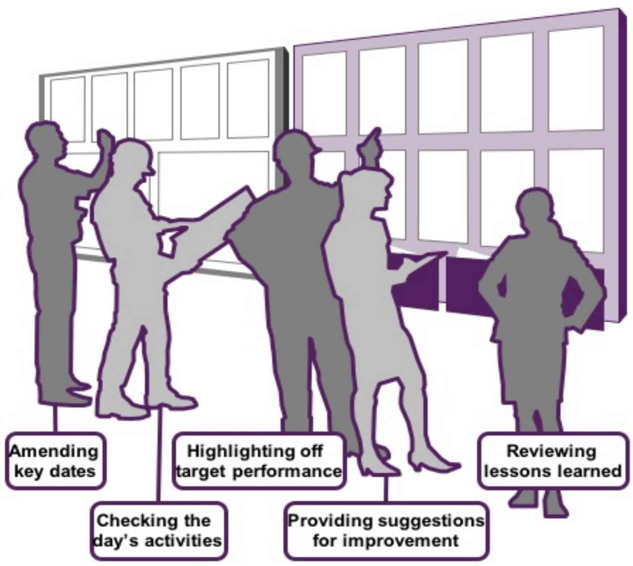


Figure 2.9: Stand-Up Meetings (HE, 2010)

- **Performance Improvement: -** this involves capturing suggestions for improvement from the team, which usually occurs during stand-up meetings. Suggestions should be simple and easy to implement without the need to involve senior management. The greater the number of improvement suggestions made and banked (successfully implemented), the more confidence the team has in the process improvement and their ability to positively influence performance. The two main tools or techniques for capturing improvement suggestions during stand-in meetings are: concern, cause and countermeasures (3Cs), and the four-folder approach (4FA).

2.6.6 Combination of Collaborative Planning System with Lean Visual Management System

According to HA (2010), the best methodology to achieve continuous improvement is to combine a Collaborative Planning System with a Lean Visual Management System (see Figure 2.10). Thus, a Collaborative Planning System plans to do work while the Lean Visual Management (LVM) concerns 'putting people' to work. Moreover, Production Control and Stand-up Meetings work together to set clear production targets and work assignments.

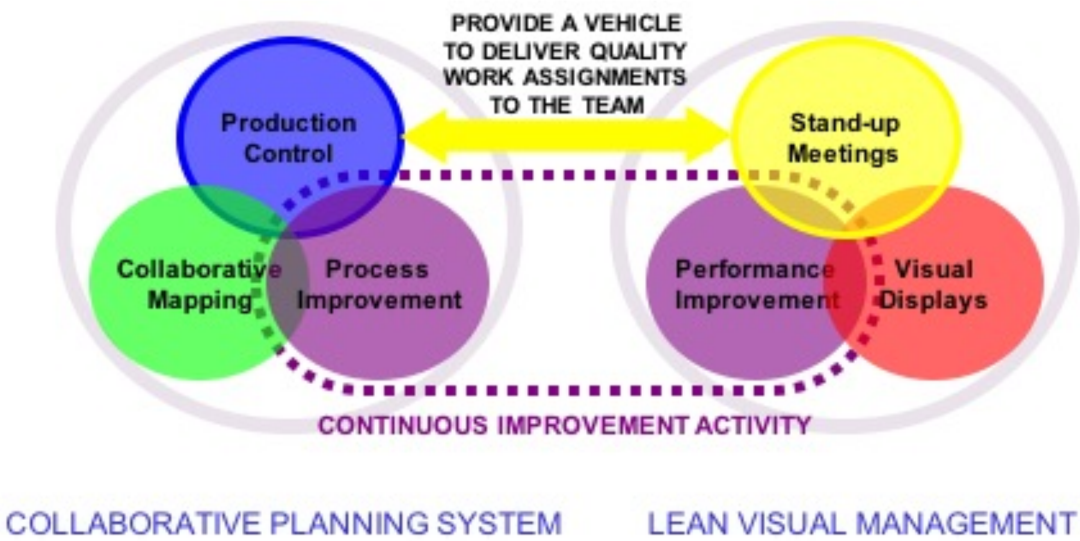


Figure 2.10: Combination of Collaborative Planning System with Lean Visual Management System

Therefore, it is astute to combine both Lean Visual Management and Collaborative Planning to ensure their synergies (shown in Figure 2.10). The colour-coded circles of both processes individually provide a process improvement/performance improvement element, which are two varieties of continuous improvement. In other words, LVM and Collaborative Planning overlap, so, if they are brought together, process and performance improvements can be condensed into one, and only five activity circles result (as indicated by the purple dotted line in Figure 2.10).

2.6.7 The Last Planner System

Last Planner System (LPS) was introduced to the industry in 1992 through the works of Ballard and Howell (2004) and has gained a widespread popularity in construction over the last decade. This is due to its ability to drive a project to achieve better completion times, costs and quality (Daniel et al., 2014). The LPS has the ability to reduce workflow uncertainties; thus, it increases predictability and reliability in the workflow, which in turn increases a project's performance (Ballard & Howell, 2004; Mossman, 2014).

The Last Planner System (LPS) has proved to be one of the most effective Lean tools in the industry (Winch, 2006). It encourages staff or teams to work closely; moreover, it is a method deployed to buffer the progress of work by only allowing value-added activities within the operation (Ballard & Howell, 2008; Koskela et al., 2002). LPS (illustrated in Figure 2.11) is a crucial system for managing logistics and collaboration in a project. (Bertelsen & Koskela, 2004).

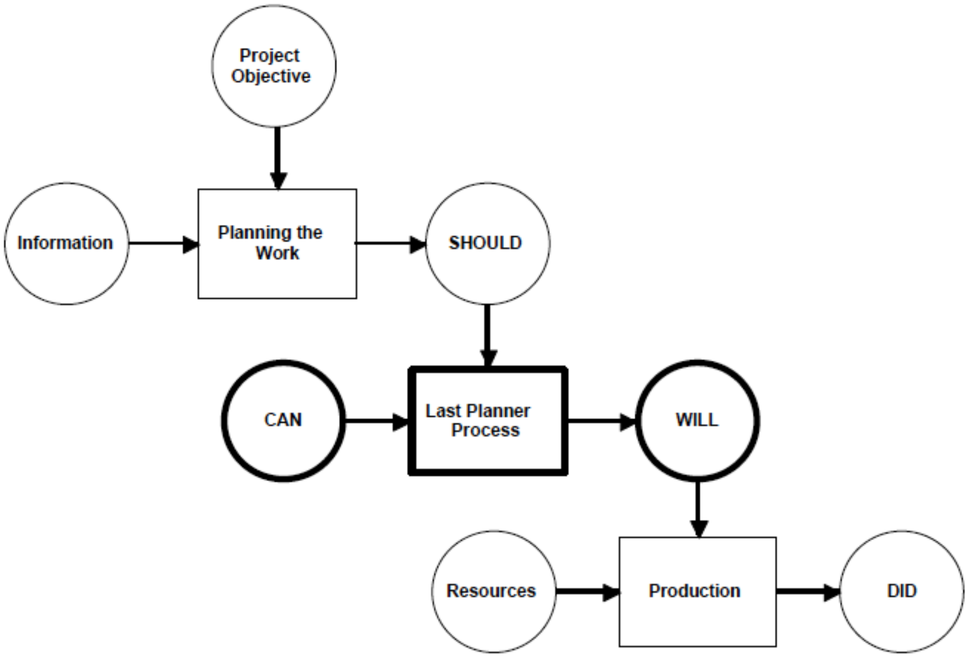


Figure 2.11: The Last Planner System (LPS) (Ballard, 2000)

Alongside other theories, Koskela's 'transformation, flow, and value' concept have elaborated on uncertainties and decision-making issues in the production process, and have largely influenced the development of the Last Planner System (Koskela & Ballard, 2006). As a consequence, the LPS seeks to increase certainty, predictability and reliability in the production process, through production planning and control, and the execution of activities according to a set plan. The Last Planner System is the vehicle upon which Collaborative Planning is driven, and the key principles of LPS meetings are generally similar. First, tasks or activities are outlined in great detail. Second, all those to execute the tasks (last planners) must be present at the meeting and their inputs are collected. Therefore, they are also required to participate in collaborative programming sessions and agree start and finish times for all tasks. Third, all constraints to the execution of the tasks are identified and removed. Fourth, accountability and performance assessment measures are formalised, and fifth, a feedback loop is developed that leads to continuous learning and improvements on future works (Ballard & Howell, 2003; Mossman, 2014). Last planners are responsible for ensuring the success of the collaborative meeting and that work flows smoothly in the construction process. They are responsible for ensuring that transformation, flow, and value creation objectives are achieved.

Furthermore, the production control components can be incorporated into the conventional management system by adopting LP within the process. LP as a mechanism is concerned with converting hypothetical scheduling into actual planning through appraising employees based on their ability to continuously and effectively deliver the work required (Ballard, 2000). Construction, site and project managers are required to schedule meetings and develop a plan of work on a weekly basis in order to successfully manage the project. Ballard (2000) further notes that LP increases performance in production and enhances reliability in planning. In addition, Frandson et al. (2014), outline below with regard to LPS:

Facilitates irregular work variances: LPS completes takt-time scheduling by facilitating uneven work variations, described as fields of work in which a continual flow is unfeasible (Frandson et al., 2014). A LPS accounts for: 'go-back' work,work in specialised access fields, and work in progress.

Facilitates low-level variation: A make ready procedure and commitment scheduling provide a system to enable management to adopt changes. PPC metric accounts for some of this variation since it impacts on the work performance (Frandson et al., 2014). Meanwhile, a takt-time planner considers the variation 'noise' and whether it affects the hand-off work; thus, the LPS is employed to acquire information.

Provides a control system: LPS provides the mechanism to generate takt-time scheduling. Takt-time scheduling is a sequencing and production levelling procedure that is implemented within similar fields of work; however, it still required the means to manage a production plan (Frandson et al., 2014).

Engages workers: LPS enables engagement with the foreman; it involves the real scheduling of work and encourages the offer of practical wisdom whilst rejecting tasks that do not meet the five-quality standard (Frandson et al., 2014).

2.6.7.1 Takt – Time Planning and the Last Planner

The word 'Takt' is German for the word beat; Takt-time is, "the unit of time within which product must be produced (supply rate) in order to match the rate at that product is needed (demand) rate" (Frandson et al., 2013). The purpose of takt-time scheduling is to develop a steady condition for the LPS by dynamically planning a continual workflow for trading activities (Frandson et al., 2014). The LPS is illustrated in Figure 2.12.

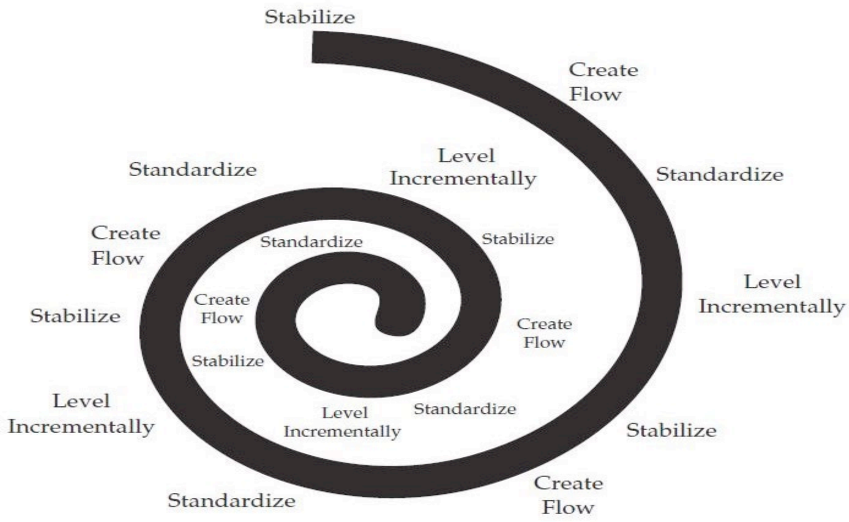


Figure 2.12: Continuous Improvement Spiral (Liker and Meier 2006)

The adoption of takt-time scheduling to production theory has been acknowledged through the use of four language games. Takt-time scheduling utilises production science to constitute a continual flow where feasible and to operate buffers in an extra crew capacity form. The process needs long-term thinking to improve team members' skills and to comprehend the significance of production scheduling. An effective production plan generated from takt-time scheduling can be achieved by the application of Systems Thinking to effectively manage employees' expertise (Frandson et al., 2014). As a result, the advantages and all stakeholder costs ascertain the conditions of satisfaction and trade sequence.

2.6.7.2 The Last Planner System Implementation Process

According to Mossman (2014), the implementation of the Last Planner System is based on the following: milestone planning, collaborative programming, making ready, production planning, and production management (Pasquire et al., 2015). Figure 2.13 shows these key processes, which are therefore important because they enhance collaboration amongst the project team. Mossman (2014) emphasises the importance of focusing on the flow of activities during LPS implementation which will lead to task optimisation.

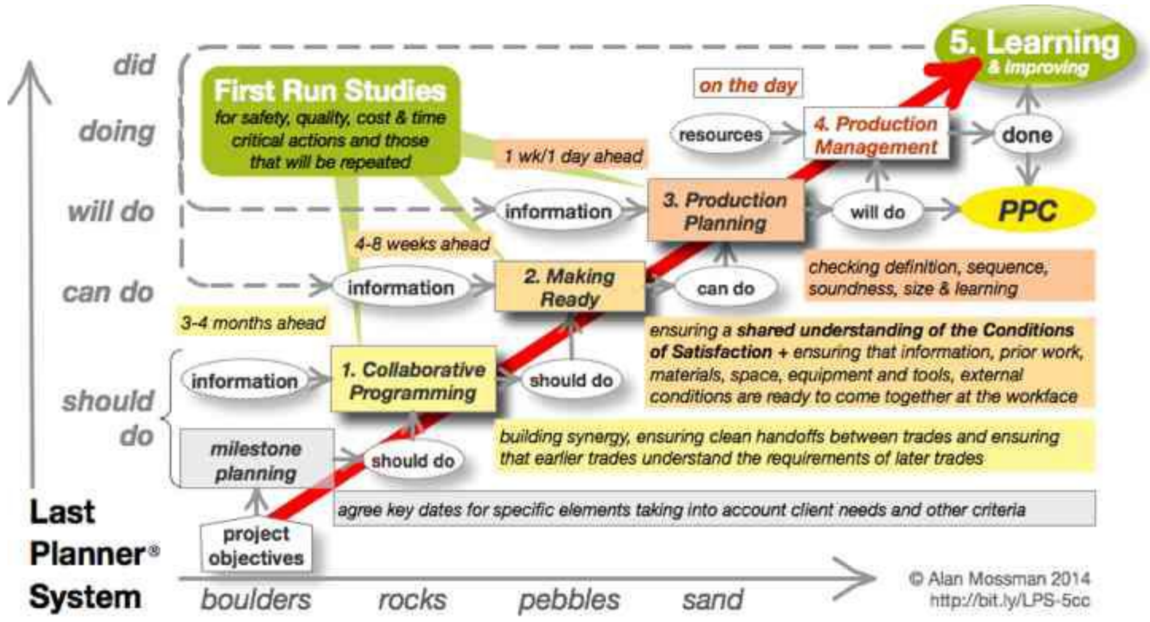


Figure 2.13: The Last Planner System Implementation Process (Mossman, 2014)

Milestone planning known as the 'Master Plan', is the first stage of the LPS implementation process which details the project tasks and activities, with their associated start and finish times, as well as the method statement for the execution of each task (including who will execute the task, and a risk assessment). There are many software programs on the market used to develop the Master Plan; Microsoft Project and Primavera are the most commonly used. The next stage is **Collaborative Programming** also known as Collaborative Planning or Phase Planning. This aims to draft a reliable and predictable construction programme using the Master Plan, by ensuring that all members of the project team and the stakeholders of the project collectively give their inputs to tasks planning, control, and execution. According to Pasquire et al. (2015), Collaborative Programming helps to reduce the miscommunications of orders; eliminate delays, rework, non-value adding activities; and reduce occurrences of project litigation.

The third stage is 'look-ahead planning', which develops a short to medium term plan from collaborative planning, and sets out the tasks for execution within the next three to six weeks. Moreover, it outlines each task constraint, permissions (if required), materials, labour, plants, resources, space, and so forth. Look-ahead planning then leads to the '**Making ready**' stage, which eradicates the constraints identified earlier in the planned activities. According to Ballard (2000), the main aim of the make-ready process is to allocate resources to the planned activities whilst taking note of current site conditions and circumstances; this aims to ensure a problem-free optimal flow of activities. Traditionally, Master Plans are not broken down into weekly plans and considered in great detail; instead, this is undertaken within the LPS. Consequently, such plans generate non-value adding activities at the construction phase because they are not 'made ready' before the start of the works on site; therefore, these sites have not had the same level of performance as those using LPS (Pasquire, et al., 2015).

The next stage is '**Production planning**', which is also known as the 'Weekly Work Plan'. It involves the project team collaboratively generating weekly work plans to review the planned activities from the previous week in order to prepare the planned activities for the week ahead. It is imperative that the Weekly Work Plan is sound it is only allowed into the production process when it is made-ready. This means that the last planner(s) has to commit to, and be accountable for, the execution of planned tasks. When last planners make these commitments, the predictability and reliability of the construction programme are assured. It is at this stage that some Lean tools, such as 5Whys, the Ishikawa diagram, and DMAICT, can be used to analyse/review the reasons for the non-completion of planned tasks from the previous week. The root cause for non-completions are identified, corrected, and documented for future learning so the project team does not repeat the same mistakes (Ballard, 2000; Mossman, 2014). On the day of production or the execution of the planned work/task, a meeting is held, usually in the morning, to review the previous day's activities and to discuss the current day's planned activity. This is called the **'Production management and control'** meeting, also known as the 'stand up meeting' or 'daily huddle meeting', when last planners meet to discuss their reservations or concerns, and raise issues with the works, so that necessary actions can be taken to immediately address them (Mossman, 2014). Lastly, '**Learning and improving'** requires the last planners to evaluate and measure the executed works against the project objective, before making corrections to ensure that the client's needs are captured. According to Pasquire (2015) and Mossman (2014), at this stage the "Percentage Promised Completed (PPC), the Reason for Non-Completion (RNC) and Reliability Index" are the most important measures in the Last Planner System. The two measures provide an indication of project productivity and consequently, that of the last planners (Liu et al., 2010). PPC is calculated by finding the percentage of the 'total number of activities completed', to the 'total number of activities promised.'

2.6.8 Collaborative Planning and the Last Planner System

Collaboration is an integral part of the Last Planner System; without this, it is impossible to achieve the desired result of the collective input from project stakeholders. Collaborative Planning requires effective weekly or fortnightly Last Planner System meetings. Project team members work collaboratively to deliver a project by setting targets and timelines, identifying constraints, eliminating constraints, measuring and recording all learning, whilst meeting the client's specification (Pasquire et al., 2015). Collaborative working is especially important for construction projects because no individual has all the knowledge required to deliver a project. Instead, knowledge is dispersed across many disciplines within the team. Therefore, a construction project requires people to work collectively, effectively and efficiently to deliver the project according to the specifications. The traditional method of procuring projects hinders collaborative working and stifles LPS; this is due to the adversarial nature of contractual relationships where the realisation of individual benefits is prioritised over the collective good of the project (Egan 1998; Latham, 1994). As a result, most traditionally procured projects are plagued with cost and time overruns, miscommunication, a lack of trust, a lack of transparency, claims and litigation (Crotty, 2012; Udom, 2013). On the other hand, the Last Planner System promotes: collaborative working relationships, communication, transparency, the sharing of information for the sake of driving the project, interactions and an atmosphere of trust, less conflict and fewer claims, the early elimination of problems, and on-time delivery at the right cost and quality.

2.7 Lean Construction Theory in the UK

As previously discussed, Lean Construction Theory (LCT) aims to eliminate all forms of waste throughout the entire construction process value-chain. Lean Thinking (LT) is perceived as progress towards LC, which focuses on meeting the client's needs by ascertaining value and successfully managing project processes with minimal labour in a shorter timeframe (Womack & Jones, 2003). Nevertheless, Forbes et al. (2002) assert that LCT is a process of enhancing value within process and supply chain management while minimising the waste through the application of Just in Time (JIT) methods. Koskela et al. (2002) define LCT as a principle by which design and construction processes reduce material, effort and time in order to generate value management.

Construction organisations have been adopting Lean Construction (LC) since 1990 with unique alterations based on their needs. Koskela et al. (2002) affirm that the purpose of LC is to integrate three systematic methods for construction planning, namely: flow view, value view and transformation view. These views all focus on different perspectives. LC is structured, developed and controlled simultaneously to achieve these objectives. Green (1999) posits that LC needs to be considered thoroughly throughout its deployment, and notes that, as Lean originally came from the Japanese automotive manufacturing its adoption by the UK construction industry (UKCI) would pose difficulties due to the cultural and organisational differences. However, various Lean implementation practices can be modified by adapting them to the UKCI based on their specific organisational culture and structure. For example, in steel manufacturing, the form of deployment includes Just-in-Time (JIT) techniques for delivering projects and a process map for value streams. Picchi and Granja (2004) state that, through the implementation of these principles, the application of LCT has enabled the broad accomplishment of its objectives.

The approach to Lean Construction within the UK helps to determine the level of profitability and aims to develop strategies for project delivery. Nonetheless, deploying Lean in construction can be challenging due to cultural and organisational differences within the industry. However, following the adoption of LC in projects, the industry has been described as more successful (Koskela, 2000; Salem & Zimmer, 2005). Some principles have been implemented within construction manufacturing with no adaptation, whilst others have been altered for the delivery of construction projects or have merely been employed to deliver construction projects towards LT.

According to Arbulu (2006), LT implementation in the construction industry promotes a change in organisational behaviour, which helps to develop the approach to project management. Indeed, these developments have increased the productivity and performance of construction firms (Arbulu, 2006). Furthermore, investigations into Lean in construction projects have demonstrated that various factors can support or hinder its implementation (Karlsson & Ahlstrom, 1996); these are discussed in section 2.5.

Nevertheless, construction firms utilising standardised production procedures to construct a significant number of affordable housing units are confronted with the difficulty of supplying customised projects for clients (Frutos & Borenstein, 2003; Rosenfeld & Paciuk, 2000). Organisations implementing conventional planning with a centralised control and the extensive subcontracting of highly customised projects face obstacles. These challenges include: the long project duration required to complete specific schemes, a loss of control by project management, and schedule and budget overflows. Sacks et al. (2005) state that Lean Construction is often of immediate interest to construction managers and planners as it brings full customisation with minimum waste and no extra resources. However, standardisation is extremely hard to achieve in construction because of the many changing variables that emerge with different projects.

2.7.1 Contracts

The Egan (1998) and Latham (1994) reports of the 1990s have had an appreciable effect both on UK contract forms and procedures, and on procurement methods. While the latter focused on the inter-relationship between parties to a contract and fair dealings, the former focused on the elimination of industry inefficiencies. These reports, amongst others, identified the production and current use of about 41 standard forms of building contract in the UK (Clamp et al., 2007). The JCT publishes 18 forms of contract, including variants, subcontracts, and framework agreements. Moreover, the Property Advisors to the Civil Estate publish another 15, including variants, whilst the ACA publishes four main forms, and the ICE another four main contracts that include all 23 documents of the NEC suite (Clamp et al., 2007). The NEC3 Contracts total six, namely options A, B, C, D, E, and F, where the contractor's level of risk decreases incrementally from A-F (See Appendix 1 for a summary of all the NEC 3 options).

These legal contracts form the basis upon which the building project is realised and describes the relationship between clients, the main contractor, subcontractors, and other members of the supply chain. The contract also forms a basis upon which responsibilities are enforced. Traditionally, there are three types of contract; lump sum, measurement, and cost reimbursement. Lump sum contracts are characterised by a contractor agreeing to complete a building for a fixed amount; these are not subject to variations by the client once the work starts on site. The variants of this contract type are; lump sum contracts 'with quantities' based on a firm bill of quantities, and lump sum contracts 'without quantities' based on a Schedule of Work, or Schedule of Rates. Measurement contracts, on the other hand, cannot be measured accurately at the time of tendering (NEC3 Option B). Cost reimbursement contracts or 'cost plus' contracts mean the contractor agrees to carry out works and is reimbursed for the actual cost of the works, plus a fee to cover overheads and profits. There are variants of this contract type, which are: cost plus percentage fee, cost plus fixed fee, cost plus fluctuating fee, and cost reimbursement based on a target cost. Target cost contracts are usually associated with cost reimbursable contracts since the contractor is paid for the actual cost of the project post-completion. At the end of the project, the difference between the actual cost and the target cost is shared on a percentage basis between the parties involved and may constitute a saving or loss. Table 2.3 elaborates more on the pros and cons of the different forms of contracts.

Table 2.3: Advantages and Disadvantages of Different Forms of Contracts

Contract Types	Advantages	Disadvantages
Fixed Price and Fixed Fee Price (NEC3 Option A)	• Reduces the client's risk and protects against escalating costs • Fixed price not subject to recalculation • Protects against the client making changes • Firm prices subject to limited fluctuation • A greater degree of certainty • Clarity in the bidding process • Provides maximum incentives for contractor efficiency and a greater profit margin • Predictable cash flow for the contractor • Reduced administrative burden on the contracting parties	• Price will generally be higher • Increased risk for the contractor and less room to vary prices • Tender preparation may be costly for the contractor • Although there is a reduced administrative burden, the record keeping for orders changes may be time intensive • A higher price for any alteration or additions • A slow tender process • The design has to be finished before construction begins leading to slower progress • More adversarial than other forms of contract
Cost Reimbursable/ Cost Plus percentage fee (NEC3 Option E)	• Reimburses the contractor for costs incurred when carrying out the works • It does not provide for any other payment • Used when the full extent of the contract works is unknown	• Does not allow costs to be estimated with enough accuracy to use fixed contract pricing • No real incentive for optimum efficiency on the part of the contractor • Can be expensive for the client
Cost Plus Fixed Fee	• Contractor is reimbursed for all allowable costs plus a fixed fee • It can be used for short contracts • Contract price can be revised subject to contract provisions • Fees are clearly defined in the contract • The price is agreed upon and fixed before the works commence	• Contractors need careful record keeping and documentation to receive reimbursements. • Contract price remains fixed and cannot fluctuate • The contractor has minimal incentives to control costs • May be expensive for the client • May be high risk for the contractor

Target Cost (NEC3 Option C and Option D)	• Cost savings and cost overruns are shared amicably between the contractor and the client or consultant team (pain and gain share). • It provides maximum incentive for the contractor to work efficiently to control cost • It promotes good collaboration • The existence of bonuses and rewards to incentivise the contractor, but these are capped to prevent adversarial behaviour	• May lead to adversarial behaviour if bonuses are not capped • Requires a competent and knowledgeable client to negotiate prices effectively, otherwise, it may become very expensive

2.8 Lean as a Business Model

According to Womack and Jones (2003), Lean is a continuous journey towards perfection. An organisation-wide Lean transformation is a progress that changes pre-existing practises to accommodate new ones by focusing on different strategies (Pekuri et al., 2014). It entails a hypothesis shift in the company that needs complete commitment from management. In construction, there are no significant differences between a firm's business models; instead, such models do not tend to focus on the administration of construction companies (Pekuri et al., 2013). This debate is supported within the field of construction research (Building Information & Research, Construction Innovation, Construction Management and Economics, Journal of Construction Engineering and Management, and Journal of Management in Engineering). Moreover, Brege et al. (2014), and Mokhlesian and Holmen (2012) argue that business models in construction conduct particular outlooks on the basis of pre-existent forms.

With reference to Seddon et al. (2004) a business model is a notional symbol of some facets of a company's policy, whilst Casadesus-Masanell and Ricart (2010) state that it is a reflection of a company's realised strategy. Companies may address similar client needs and follow the same business strategies with altered business models (Pekuri et al., 2014). Therefore, business models and strategies are completions not substitutes (Zott & Amit, 2008). Furthermore, specialists consider that business models encourage an important connection among operations and strategies by clarifying how the operations of a company perform together to carry out the strategy (Osterwalder, 2004).

Furthermore, the business model provides a new focus of innovation that is more significant than conventional alterations (Johnson et al., 2008; Zott et al., 2011). Hamel (2000) states that the business model is a theory that can be practiced, and considers that its alteration is merely a method to avoid competition (Pekuri et al., 2014). Changing a business theory is vital to bring about innovation for value generation; however, such change needs the capability to perceive different business concepts and new methods of distinguishing pre-existent business concepts (Hamel, 2000).

2.8.1 Business Concepts in Construction

Baden-Fuller and Morgan (2010) assert that, when defining a business model, it is important to consider the essential elements that help the model to perform; these are unrelated, and generate no difference from one company and another. Seddon et al. (2004) suggest that the analysis of a business model considers it an abstract symbol of some facets of company's strategy; in comparison, Baden-Fuller and Morgan (2010) define it purely as a 'model' that is insignificant, basic, and merely defines the restricted facets of an actual entity (Pekuri et al., 2014). Therefore, business models select details that are vital indications of the entity, such as information that comprehends how and why a business model performs in a particular way (Casadesus-Masanell & Ricart, 2010).

2.8.2 Conventional Business Concepts in Construction

Based on construction professionals' views, two business models are commonly utilised in the sector (Pekuri et al., 2014). The most frequent model is the contracting model, where the senior management aim to obtain different projects to sustain the resources used and to discover a proficient construction manager to manage the projects on site. In this model particular factors (low cost, previous references, and financial status) establish the company's value proposition. The real purposes and assurances are to carry out the project based on the plan and without any deficiencies. Therefore, as this perspective is concentrated on short-term survival nearly anything is suitable for the company's tactical profile (Pekuri et al., 2014). Construction project management, tender preparation activities, and financial and people resources are the main elements in the value generation system of conventional contractor firms.

Specialists have broadly ascertained the project accomplishment and highlighted how valuable projects a firm can execute, as more valuable projects need more financial resources (Pekuri et al., 2014). The revenue model may involve altered payment methods; for example, a fixed lump sum, an hourly or unit cost that are specified in the contract. Furthermore, the revenue model of a conventional contractor firm can be completed in two different ways: firstly, several firms can encounter ambiguities and create additional revenue as alteration demands extra tasks (Pekuri et al., 2014). Secondly, the main contractors fund their procedures with customers' resources by negotiating extended payment periods with subcontractors while simultaneously holding the client's resources on their account.

The other model is the developer model, where a firm attains a plot and generates the most profitable notion to develop it. In this model there is more focus on improved resolution, the cost of marketing, and negotiations with regard to the main business concept components; however, the main consideration is the firm's internal assets and funds rather than the client. Therefore, none of the existing business concepts utilised in construction are client focused. The concepts do not rely on division to determine clients with certain requirements, nor do they propose anything characteristic to the sector (Pekuri et al., 2014). Instead, these concepts demonstrate the 'anything to anyone' label that is utilised later to define the origin of the conventional business concept in construction.

2.8.3 Lean Driven Business Concept for Construction

Nevertheless, LC is a methodology to develop project delivery practices in order to produce more effective project results (Howell et al., 2011). As a broad management theory, Lean needs to be used across the whole organisation to accomplish its advantages (Emiliani & Stec, 2005; Liker, 2004; Spear & Bowen, 1999; Womack & Jones, 2003). Many organisations start their Lean implementation with only with a few employees (Pekuri et al., 2014). The companies aim to occasionally adopt specific Lean tools and techniques, and the results may be remarkable; however, such development processes can be isolated and disconnected from the broader organisational perspective.

Construction experts consider that the issue lies in comprehending Lean as a system and applying it as such within the limits constituted by pre-existent business concepts (Pekuri et al., 2014). Neither of the predominant business concepts in construction focus on the client, which explains why companies are willing to use Lean. It is perceived as rational and client-focused; moreover, it is both hypothetically-explained and practically-illustrated, which enhances an organisation's performance (Jaworski & Kohli, 1993; Morgan et al., 2009). Whilst the random application of Lean techniques is insufficient the full methodological change required for the transformation can be challenging (Pekuri et al., 2014). However, extensive Lean transformation is not possible if the firm is reluctant to change or if its managers do not sufficiently understand the business strategy.

Since Lean focuses on new theories and processes over traditional methods, conflict may arise if it is only partly implemented. Hence, before adopting Lean it is essential for managers to comprehend their firm's existing business concept, including the way it operates and why it is effective (Pekuri et al., 2014). Moreover, it is crucial to comprehend Lean as a system so that it thoroughly impacts the pre-existent business concept, and effects transformational change.

2.8.4 The Toyota Approach to Employee Empowerment

According to Liker, the Toyota Production System strives to achieve high levels of productivity by considering the motivational needs of the employees. Liker comments that In Taylor's scientific management approach, the employees were perceived as machines who had to be very efficient by the manipulations of industrial engineers and autocratic managers. Taylor achieved great deal of productivity wins by implementing scientific management methods. However, he also developed rigid bureaucracies where managers were responsible for thinking and employees were to merely carry out standardised procedures (Liker, 2004).

An organisational theory specialist, Paul Adler has looked at organisational practices, acknowledged from a comprehensive study of Toyota's NUMMI plant in California that the works are very repetitive with short cycle periods. The employees adopt a thorough standardised processes, which impacts every aspect of the company. Liker (2004) states, "*In the workplace, there is a place for everything and everything is in its place*". To continuously enhance the productivity, waste is being reduced. There are many leaders and a considerable hierarchy. NUMMI is closely linked with bureaucracy and a highly mechanistic organisation that is what Fredrick Taylor's scientific management strived to accomplish. However, NUMMI also looks at substantial involvement of the employees, flexible working, increased communication, high morale and a rigorous client focus. This led Adler to reconsider some conventional concepts in relation to bureaucratic organisations. He noticed that the organisations are categorised in minimum of four groups as coercive bureaucracy, enabling bureaucracy, autocratic and organic (Liker, 2004). NUMMI's TPS was demonstrating that the technical standardisation could enable bureaucracy when combined with enabling social structures.

The fundamental difference among the Toyota Way and Taylorism is that, the Toyota Philosophy perceives the employee as the most significant resource as they are the ones carrying out the works and solving the problems. Based on this view, Toyota's bureaucratic, top-down approach turn into the foundation for innovation and flexibility. This was referred to as democratic Taylorism by Adler (Liker, 2004). Toyota Way demonstrates that, to continually remain in the sector leaders and stay competitive in the long term, a firm needs to have empowering and feasible standards so that it can continuously develop on repetitive procedures.

2.8.5 Management by Objectives (MBO)

Management by objectives is a business tool that aims to resolve problems in contemporary organisations. It has been used by many business organisations, especially in manufacturing, to increase organisational performance (Drucker, 1996). It was first proposed by Peter Drucker in 1954 in an effort to educate organisations to decentralise control and delegate management to individuals tasked with the responsibility for the vision and efforts of the organisation. This was achieved by harmonising the goals of the individual with that of the overall organisation. Popescu (2013) defines management by objectives as a,

> *… management tool that enables the increase in performance of an organisation, by focusing on results, not on the work itself, providing cascade and aligning company goals with individual goals of managers who are at different levels within the organisation.*

MBO is achieved by: first, rigorously determining objectives from the top management through to the shop floor; second, by determining those who established the objectives and those responsible for achieving them; and third, by determining the rewards and sanctions linked to the achievement or non-achievement of the established objectives (Deac, 2014).

Drucker (1954) argued that the only principle that can harmonise both a company and individuals' goals, whilst increasing organisational performance through teamwork, and enable a focused company's vision, is "management by objectives and self-control." In other words, the success of the overall company goal depends on the alignment of the general objectives with the those of its organisational subdivisions and the interests of the entire personnel within the economic unit (Farcas & Vuta, 2015). Therefore, every participant in the process, including divisions, teams, managers, and employees work freely because they feel that they are achieving their own respective goals in the process. Drucker (1954) asserted that MBOs;

> *… make the common weal the aim of every manager. It substitutes for control from the outside for the stricter, more exacting and more effective control from the inside. It motivates the manager to take action not because somebody tells him to do something or talks him into doing it, but because the objective needs of his task demand it. He acts not because somebody wants him to but because he himself decides that he has to – he acts, in other words, as a free man.*

Management by objectives is about enabling self-motivation and development (Drucker, 2010), where employees perform a function not just because the company process demands it, but because they also achieve their own goals. Therefore, they exercise self-control and self-preservation to perform the function; they win and the company wins, which is highly motivating. MBO is an annual cyclical process that is characterised by five steps, as illustrated in Figure 2.14.

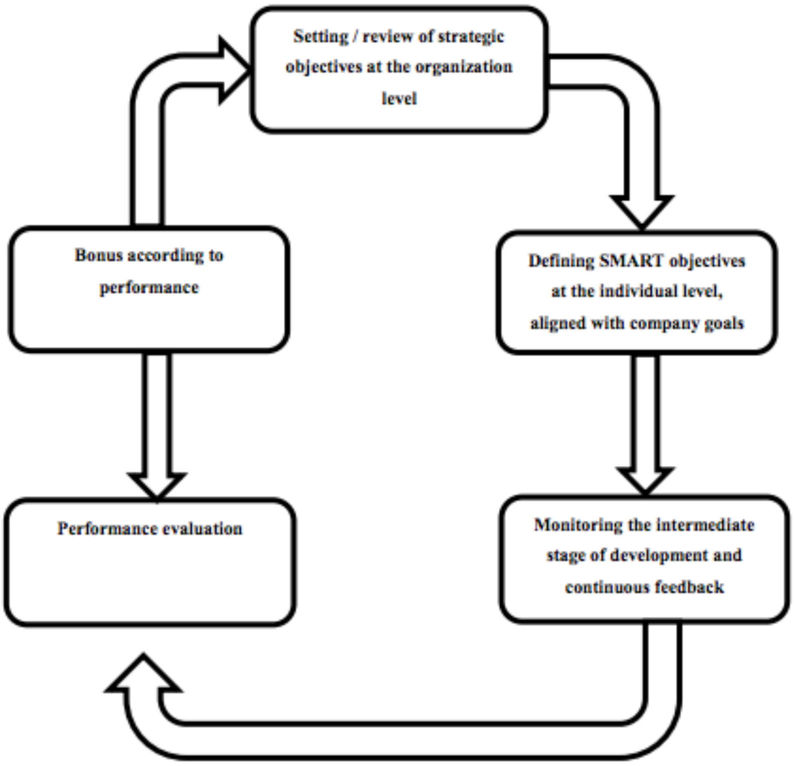


Figure 2.14: The MBO Process (Source: Farcas & Vuta, 2015)

In the MBO process, top management sets strategic objectives at the organisational level, which are aligned with objectives at the individual level. This unifies the goals of organisational members and enables understanding of the key roles they each have to play to achieve the set objectives. These set objectives must be clearly defined alongside the evaluation strategy so that management can accurately assess results. Senior managers must also motivate line managers and 'shop floor' employees to assume ownership, pursue continuous improvement, monitor and analyse results, evaluate performance, and reward results according to performance (Farcas & Vuta, 2015). However, the success of MBO heavily depends on the clarity and measurability of the set objectives. According to Farcas and Vuta (2015), the objectives must be clear, unambiguous, specific and measurable; they "must include the temporal element and all targets must be results-oriented" and most importantly, "there must be agreement between the organisation's policies and objectives." Table 2.4 outlines the advantages and disadvantages of MBO.

Table 2.4: Advantages and Disadvantages of Management by Objectives (MBO)

Advantages of implementing the MBO
– focusing the efforts of all the components of the company to achieve the pre-set objectives – managers skills development to scrutinize the future of the unit, to be flexible and dynamic in action – improving interpersonal relations from the unit and broadening of accountability to all components – ensuring the widespread application of participatory management techniques – amplification of the entire staff motivation level from the unit – rationalization of managers time in exercising the control function and in solving the perspective problems of unity – closer correlation of the wages with the results obtained in achieving the objectives – the economic efficiency increasing of management activity and achieving better results on economic activity as a whole unit
Disadvantages of implementing the MBO
– high consumption of time – possible conflicts between managers and subordinates – problems on various hierarchical levels

2.8.6 Management by Objectives (MBO) and Lean Construction

Management by Objectives (MBO) and Lean Construction are both designed to increase organisational performance. Lean prompts consideration of how the production process can be made to work efficiently on a continuous basis, while MBO aims to ensure that employees follow the process. Lean Construction aims to eliminate all forms of waste throughout the entire value-chain of the construction project process (Koskela et al., 2013; Koskela & Ballard, 2012). Lean implementation in the construction industry has encouraged changes in organisational behaviour to a certain extent, but it faces numerous factors that hinder its application within construction, such as human behaviour. The construction industry struggles to maintain commitment and motivation to the Lean process, even when they know it is efficient. This lack of motivation and commitment is driven by an inability to see how they will benefit from the process, or how individual needs and objectives will be met.

MBO, on the other hand, attempts to understands human nature. It considers that people will only be committed and motivated to perform effectively and efficiently to the best of their abilities when they are working for their self-interest. Thus, MBO strives to create a win-win scenario where organisational goals are aligned with individual goals. It maximises the use of individual initiative, where managers are given opportunities to develop their objectives within their own sphere of responsibility, and resources that lead toward the accomplishment of the overall organisational goals (Pope, 1975). According to Farcas and Vuta (2015), the MBO technique is applicable to any organisational goals, and is therefore applicable in construction. They assert that, if "properly implemented and rigorously applied, management by objectives is a highly effective solution to the underlying problems that are facing the modern organisations." (Farcas & Vuta, 2015).

2.9 Construction Value Delivery

Value in the context of the manufacturing industry is usually achieved by the manufacture of identical products, namely cars, engines, or seats. In this respect, value and its delivery differ for construction which involves houses, shear walls, or windows. In comparison with many manufacturing products, buildings are big, stationary and unique products that are mostly constructed on site, where the assembly location generally differs to the component manufacture location (Bertelsen & Koskela, 2005; Gann, 1996). However, in recent years, construction products have been delivered through provisional manufacturing systems (Bertelsen, 2003).

2.9.1 Non-Value Adding Activities in Construction

There are several perspectives that explain why waste occurs; however, in Lean all non-value adding activities in the production process are referred to as waste. In the production flow two main activities arise, which are; non-added value and added-value activities. Koskela (2000) states that non-added value activities use additional resources, space and time but do not add value, whilst added value activities transform material and information as required by the client. Thus, Koskela, (2000) proposed the reduction of non-added value activities if they are not eliminated from the production process. The purpose of minimising or reducing non-value-added activities is to generate increased value for the client (Thomas et al., 2012). Many reasons such activities have been ascertained (Alves et al., 2005; Ralph & Iyagba, 2012; Zhao & Chua, 2003), which include: the concept of waiting time for instruction, insufficient or vague site drawings, inadequate quality site information, inadequate design, design modifications, slow drawing revisions and uncertain specifications, a lack of integration and collaboration amongst teams, inadequate scheduling, undependable materials, delay in the material delivery to site, and poor weather conditions. Non-added value activities are categorised into three groups based on their root causes, which are; the form of the production system, the production control method and the nature of production (Koskela, 2000). Therefore, most of these activities appear to mitigate the LPS of production control and planning.

2.9.2 The Implementation of Lean Principles in the Construction Industry

In recent years, there has been a level of acceptance in the adoption of Lean principles to construction processes (Ballard & Howell, 2003). Some specialists consider that Lean manufacturing practices are similar to Lean construction practices as both industries produce products and services (Salem et al., 2006). Chee et al. (2009) state that construction organisations have endeavoured to adopt the TPS, for example, the implementation of the continual development model of TPS in construction may involve weekly meetings, investigations as to why planned work is unsuccessful, the elimination of defects, the synchronisation meetings with subcontractors, and the use of LC methods amongst other teams. Other TPS models, including the total quality model and senior management commitment, can be adopted within construction processes to encourage the approval of proposals and to elicit subcontractor feedback. Therefore, TPS can be directly implemented for control on site, effective production scheduling and quality control.

However, Koskela (2000) states that construction projects are complex and ambiguous, which could result in their ineffectiveness. Effective production scheduling and control are hence the most suitable methods to mitigate these ambiguities (Howell & Ballard, 1998). Whilst scheduling refers to a standard of achievement, control manages a situation to adopt a schedule. This can be achieved by an advanced scheduling technique, such as LPS, where project scheduling is associated with planning (Ballard & Howell, 2003).

2.10 Transport Infrastructure Construction

Good transport infrastructure ensures that the UK remains competitive in the international market place and unlocks opportunities for regeneration and new housing development. The Infrastructure and Project Authority (IPA) state that the UK is keen to develop its modern transport infrastructure as quickly as possible as it is the backbone of the UK's economy. Hence, from 2015 to 2020 the government committed to a 50% increase in transport investment, which will enable the biggest modernisation of the country's rail and road infrastructure since the 1970s (IPA, 2017).

The UK transport infrastructure industry comprises road, rail, airport and seaports, and in 2017 contractors' outputs for this sector totalled £8.6bn (IPA, 2017) . Major transport infrastructure projects in the UK are driven by five-year contracts for tier 1 contractors, with funding released annually, and renewed after five years. Highways England (HE) is responsible for the construction and maintenance of roads, which is driven their five-year Roads Investment Strategy (RIS1). According to the Infrastructure and Projects Authority (IPA), the value of planned investment for transport infrastructure between 2017/2018 and 2020/2021 is set at £78.5b, and at £56.8b beyond 2020/2021 (Table 2.5 and Figure 2.15). Hence the Lean principles are needed to guide the allocation and execution of the works on budget, time and at an appropriate quality.

Table 2.5: Transport Pipeline Investment

Sub-sector	Number of Projects	Programmes and Other Investment	17/18 to 20/21 (£bn)	Beyond 20/21 (£bn)	Total Pipeline (£bn)
High Speed Rail	1	0	£13.4	£37.8	£51.2
Rail	12	19	£27.1	£11.2	£38.3
LA majors	22	72	£14.0	£3.0	£17.0
London	4	19	£7.7	£3.9	£11.6
Roads	67	11	£10.8	£0.2	£11.1
Airports	0	13	£4.9	£0.6	£5.5
Ports	1	1	£0.6	£0.0	£0.6
Total	**107**	**135**	**£78.5**	**£56.8**	**£135.3**

Source: IPA (2017)

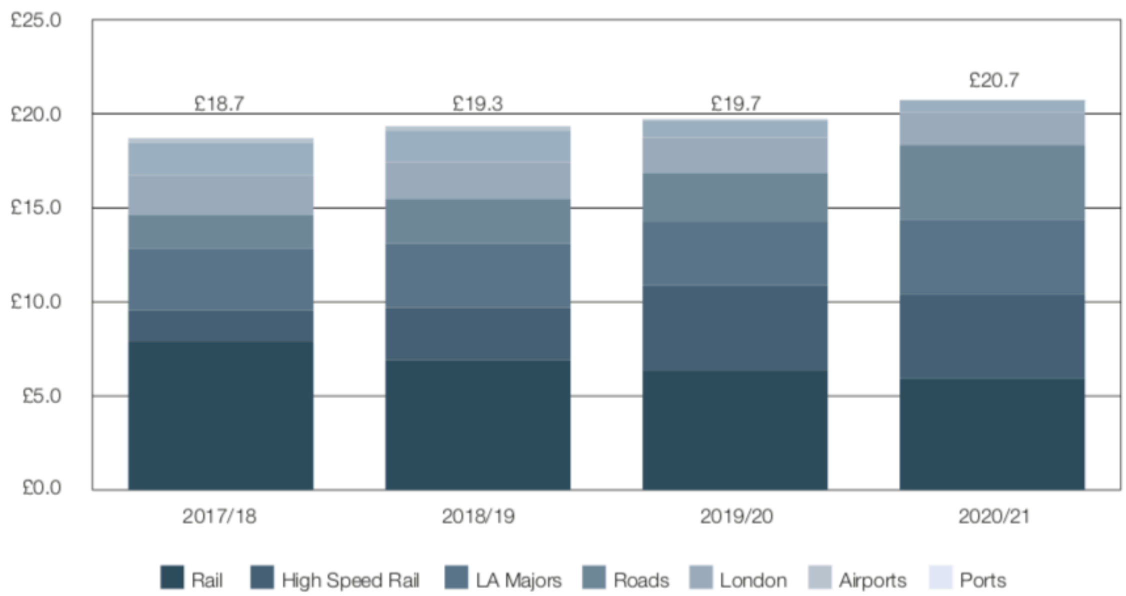


Figure 2.15: Transport investment from 2017/18 – 2020/21 Split by Sub-Sectors (£bn)

2.11 Lean in Transport Infrastructure Construction

Highways England (HE) is a government-owned company charged with operating, maintaining and improving England's motorways and major A roads. It is the main client to several Tier 1, 2 and 3 construction companies. HE champions the application of Lean principles in the delivery of its infrastructure projects. Highways England carries out 80% of all traffic systems in England, and is responsible for operating, and maintaining over 7000 kilometres of motorways and trunk road networks valued over £105 billion; this means that HE has a substantial responsibility to provide value and safety for road users (Pasquire et al., 2015). As a result, HE is continuously searching for ways to improve its performance and better execute its mission of effective and efficient value creation for road users in terms of safety, time, cost and quality.

HE’s adoption of the Lean philosophy demonstrates its dedication to this cause. In 2009, HE started to deploy Lean on some of its projects, by assembling an in-house team of dedicated Lean-trained personnel with the sole purpose of deploying best practice amongst all its projects and supply chain (Drysdale, 2013). The best practice tools upon which HE deploys Lean, amongst others, are: collaborative planning, Visual Management, 5S, process mapping, and the 5whys (Pasquire et al., 2015). This is because they have proven beneficial in saving cost and time on numerous HE projects, as well as improving both safety and project team engagement. Visual Management and Collaborative Planning are the most widely used tools in HE's Lean deployment strategy. Highways England and its suppliers have deployed Lean visual management and collaborative planning techniques on projects/processes and found the outcomes to be highly beneficial. This suggests that a greater uptake in the sector would improve efficiency in construction design, maintenance, and back office activities.

HE and its supply-chain have worked collaboratively in Lean deployment, which has resulted in over £80 million in project cost savings, 70% plan reliability (an increase from 40%), and a 30% reduction in time (Fullalove, 2013; Pasquire et al., 2015). HE also committed to £1.212 billion efficiency savings in 2017-18 (HE, 2017); however, it also requires its supply-chain to be committed to the efficiency target as its supply chain executes 90% of HE's contracts. HE has undertaken significant efforts to develop its supply chain through Lean Construction principles; this has been achieved by committing "*£5 billion to the development of a collaborative delivery framework to support the development of its supply chain*" (Pasquire et al., 2015, cited in HE, 2015).

2.12 Summary

This chapter presented a comprehensive literature review on Lean Thinking in its original production pattern. The main principles of the Lean Manufacturing system and Toyota House were explained in detail. Furthermore, attention was given to Lean Production and Lean principles, which led to an overview of Lean Construction that determined the Lean manufacturing practices currently adopted within the industry. The value of Lean Construction was explained to provide an understanding of current best activity in the UK industry. Figure 2.16 summarises the current best practice for Lean implementation in infrastructure construction.

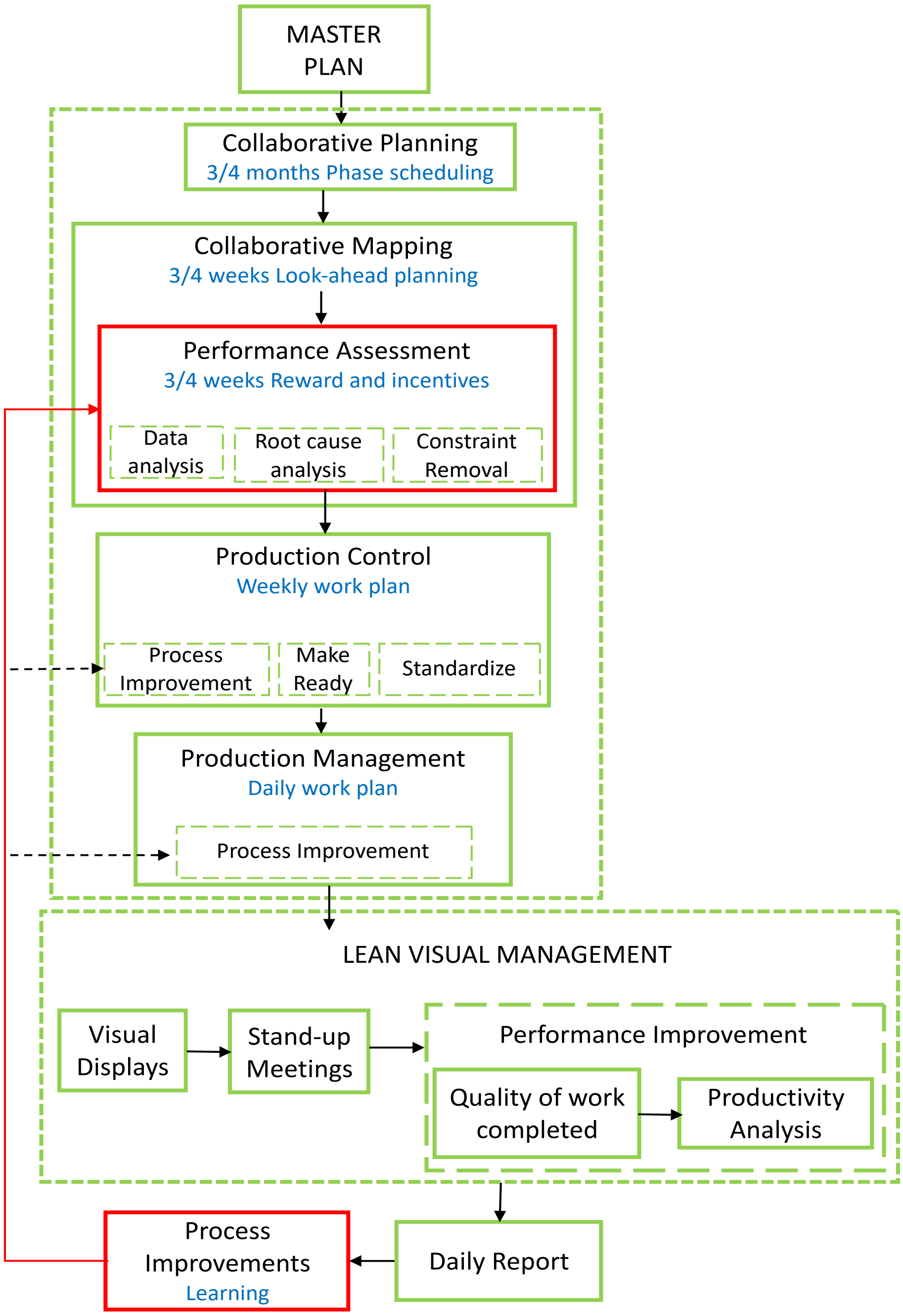


Figure 2.16: Literature Summary of Lean Implementation in Infrastructure Construction

The master plan informs Collaborative Planning at which phase all members (contractor and subcontractors) discuss and agree deadlines/target dates on a three to four month phased schedule. Members of different companies work together to create a three to four week, short to medium term plan and to: agree sequence of work, set milestones, identify and understand the enablers, and eliminate constraints to ensure success. During CP there is a regular performance assessment where the project team and staff are assessed against their evidence of having met Lean short-term goals. Here, the project team makes use of a variety of Lean tools including, but not limited to: Blitz, DMAICT from Sig Sigma, TQM, 5Whys, 5S, and Agile Management. These are employed for data analysis, root cause analysis, and constraint removal. During production control, team members have the opportunity to discuss and agree requirements, and determine responsibilities, including: make-ready tasks, the allocation of resources, the start and finish times for activities, and the key weekly targets and accountability measures. Each individual team member commits to tasks and is measured on their successful reliable task completion (PDCA). On the day of production or execution of the planned work/task, a meeting is held, usually in the morning, to review the previous day's activities, (which will include any learning captured) and to discuss the current day's planned activity.

Lean Visual Management (LVM) employs visual displays boards and stand-up meetings (usually lasting for 10–15 minutes), and seeks continuous performance improvement by; measuring, monitoring and reviewing team performance using tools such as 3Cs and 4FA. Finally, measurement and learning generate robust performance data that can be analysed to show areas to improve performance; this can be included in the daily report. Lastly, efforts have been taken to collect data, whilst acknowledging the challenges of implementing Lean Manufacturing practices in the construction industry. In the next chapter, the research existing Lean implementation frameworks will be discussed.

3 CHAPTER THREE| EXISTING LEAN IMPLEMENTATION FRAMEWORKS

3.1 Existing Lean Implementation Frameworks

Several Lean implementation frameworks have been presented over the last 20 years. Examples of these frameworks include those by: Åhlström (1998), Ballard & Howell (2003), Beck (1999), Chick (2013), Hilbert (1998), Hines et al. (2004), Mathaisel (2005), Mostafa et al. (2013), Kowalski (1996) and Shingo (1989). Meanwhile, others specific to the construction process include those by: Aziz et al. (2016), Ballard (2000), Bassioni (2004), Harbour (2012), Kasiramkumar & Indhu (2016), Pasquire & Gibb (2002), and Wright (2015). These frameworks are usually roadmaps guiding organisations on how to implement Lean Manufacturing, highlighting the sequence to introduce Lean tools into the organisation, and in some cases, noting the success criteria.

Figure 3.1 provides a macro view of the framework proposed by Kasiramkumar and Indhu, (2016), which describes a fusion of traditional project management (procurement model and earned value management) with Lean Construction (Lean Thinking and Integrated Project Delivery) that makes implementation easier.

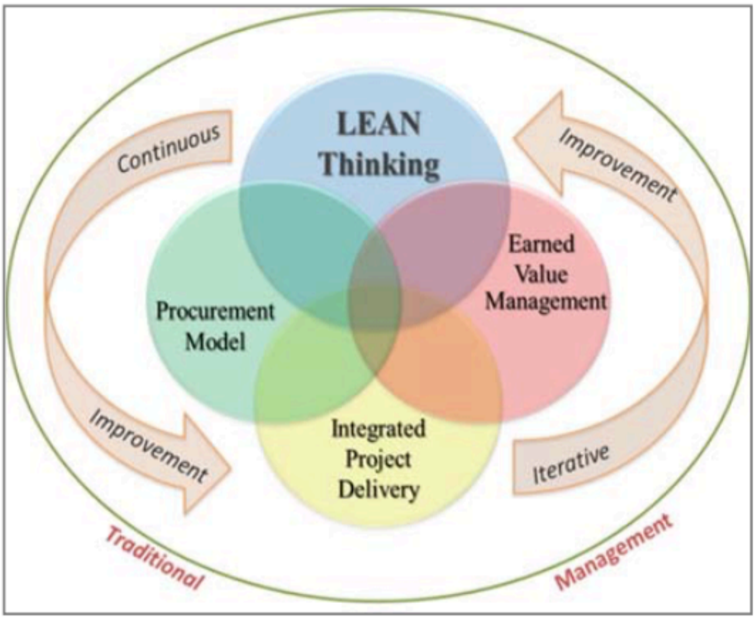


Figure 3.1: Traditional Lean Model (Kasiramkumar and Indhu, 2016)

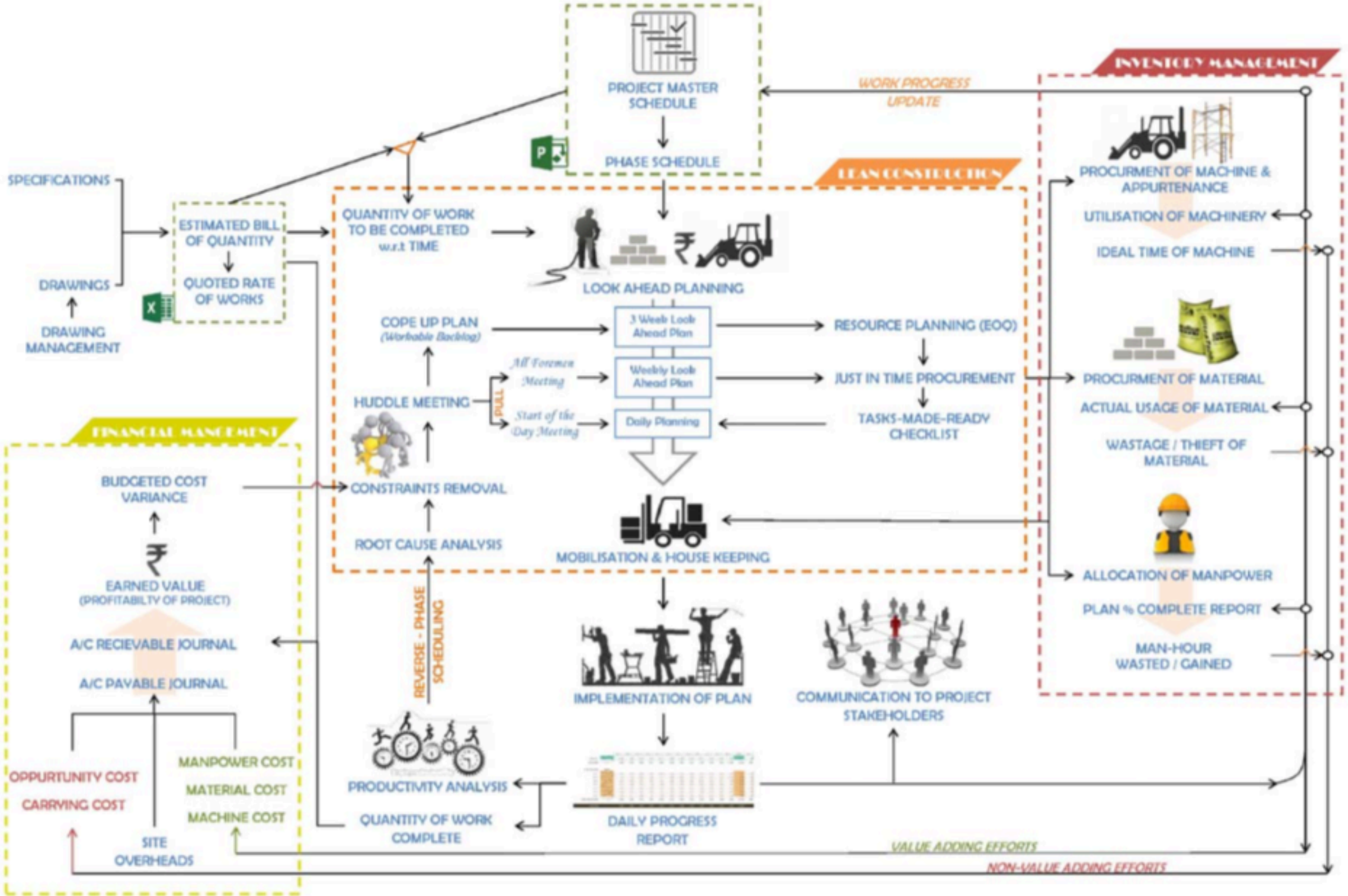


Figure 3.2: Lean Implementation Framework (Kasiramkumar and Indhu, 2016)

However, Kasiramkumar and Indhu (2016) expanded their generic framework to show the use of several Lean construction principles and techniques at every stage of the construction process, for the effective adoption of Lean (shown in Figure 3.2). They state that, for a framework to be robust, 'Lean Thinking' is imperative at all project stages of the construction process. Although the framework effectively integrates Lean principles in the process, it does not incorporate aspects that ensure commitment and motivation from the project team and stakeholders.

Another Lean implementation framework is that by Al-Aomar (2012), pictured in Figure 3.3. It combines three stages, namely the design, supply, and assembly of a construction project. It is similar to Koskela's (1992) 'transformation, flow, value' model but incorporates engineering in a Lean design at the conceptual design stage while using value engineering to eliminate waste and reduce costs. The supply stage entails the sourcing of resources, procurement decisions, logistics (namely the 'flow view'), and sustainability. Assembly refers to the construction stage where project management principles and Lean tools and techniques play a major role in the delivery of the project on time, at the right cost, and at the right quality.

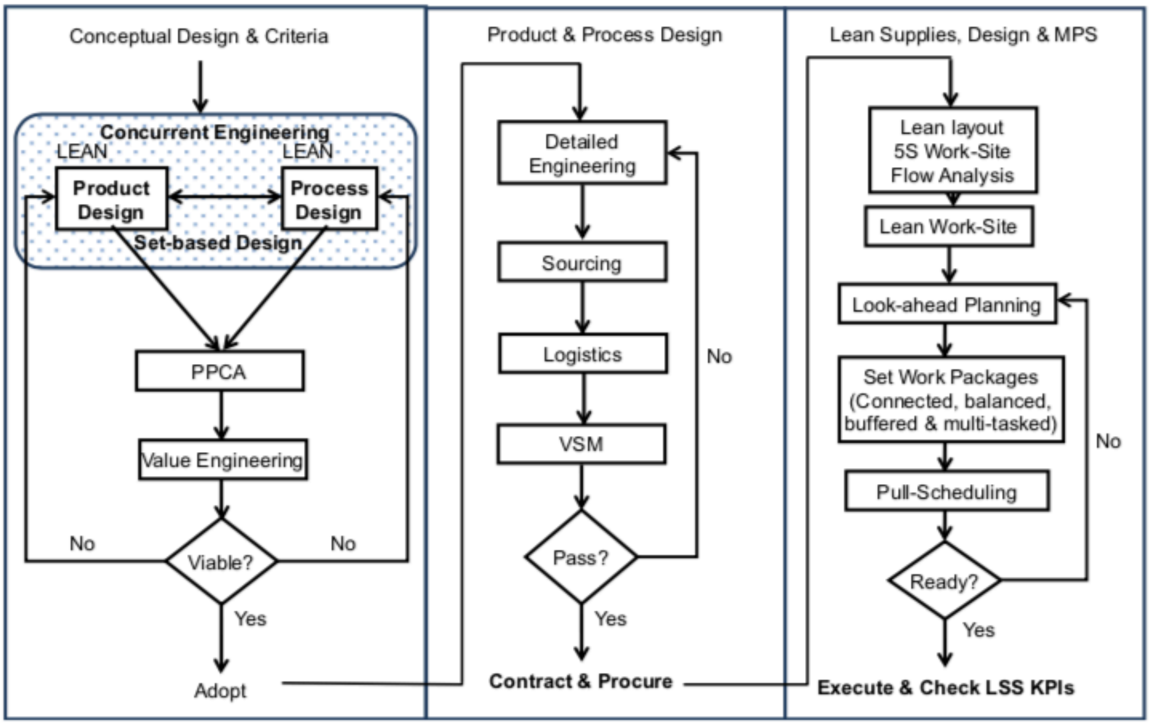


Figure 3.3: Lean Construction Framework (Al-Aomar, 2012)

In 2000, Glenn Ballard created The Lean Project Delivery System (LPDS). This was designed “to guide the implementation of Lean Construction on project-based production systems” (Ballard & Howell, 2003). The system incorporates a group of functions, a guide for decision-making and the execution of these functions, which are interlocked and sequenced to successfully implement Lean Construction. The framework is shown in Figure 3.4; it contains five functions (project definition, lean design, lean supply, lean assembly, and use) that overlap at each module (each function contains three modules). The framework is designed to produce value-engineering functions and to streamline production flow (Ballard, 2000; Ballard & Howell, 2003).

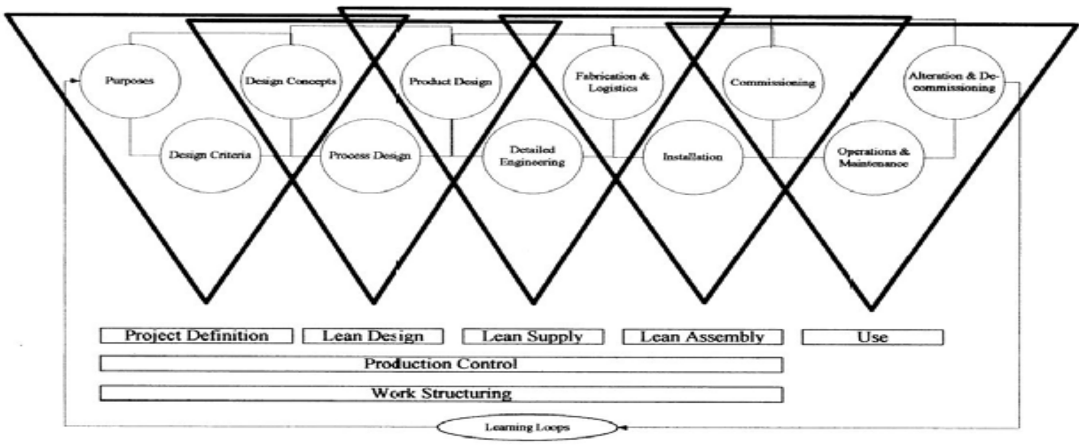


Figure 3.4: Lean Project Deliver System (Ballard and Howell, 2003)

According to Hines et al. (2004) Lean exists at both the strategic and operational levels. They developed a framework that allows companies to evolve their thinking to Lean Thinking by developing concepts that can drive change and continuous improvement from the strategic to the operational level. Although this framework is valid and useful, it is generic and not tailored to the construction industry. Furthermore, it does not incorporate elements that ensure that culture change and Lean Thinking emerges. Figure 3.5 shows the framework developed by Hines et al. (2004).

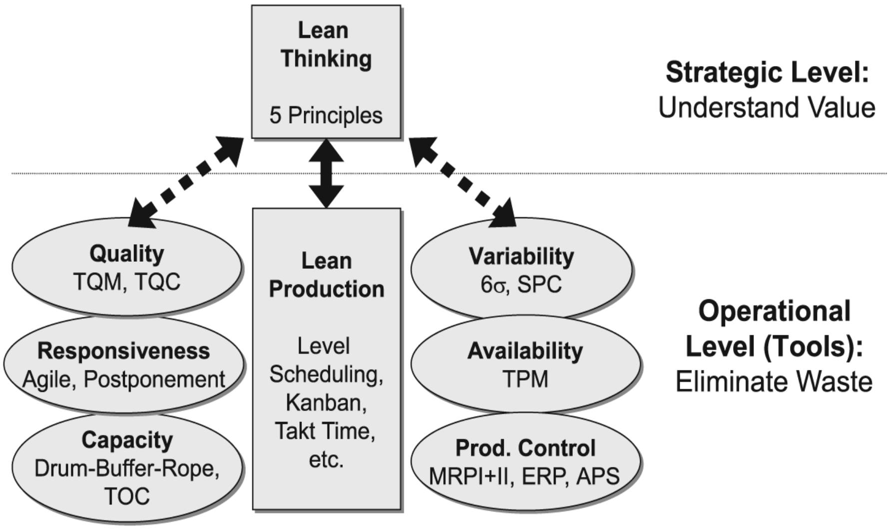


Figure 3.5: Lean A Framework (Hines et al., 2004)

Mathaisel (2005) developed "The Lean Enterprise Architecture (LEA) framework" for construction companies to successfully design, construct, integrate and implement Lean principles and system engineering methods on projects. While it is useful to refine and sustain continuous improvement within a project lifecycle, it is generic and limited to the definition of the performance requirements necessary for the successful implementation of Lean (shown in Figure 3.6).

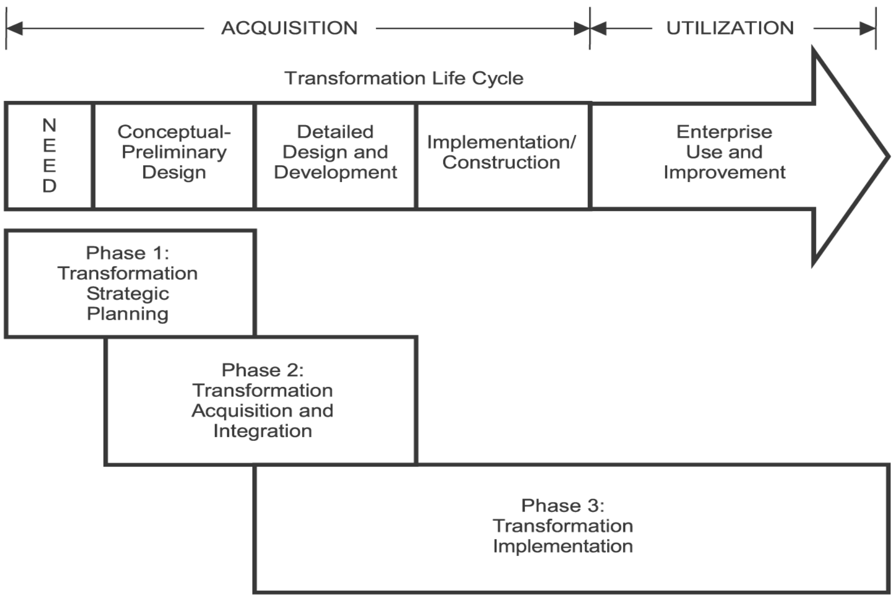


Figure 3.6: Lean Enterprise Architecture Framework (Mathaisel, 2005)

3.2 Lean Implementation in Highways England's SMEs

Based on Highways England's five strategic outcomes (HE, 2015), the following framework (shown in Figure 3.7) aims to enhance Lean collaborative working and engagement amongst the Small and Medium-sized Enterprises (SMEs) within HE's supply-chain (Aziz et al., 2016). Unlike most other frameworks that concentrate on the process, this is designed to deliver and focus on customer needs, through waste reduction and elimination, cost saving, value and quality increases, and continuous improvement through innovation in the construction process.

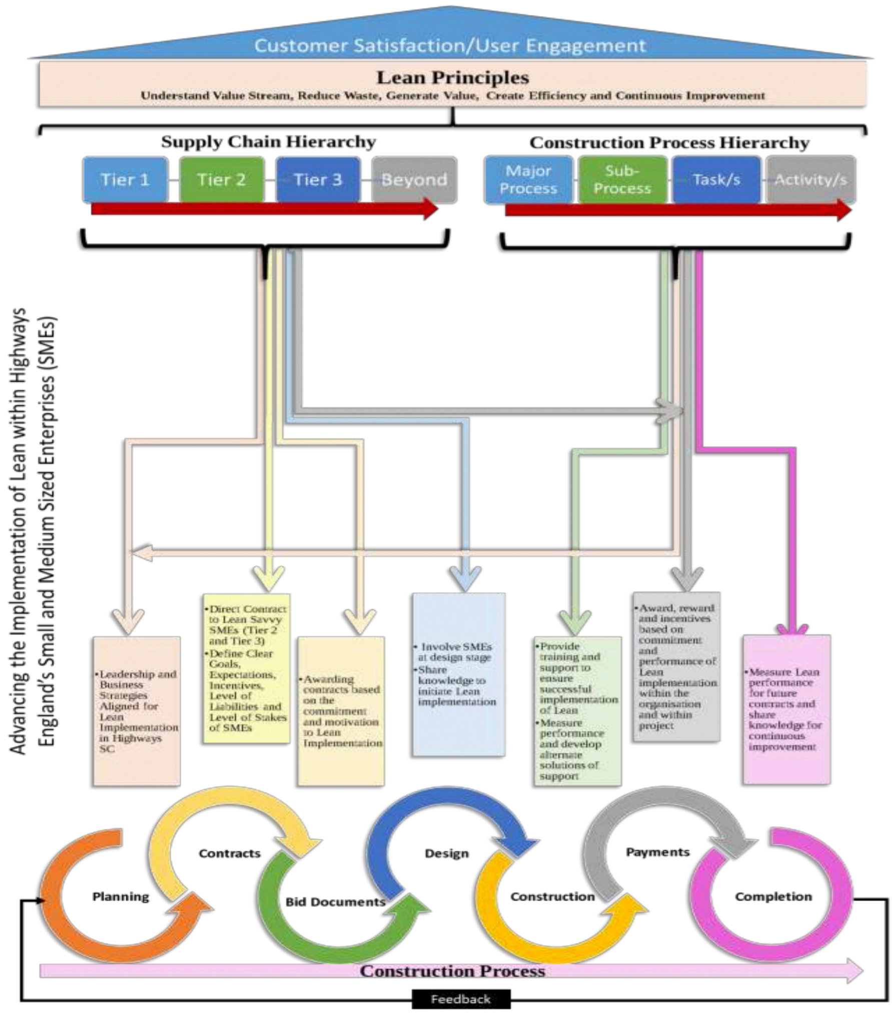


Figure 3.7: Advancing the Implementation of Lean in Highways England (Aziz et al, 2016)

The findings of Aziz et al. (2016) showed that, in HE's supply chain, SMEs lacked the motivation and commitment to the Lean implementation process. They recommended that there is a need to ensure SME commitment to Lean through "raising both the level of stake and level of liability". They recommend that the, "contractual agreement must clarify the gains and benefits (or pains) client an SMEs are likely to get in return for successful lean implementation" (Aziz et al., 2016). Furthermore, they recommend, long-term relationships (contracts) between HE and the SMEs, training and support, knowledge sharing, and leadership and the alignment of business strategies.

In 2011, Anvari et al. (2011) developed another framework by reviewing existing Lean frameworks and identifying three main areas associated with Lean implementation (Mukherjee, 2017), namely, preparation, design and implementation. This led to the development of a 22-step Lean implementation guide, as shown in Table 3.1.

Table 3.1: Lean Implementation Stages and The 22 Steps As Suggested

Lean Stage	Step
Stage 1: Preparation	• Gap assessment strategic planning Understanding waste • Establishing the objective • Getting the organizational structure right Finding a change agent • Creating an implementation team • Training the staff in team building and lean principles • Suppliers and customers involved Recognizing the need for change
Stage 2: Design	• Mapping the value streams • Analysing the business for improvement opportunities • Planning the changes • Identify indicators to measure performance • Creating a feedback mechanism
Stage 3: Implementation	• Starting with a pilot project • Starting the next implementation projects Evaluating and sustaining changes Changing the material SC systems and philosophies • Selling the benefits of "lean" thinking Pursue perfection • Expand the scope

Source: Anvari et al (2011)

The frameworks outlined below, and Table 3.8 also elaborates some of the frameworks found in literature; these frameworks are generic and not specific to the infrastructure construction industry.

Pasquire & Gibb (2002) created a framework within which to model and evaluate the benefit associated with Standardisation & Pre-assembly (S&P), which is shown in Figure 3.8. According to this framework, the evaluation can be carried out at any phase of the project by the supply chain. During the strategic project stage, the usage of pre-assembled services modules is provided within Table 3.2. Scoring systems are utilised for value engineering and the information interrogation methods will have their origins within the VE study and Lean value theory (value, value stream, flow, pull and perfection) (Womack and Jones 1996). These enable the critical appraisal of Client's requirement (Pasquire & Gibb, 2002). This model should show every aspect of S&P whether it is sufficient or not.

During pre-construction stage, the evaluation of components may be carried out that ascertain the added value activities by virtue of performance improvement, increased efficiency and enhanced effectiveness (Pasquire & Gibb, 2002). Table 3.3 illustrate an example of the factors and their value evaluation. Furthermore, Table 3.4 gives an example of the comparison of direct cost factors while Table 3.6 utilises a scoring matrix to prioritise factors, which cannot directly be costed.

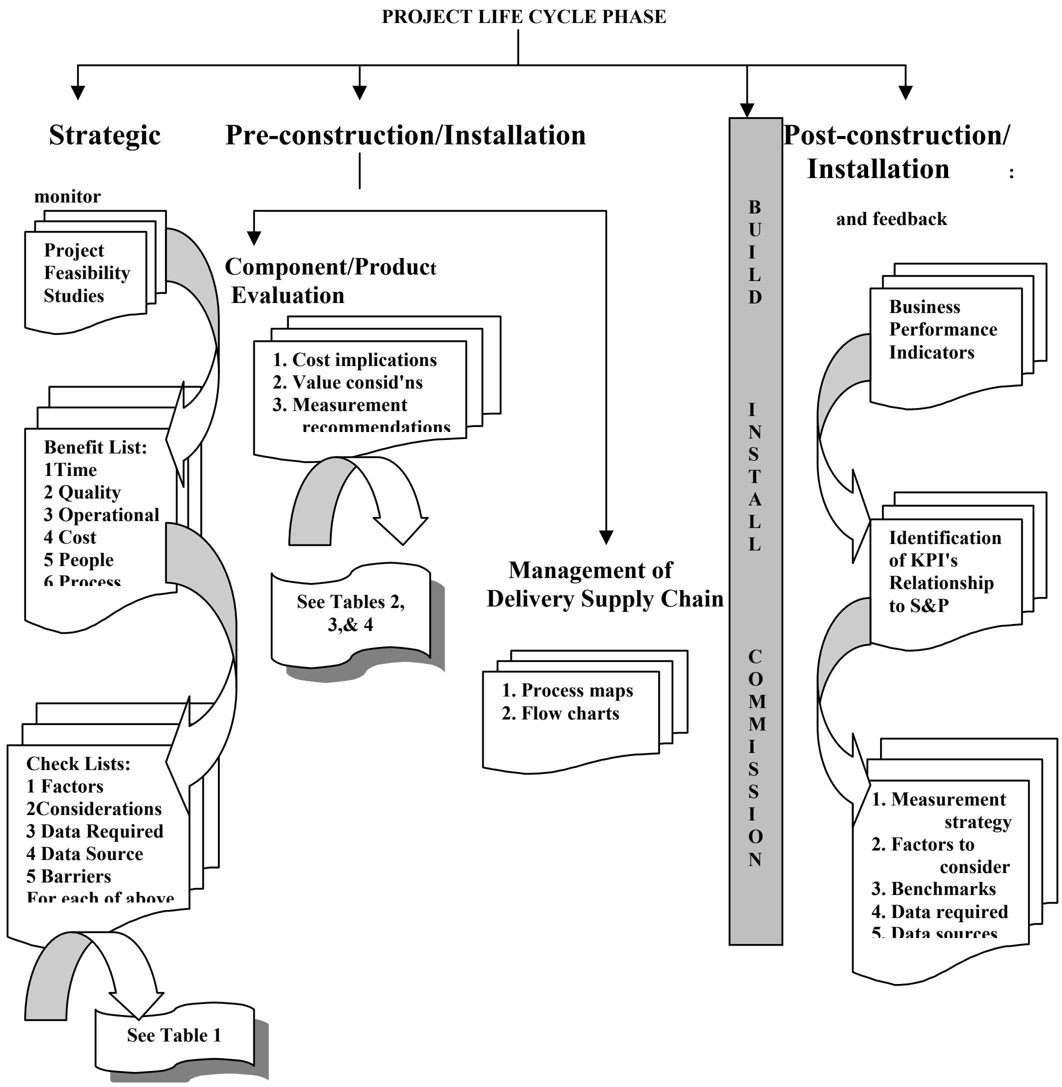


Figure 3.8: Framework for the realisation of the benefits of pre-fabrication, standardisation, and pre-assembly (Pasquire & Gibb, 2002)

Table 3.2: List of Benefits (Pasquire & Gibb, 2002)

1. For standardised processes the benefits include:		
Rationalised interfaces	Minimised disruption	Improved quality control
More predictable on-site activities	Better able to cope with congested sites	Improved certainty of completion date and cost
Increased productivity through familiarisation	Statistical reduction in H&S and environmental hazards	Fewer on-site operations, personnel & duration
Less waste, noise, dust etc		
2. For standardised components the benefits are:		
Tried and tested track record	Available replacement parts	More predictable lead-in times
Increased productivity through familiarisation both in design and on-site	Greater certainty of completion date	Predictable quality & performance
Reduction of waste	Minimised overall project time	Off-site inspection
Use of the same components on follow-on projects		
3. For pre-assembly generally the benefits are:		
Rationalised interfaces and improve tolerances	Reduction in H&S and environmental hazards	Improved certainty of project completion date and cost
Improved quality control	Minimised disruption	Transfer of skills from site to assembly point
4. For off-site assembly/manufacturing (in addition to pre-assembly generally) the benefits are:		
Minimised on-site operations, personnel & duration	Multi-skilled factory work force	Predictable, high-quality finishes
Less waste, noise, dust etc	Less on-site activities	Reduction of on-site rework
Decongests site	Off-site inspection	

Table 3.3: Benefit Evaluation Matrix for Use at Strategic Level (Pasquire & Gibb, 2002)

1) Pre-assembled services modules incorporating major framed components: cost reduction **£71,250;** programme reduction **33 days**

Outline description of project strategy e.g. 5 storey steel framed office block XXm² plan area "Traditional" construction: Budget cost: £9,500,000 Contract period: 537days								
	Factors	Considerations	Data Req'd	Data Sources	Barriers	Add Value	Days	Cost Impact
Time	Less on site time	Certainty of Delivery	Lead in times	Manufacturer	Delays [illegible] other element[illegible]		- 30	- 0.75%
Quality	Pre-tested Zero defects	Careful site handling	Test certificates	Manufacturer	Da[illegible] s[illegible]		-1	-0.01%
Operational	Fewer operations	Standard interfaces	Design[illegible]	Manufacturer & Engineer	P[illegible] co[illegible] ord[illegible]ti[illegible]		-2	-0.02%
Cost	Higher first cost	Incre[illegible]se ce[illegible]	[illegible]	Man' & installer	None		0	
People	Multi-skilling off site Fewer on site	R[illegible] site facil[illegible]s; Improved safety	[illegible]	Installers	Insufficie[illegible] consideration of operation	✍	0	
Process	JIT supply	Reduced on site storage	[illegible] details	Manufacturer	Premature/late delivery	👥	0	-0.01%

Pull down menus to provide detailed considerations for each factor selected for inclusion in next column

Pull down menus list what data required & where held. Includes URL/Web links

Barriers identified as pull down lists of things to avoid or look out for

Table 3.4: Items to be Costed for Component Comparison (Pasquire & Gibb, 2002)

Item	**Unit**	**Value**	**Item**	**Unit**	**Value**	**Item**	**Unit**	**Value**	**Item**	**Unit**	**Value**	**Item**	**Unit**	**Value**
Design	Hrs	££	Supervision	Hrs	££	Energy	KJl	££	Quality	Item	👥	Variations	various	££
Transport	Item	££	Site Welfare	Item	££	Enviro ditto	Item	👥	Risk	Item	££	Teamwork	Item	👥
Enviro ditto	Item	👥	Plant	Hrs	££	Testing	Item	✍	Co-Ordinate	Item	👥	Supply chain	Item	👥
Materials	Var	££	Productivity	Hrs	££	Commission	Item	✍	Integrate	Item	👥	Procurement	Item	✍
Site Labour	Hrs	££	Enabling wk	Item	££	Safety	No	✍	Cost-in-Use	var	👥			

KEY: Added Value Descriptors = Efficiency **££** Effectiveness ✍ Performance 👥

Table 3.5: Measurement of Plant as Part of a Component Comparison (Pasquire & Gibb, 2002)

Pre-Assembled Service Modules Comprising : Air handling unit, duct & pipework, vent & extract grilles, controls, power & light supply, insulation, testing, protection, primary and secondary steel framing, painting	**Traditional Construction comprising :** Measurement of each item separately:
Plant required during manufacture : INCLUDED IN MODULE COST	Unloading & Storing Materials - repeated for all materials
Plant required for moving on site : INCLUDED IN INSTALLATION	Transporting & lifting to position - ditto
Plant required for installation : **Crane** - lift from delivery lorry Hrs/module per crane type	Equipment needed to fix in position - ditto
Crane - lift into permanent position & support ditto	Plant needed to dispose of waste & packing - ditto
Weld/bolt - fix steel framework Hrs/module plant specified	
Connect - duct/pipe/cables module to module ditto	
Crane - remove packaging	
Allow - standing time, double handling (RISK ITEM) Contingency required %age addition	**Allow** - standing time, double handling (RISK ITEM) For each item - Contingency required %age addition

Table 3.6: Benefit Evaluation Matrix for Use at Detailed Level (Pasquire & Gibb, 2002)

Importance of Factor : (named) e.g. Transport (although the considerations used here will reoccur within many design and procurement issues)	**Score**	**A**.Environmental impact across delivery supply chain	**B**.Environmental impact at site level	**C**. Certainty of delivery	**D**. JIT delivery	**E**. Supply chain [illegible]ation	**F.** Likelihood of pre-assembly improving performance in these issues
Imperative - is an overriding factor influencing the design and/or procurement decision	9 - 10	Client is high profile green	Ditto	Contract period main [illegible]uremen[illegible] for	Will contribute highly where certainty of delivery a [illegible]ority	Will contribute highly where JIT & green issues important	Yes, in all building elements
Very Important - should be a major influencing factor in design/procurement choice	7 - 8	Clie[illegible] is committed green		[illegible]ct [illegible] is equally important procurement issue for Client	Should be encouraged as will contribute to Client benefit	Should be encouraged as will contribute to Client benefit	Yes, in some building element
Quite Important - should influence design/procureme[illegible] choice	5 - 6	Client [illegible]e	Ditto	Time not a driving factor in procurement	Benefit will be accrued lower down delivery supply chain and may reach Client	Benefit will be accrued lower down delivery supply chain and may reach Client	Yes, in (named) element
Important - should be considered in decision	3 - 4	Client does not ignore green issues	Ditto	Lowest score recommended for this factor	Implemented for benefit of delivery supply chain no benefit to Client	Implemented for benefit of delivery supply chain no benefit to Client	Unknown
May be important if combined with other factors (named as:)	1 - 2	Client views this as a bonus but not essential		Unlikely to occur	Only of benefit to certain members of delivery supply chain	Only of benefit to certain members of delivery supply chain	Unlikely
Unimportant - discard	0	Client not interested	Ditto	Unlikely to occur	No benefit to any party	No benefit to any party	Not at all

Factors from check list or input own

Pull down menus for identified factors or insert own (help given)

Pull down menus allow various ranking terms

Score pre-set or changeable

In 2004, Bassioni (2004) developed a non-prescriptive guideline for development of organisational strategy maps in contractor firms and called it the "Construction Strategy Map" measuring the benefits of Lean Construction (shown in Figure 3.9). This method was based upon the adaptation of the Balanced Scorecard Strategy Map to construction. The empirical analysis of this technique is achieved via a case study on a major UK contractor firm, in which the Construction Strategic Map was utilised to create an organisational strategy map and alter their pre-existing performance evaluation method (Bassioni, 2004). The Construction Strategy Map comprise four tiers that link to the four aspects of the Balanced Scorecard that are financial, external customer, internal processes and learning and growth as shown in Figure 3.9.

The indicators are chosen for each tier based on the company's policy and management approach of the business (Bassioni, 2004). These indicators are used as an early warning system where the strategic improvement is monitored.

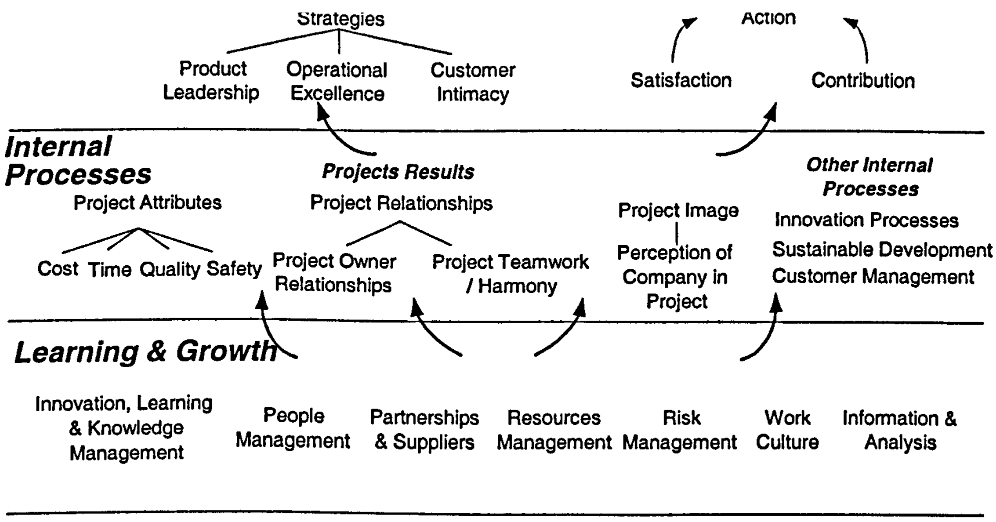


Figure 9.1: The Construction Strategy Map

Figure 3.9: Construction Strategy Map (Bassioni, 2004)

In 2003, Chick (2003) developed six-step implementation framework to provide an overview of how Lean could be introduced and applied particularly from the perspective of a client on projects within infrastructure and building sectors as indicated in Figure 3.10.

Even though, the guidance is particularly developed for client firms, it can be adopted by the supply chain for their projects due to the general applicability of Lean principles.

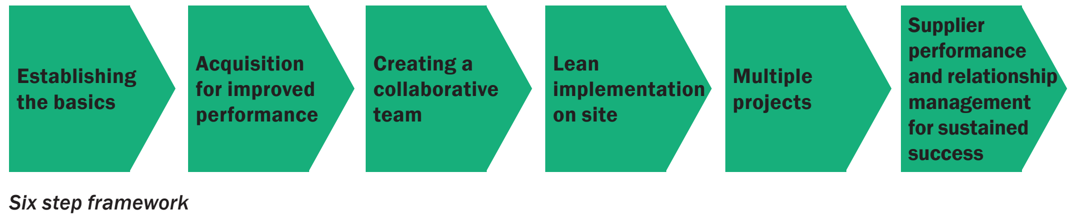


Figure 3.10: Six Step Framework (Chick, 2013)

Kowalski (1996) generated a roadmap to Leanness: a 10-step approach for the development of effective working systems and the standardisation of work. This model gives an outline of the process Ford should follow to deploy Lean manufacturing as illustrated in Table 3.7. This model comprises 10 focal steps for Lean implementation, which is akin to TPS. The list includes some of the desired outcomes from each stage. The characteristic measures defined are arisen from various sources on Lean manufacturing systems that are not necessarily used by TPS.

These steps explain what is vital for Lean manufacturing systems to operate. Even though these features do not necessarily need to be progressive, their order is significant. The technique adopted to improve machine uptime could be more efficient if effective workstreams are generated. Furthermore, standardisation of activities improves equipment reliability by reducing variability of how equipment is utilised (Kowalski, 1996).

The effectiveness of the following stages, including JIT and reduced inventory are based on previous stages comprising reliable equipment, reduced set-up times and machine layouts. Kowalski (1996), states that the 10 steps could be defined as encapsulations of Design Parameters (DP's) and Functional Requirements (FR's) of Lean manufacturing (Kowalski, 1996). However, the mapping amongst DP's and FR's or FR's and the Client Requirements are not explicitly called out.

Table 3.7: A Description of 10 Steps Required for Lean Production (Kowalski, 1996)

	Steps	Desired Traits	Typical Measures
1	Machine Layouts	short length of part travel reduced number of operations reduced plant space	length of part travel number of operations
2	Effective Workteams	skilled workforce employee involvement continuous improvement activities	skill evaluation number of suggestions number of job classes training hours absenteeism percent in teams
3	Standardized Work	streamlined work flow optimal workload for each employee	productivity measures
4	Reduce Set-up Times	short set-up times small batch sizes / "batch of one"	changeover time average batch size
5	Mistake Proofing "Built-in Quality"	inspection at each station error-proof design of part / fixture	number of defects per unit size of repair area
6	Reliable Equipment	preventative maintenance to maximize uptime	unplanned downtime MTBF
7	Level Production, Sequenced Production	produce to demand reduce variability in quantity and product mix	number of disruptions to schedule
8	Just-in-Time	"pull" system for controlling quantity and timing	build-to-sequence percent on-time delivery
9	Reduced Inventory	minimum inventory delivery right to production line	dock-to-dock time total inventory
10	Cost Reduction	elimination of waste focus on non-value-added activities	total cost

Åhlström (1998) produced another Lean implementation model implementation guide for waste elimination, pull scheduling, and management leadership as illustrated in Figure 3.11. This model provides a guidance on how management effort and resources should be moved amongst various Lean Manufacturing practices. The vertical dimension represents management effort and resources while the horizontal dimension represents a firm's Lean manufacturing adoption period.

According to Åhlström (1998), management effort and resources could move to commencing continual improvement as a core comprising of zero defects and delayering is laid. This means utilising multifunctional teams to resolve issues as part of their daily tasks. Continuous improvement can be achieved by developed multifunctional groups with tasks assigned to them, operating various activities within the production line.

Furthermore, Åhlström (1998) pointed out that the volume of management effort and resources, which can be dedicated to Lean implementation could shift in time. Lean Manufacturing does not have an end point, however leads a firm to continuously shift to right direction.

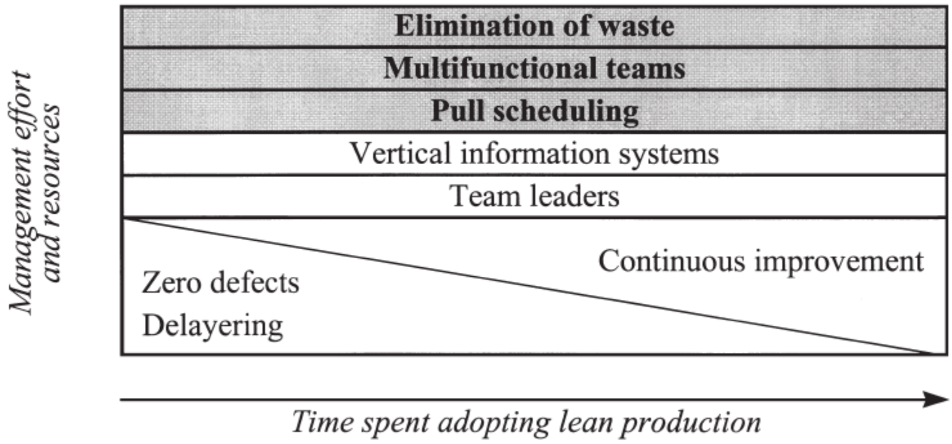


Figure 3.11: Sequences in the Implementation of Lean Production (Åhlström, 1998)

In 2012, Harbour (2012) developed a Four Phases roadmap to Lean implementation, which is called Lean Implementation Curve (shown in Figure 3.12) as outlined below:

- *Organisational Development*: During this stage, the supplier determines it values, vision and mission, sets KPIs and identifies organisational structure and monitoring period. The roles and responsibilities are also defined at this phase where all team members are involved.
- *Discipline Building*: The organisation commences adopting fundamental principles of Lean Manufacturing at this phase, such as visual management and 5S. The positive outcomes in terms of cost, quality and time can begin to be realised.
- *Lean tools of quality, delivery and cost improvement*: At this stage, the firm applies Lean Manufacturing practices, such as Kanban and Andon.
- *Continuous Improvement and Collaboration*: During this stage, the company diffuses its Lean methods to the supply chain to collaborate and create new systems for production. Lean is adopted to entire organisation and its partners, hence becomes a way of working where all stakeholders embed the philosophy (Harbour, 2012).

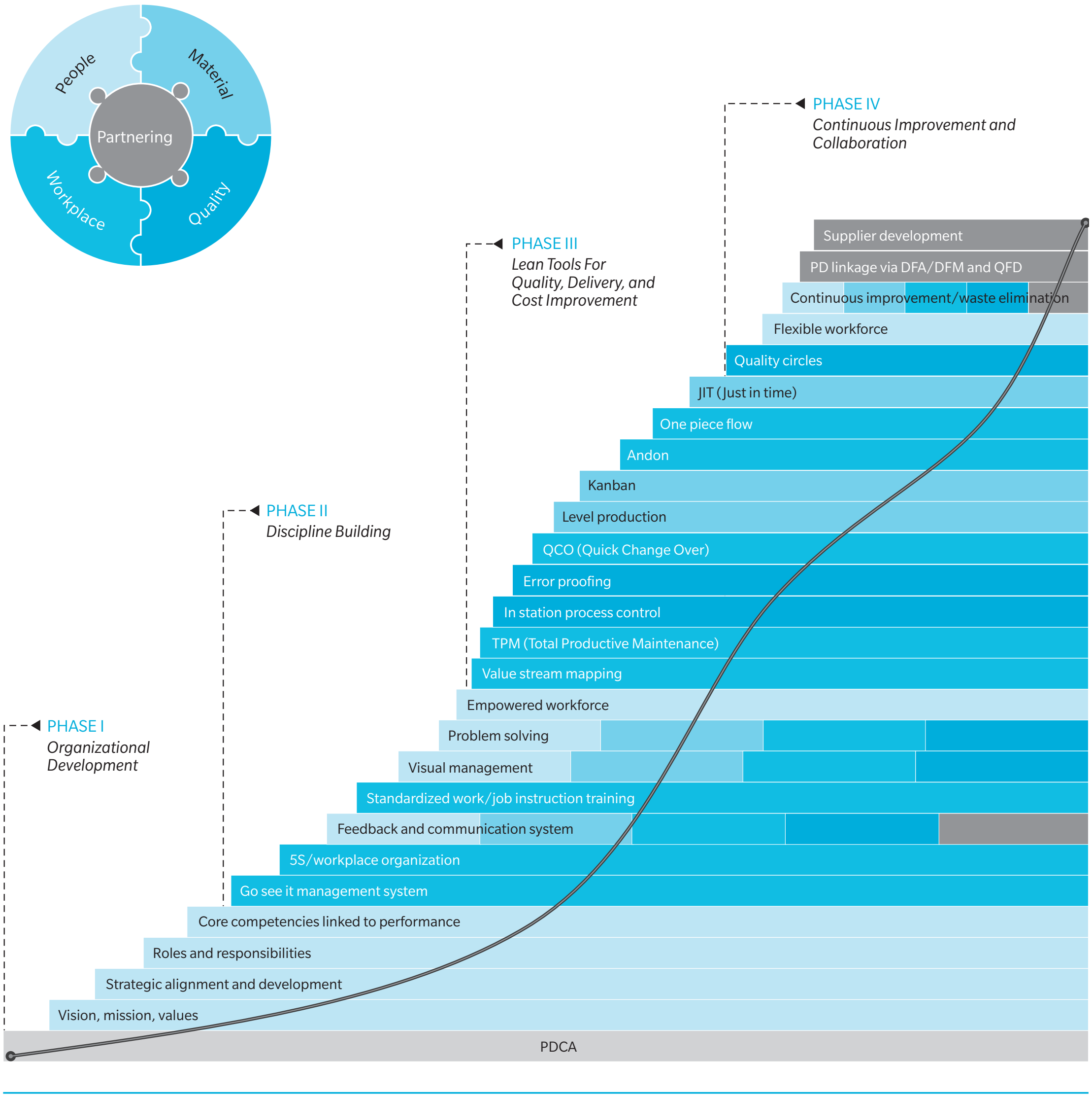


Figure 3.12: Four Phases roadmap to Lean implementation (Harbour, 2012)

Table 3.8: Other Lean Implementation Frameworks in Literature

Author	Framework
Shingo (1989)	Lean implementation roadmap with 14 Lean tools and techniques.
Beck (1999)	Roadmap to Leanness: a 10-step model for design and layout planning
Lean Aerospace Initiative (2001)	Enterprise Level Roadmap designed for senior management to improve Lean performance in their organisations.
Mostafa et al. (2013)	Four-phase Lean implementation framework, involving conceptual, implementation design, implementation and evaluation.
Wright (2015)	20 Step Roadmap to Lean implementation in manufacturing production line.

The frameworks reviewed above illustrate the range of implementation approaches in Lean manufacturing and Lean Construction. These frameworks focus primarily on incorporating Lean tools and techniques designed to solve Lean manufacturing and construction efficiency issues. Although this is not an exhaustive list of Lean implementation frameworks and models, the common theme is that none focus on how to address commitment and motivation through a win-win dynamic of the contract.

3.3 Summary

This chapter has served to review the literature to identify the current Lean implementation frameworks that currently exist, and it has presented them together here for purposes of completeness. In the next chapter, the research methodology conducted in this study will be evaluated and discussed.

4 CHAPTER FOUR| RESEARCH METHODOLOGY

4.1 Introduction

Research is referred to as a procedure that a researcher follows in order to systematically achieve particular aims and objectives. This procedure comprises the techniques and methods adopted to acquire data, ensure the findings make sense and that the descriptions of any limitations are relevant to these findings. Moreover, accomplishing the aims and objectives is similar to completing a set of tasks within a set timeframe to create particular opportunities (Becker, 1998). Sekaran (2003) describes research methodology as a scientific query or survey that is critical, information based, logical, objective, and methodical. It is carried out in order to meet a need to explore solutions/answers to a specific problem. Research enables the acquisition of data which leads researcher to take appropriate actions to effectively overcome issues and to conduct the research successfully. However, it requires the design of a 'route' to undertake accurate research and to acquire the most acceptable outcomes in order to accomplish the aim/s and objectives.

Research methodology is an overall research process, that range from the foundation to the data collection and analysis phases of a study (Collis & Hussey, 200) In essence, it is a statement of a direction that needs to be taken to achieve the research aim/s through meeting the objectives. In distinct fields of study, the adoption of particular research types is influenced by theoretical abstractions; thus, the considerable amount of knowledge gained of the theoretical foundations arise from research based on real-world events (Chakraborty & Dixit, 1992).

Smith and Dainty (1991) refer to research as a methodical, organised, information based and systematic examination that focuses on specific issues, which are carried out to provide solutions to such issues. A methodology establishes ways to gather the necessary data and encourages the investigator to make appropriate choices to identify answers to the research problem. Research is also referred to as a procedure for critical investigation, the purpose for finding data or connections, as well as expanding, testing and verifying both historical and current information (Smith & Dainty, 1991). Furthermore, Kumar (2005) refers to research as a methodical procedure to obtain, interpret and analyse data in order to find answers to particular research questions. However, this procedure can only be qualified as research when it fulfils particular criteria and as such, needs to be systematic, provide rich data, and be verifiable, valid and empirical.

Saunders et al. (2012) conceptualises the research methodology as an 'onion' (Figure 4.1). This is viewed in relationship to the research objectives. Hence, various layers need to be 'peeled away' by considering each of the contributing facets of the research methodology and the choices made that fit the requirements of the study. Therefore, these layers are critical facets that establish the methodology of a specific study. Saunders et al. (2009) described the research strategy as an overall design that forms the process to find answers to research questions (Bryman; 2008; Saunders et al., 2009). This chapter outlines and justifies the research process followed in this study. This includes the research concept, philosophical stance, approach, methods, techniques, strategy and data collection and analysis methods selected to accomplish the purpose of this study.

4.2 Research Concept

A research focuses on evaluating relationships and resolving problems, which leads to the construction of body of knowledge. The investigator, in essence, is required to comprehend the research process thoroughly along with its associated assumptions to acquire adequate and accurate research findings (Smith & Dainty, 1991). Furthermore, Smith and Dainty (1991) refer to research as a methodical and thorough investigation to explore various data and interactions, and to validate current information for a specific purpose. Saunders et al. (2012) state that effective research is formed through a well-designed plan that adopts the most applicable methods and concepts and uses the best-suited strategies to collect and analyse data to enhance knowledge based on the research aims and objectives. Ascertaining the design and type of research are two significant elements for the conduct of a study. It is critical to identify the research design since it defines the data collection and analysis process (Churchill, 1979). A thorough consideration and analysis of various resources is also required to provide a rational relationship between the concept and the discussion (Frankfort-Nachimas & Nachimas, 2008).

This study adopts the 'Research Onion' model developed by Saunders et al. (2012) to guide the development of the research methodology. This model's focal characteristic is its concise concept, which allows the researcher to choose the most appropriate characteristics throughout each layer. Figure 4.1 demonstrates the Research Onion model.

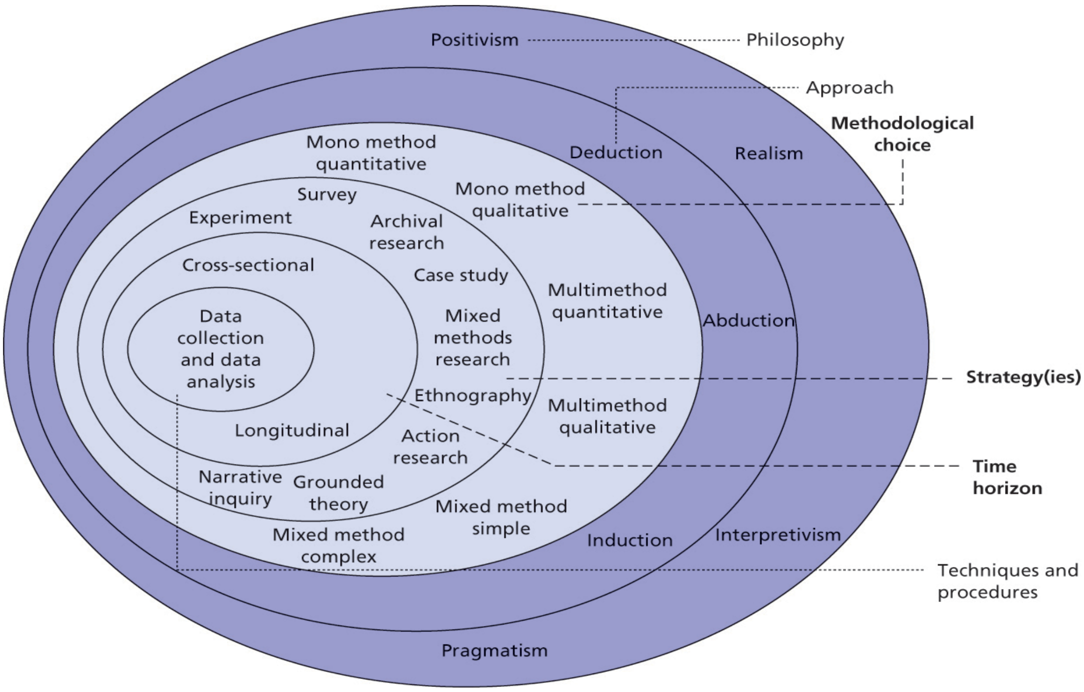


Figure 4.1: The Research Onion (Saunders et al., 2012)

In accordance with this model, the research process needs to commence at the first layer, which considers the research philosophy deployed by this study. The second layer considers the research approach, which is influenced by the choice of philosophy. The third layer looks at various methodological options some of which may be deployed in this research. These are influenced by the research approach and philosophical stance. The fourth layer focuses on the best-suited strategy for the research followed by the phase that looks at the study's time horizon, which is based upon the limitations and requirements of the research. The final layer relates to the data collection and analysis methods adopted. Selecting the most appropriate methods for the data collection and analysis is dependent upon the research questions and the preceding layers (Saunders et al., 2012). The following section outlines the various types of research.

4.2.1 Types of Research

The research type is based upon the purpose of the study and enables the investigator to effectively and efficiently structure the research methodology. The core types of research are categorised into three groups, namely: exploratory, descriptive and explanatory (Saunders et al., 2012), and are outlined as follows.

Exploratory research is described as an efficient approach to explore and acquire rich information through an open-ended query (Saunders et al., 2012). This type of research depends on the quality of information collected from the participants and can be carried out by interviewing specialists in the field, by carrying out interviews with a focus group, and by conducting a critical literature review. Moreover, by identifying problems and generating avenues to undertake a more precise examination for future studies, exploratory research can enable comprehensive understandings, or clarify a present situation. An exploratory study may be used in qualitative research (Collis & Hussey, 2009). Furthermore, such research is utilised in the development of models; it explores and examines hypotheses, concepts and views. The main benefit of exploratory research is its flexibility and adaptability to different variations.

Descriptive research aims to answer queries with regards to who, how many and what, and to define a set of circumstances or situation (McNeil & Chapman, 2005). This form of research enables an accurate individual profile, or descriptions of conditions or events. It can advise on the conditions of various social indicators, pose questions that might require further investigation, and justify the rationale for the existence of particular phenomena (Saunders et al., 2012). Quantitative methods are commonly adopted for the data collection and analysis of descriptive studies; this helps to outline numerous features, which comprise the phenomenon, but are not the fundamental reasons for its existence (De Vaus, 2001; Saunders et al., 2012). Nevertheless, such research may also enable a researcher to undertake subsequent explanatory and exploratory studies (Saunders et al., 2012).

Explanatory research can employ quantitative and qualitative methods in order to explore and clarify how and why the phenomenon has arisen or is arising (Collis & Hussy, 2003). Explanatory research aims at defining the situation on the basis of linking variables through an investigation of a phenomenon (Saunders et al., 2012). Nevertheless, distinguishing explanatory research from descriptive research is not easy since it also aims to answer 'why' queries. Furthermore, the explanations encompass depictions. In order to elucidate the disparity, a description is developed to understand the existence of a phenomenon and to thus recommend a solution, while a depiction merely provides the synopsis of a phenomenon (DeVaus, 2001). Hence, explanatory research focuses on explaining the relationships amongst variables within a situation or problem.

This research focuses on the UK Infrastructure Construction Industry and the adoption of Lean Construction, as there are challenges that affect its implementation. The purpose of this study is to develop a framework for the implementation of LC in the UKICI in order to enable construction organisations to develop a better understanding and to understand and represent effective implementation strategies within the industry. Hence, this study adopts explanatory and exploratory research. The next section of this research discusses the research philosophy, namely the initial phase of the research onion developed by Saunders et al. (2012).

4.3 Research Philosophy

Saunders et al. (2012) imply that a research philosophy relates to the development of knowledge and the origin of the information. They also affirm that the research philosophy deployed by the investigator is associated with theory and how they perceive both reality and the world. Moreover, these theories focus on variances, which have an impact on how the investigator considers the research process, and will advocate and rationalise the selected strategy and methods to conduct the research. Easterby-Smith et al. (2008) stated that three fundamental factors highlight the criticality of the research philosophy for the methodology. The first factor is that philosophy helps to justify the design and advocates the simplification of research through the collected and analysed data. The second factor is that the philosophy enables the researcher to explore the designs that are most applicable to the research. The last factor is that the philosophy advocates that the investigators ascertain and generate research strategies, whether they have relevant experience or not.

According to Saunders et al. (2012) and Creswell (2009), three fundamental philosophical assumptions are; *ontology, epistemolog*y and *axiolog*y. This philosophy considers the nature of knowledge and its development. Easterby-Smith et al. (2002) state that a comprehension of philosophical matters is crucial to ensure the researcher ascertains, explicates and generates applicable research methods. Creswell (2009) posits that scrutinising various philosophical assumptions and views is essential, which needs to be conducted at the early phase of the study.

A research philosophy is essentially considered in relation to theories, which the investigator also examines. There are two typical philosophical approaches, namely social constructivist and positivist, although there is confusion concerning this (Collis & Hussey, 2003; Easterby-Smith et al, 2003). Positivism perceives that the universe's existence is objective and external, and its entities must be evaluated via unbiased methods, whilst social constructivism views reality as subjective and internal although it is labelled and built socially by individuals (Easterby-Smith et al., 2003). Moreover, a study's research philosophy relates to five assumptions, namely, ontology, epistemology, axiology, methodological and rhetoric assumptions (Creswell, 2009). The assumptions of ontology, epistemology and axiology inform the philosophical position of the study, whilst the methodological and rhetorical assumptions inform the research method and type.

4.3.1 Ontology

Ontology considers the investigator's viewpoint; it enables the scholar to learn more about the subject matter and conduct the research in an efficient and effective manner (Peffers et al., 2007). Ontology defines our perceptions, which can be assumptions or claims regarding reality. This considers the subjective or objective reality that is generated in people's thoughts. Blaikie (1993) defines the root definition of ontology as,

> *… the science or study of being and develops this description for the social sciences to encompass claims about what exists, what it looks like, what units make it up and how these units interact with each other.*

According to Mason (2002), ontology focuses on reality or the type of phenomenon that the researcher aims to evaluate. Collis and Hussey (2003) affirm that, in an ontological assumption, the researcher determines whether reality is socially constructed namely whether it is comprehended through social actors, or objective and exterior to the investigator. Johnson and Duberly (2000) acknowledge that such ontological assumptions are realist while Gummesson (1991) refers to them as relativist/idealist. Consequently, an individual can have profoundly fixed ontological assumptions with regards to the reality they aim to impact as an investigator. In the event that the fundamental assumptions are not taken into account or ascertained, the scholar would struggle to comprehend the particular features of the query and the phenomenon as these are deemed indirectly; thus, they are not open to inquiry and discussion. Ontological studies are segregated into two types, namely objectivism and subjectivism (Saunders et al., 2012).

In ***objectivism***, the phenomenon is considered to be an exterior objects, and hence are not influenced by people (Bryman, 2008). *Objectivism* is an ontological assumption that endorses the perception that an entity's existence is autonomous from human influence. Thus, physical rules occur independently without being impacted by social actors in a predetermined cycle, or in reality as an established pattern to which social actors adhere. According to Saunders et al. (2009), in objectivism the concept and pattern are uniform throughout and potentially generic.

In comparison, ***subjectivism*** perceives that social phenomena are socially constructed and constantly influenced by social actors (Saunders et al., 2012). *Subjectivism* is the formation of a phenomenon through individuals' views and their ensuing actions; it comprehends the values that people attribute to the phenomenon (Saunders et al., 2009). Hence, since individuals continually interact with one another and their environment, social phenomenon constantly changes. The phenomenon itself is a direct reflection of the interpretations of the circumstances of these social actors. Furthermore, Saunders et al. (2009) mention that these individuals strive to comprehend and interpret their positions.

Hatch and Cunliffe (2006) utilise a social science example and an everyday example to demonstrate the viewpoint. A workplace report is an everyday example, which asks the question that defines what is really happening, or merely what does the author perceive is happening. They emphasise the difficulty concerning certain phenomena, namely culture, control or power, and whether they exist in reality or merely through perception. The argument is extended in the way that individuals define reality, whether reality arises autonomously from real-life events (objectivism) or from experiences (subjectivism).

This study develops a framework for successful LC implementation in the UKICI. In order to develop an appropriate and rigorous framework, this research requires the involvement of clients and stakeholders to understand LC implementation and its factors for the UKICI. Therefore, such a process requires various responses from these participants, which then results in the acquisition of subjective ideas regarding the topic area. Nevertheless, socially constructed reactions by the informants are vital, and need to be taken into consideration. Having considered the research questions and aforementioned situations, the ontological approach of this study leans towards ***subjectivism***.

4.3.2 Epistemology

Associated with ontology and its concern for what constitutes reality, epistemological assumptions concern ideas; in particular it questions the assumptions made about ‘real-life’ in an appropriate way (Easterby-Smith et al., 2008). Saunders et al. (2012) considers epistemology in relation to how information is to be obtained that seeks to answer how the information is known and what constitutes valid information. In essence, epistemology focuses on the roots of the information from the researcher’s perspective (Crotty, 1998). Such assumptions look at the definition of knowledge, from where the information arises, and the limitations of this information (Eriksson & Kovalainen, 2008). Blaikie (1993) asserts that epistemology is “the theory or science of the method or grounds of knowledge”, and extends this to assumptions or a range of statements concerning whether information obtained from reality is possible, what can be conceived, how existence can be conceived, and what standard should be met so that information can be defined as knowledge. With reference to Chia (2002), an epistemological assumption concerns ‘how and what it is possible to know’ and the requirement to replicate techniques by which reliable and demonstrable knowledge is formed. According to Hatch and Cunliffe (2006), epistemology acknowledges how you know, how information is formed, what norms distinguish acceptable from inadequate information, and how actuality must be defined. The interdependent link amongst ontology and epistemology is highlighted and how they inform and depend on one another. Furthermore, Mason (2002) mentioned that each epistemological assumption has different ideas to examine these issues; they concern the identification of the knowledge status. The concept, which confirms that the aforementioned views are determined as positivist and interpretivist assumptions, is outlined below (Bryman & Bell, 2011; Saunders et al., 2007).

Positivism perceives credible information as merely phenomena, which may have statistical or perceptible variables. Hence, positivism debates that, in order to obtain knowledge of the social world, a natural science methodology needs to be adopted. Hence, positivist researchers frequently conduct quantitative research. Such research utilises existing theory to generate hypotheses, which are verified through large sample populations to validate statistics (Bryman, 2008; Easterby-Smith et al., 2002, Saunders et al., 2012). A positivist assumption generalises the outcomes through observations of social reality. Furthermore, a positivist perspective accepts that phenomena that can be observed, which may enable acceptable and verifiable data (Saunders et al., 2009). One of the vital features of a positivist perspective is its value-free approach, whereby the investigator does not influence the collected information.

Furthermore, ***interpretivism***, debates that the topic within the social sciences, namely individuals and institutions, is unique, complex and dissimilar to the natural sciences. An interpretivist perspective considers whether the use of a natural sciences method is useful to obtain knowledge in a complex social world. Bryman (2008) suggests that a social world study needs a distinctive rationale for its research method that endeavours to comprehend the subjective meanings of social action. Blaikie (1993) argues that, as social research has various alternatives, there is an opportunity for scholars' views and choices to impact on the process, which results in complexity for this reality. *Interpretivism* considers social actors (individuals) instead of objects in the conduct of the research. It is suggested that the researcher needs be part of the process to enable social actors to interact and act effectively; this helps them understand the issue, which is dependent on the actors' roles. Nevertheless, the comprehension of the researcher is rarely continuous but constantly changes based on other social actors' actions. Saunders et al. (2009) states that the scholar should enter the environment of the topic area and use an empathetic stance in order to interpret the world from the perspective of social actors. Interpretive studies are frequently adopted for qualitative studies, wherein the researcher can closely interact with the examined phenomenon to enhance the interpretation from a complicated position.

Realism is a branch of epistemology akin to the positivist perspective; however realism considers that the existence of objects is autonomous of people's knowledge of their being. In other words, what people's minds illustrate to them is reality. Realism is segregated into two types, namely critical and direct realism. Critical realism promotes the idea that occasionally individuals' minds mislead them; hence, what they perceive might not be a true reality. Meanwhile, direct realism considers that what is seen is what is obtained, and that what is experienced by the senses reflects the true universe (Saunders et al., 2009). For instance, an illusion does not illustrate actual reality.

The involvement of project teams and stakeholders are critical to this research, since the actors and their understandings, views, knowledge and experiences in the UKICI are sources of data. Attention is given to actors' thoughts, opinions and knowledge in relation to LC, and in terms of developing a framework to implement LC in the UKICI. In essence, it focuses on comprehending the phenomena through an evaluation of the meaning, which social actors, or participants, impute to the subject matter. Furthermore, consideration is given to the analysis and interpretation of the situation to develop methods and processes (Bryman, 2004; Saunders et al., 2012). For this reason, it is important that the researcher becomes part of what is being observed and interacts with informants; this advocates that the researcher comprehends and obtains related data to clarify how and why the phenomena exist. Hence, this research leans towards ***interpretivism***, as it acquires subjective information and realities, which determine the accuracy of the situation.

4.3.3 Axiology

Axiological assumptions consider the impact that the researcher's values have on the entire process of the study (Saunders et al., 2012). According to positivism, the process of research is value free. Notwithstanding, social constructivism considers that the researcher has values, which identify what is acknowledged as reality and the understandings that arise from it (Collis & Hussey, 2003). Axiology examines perception regarding the value system and seeks to determine its role (Saunders et al., 2012). Bryman (2008) states that, throughout the research process, values could be real and the investigator may have or develop sympathy for these. It is recognised that a social phenomenon examined by the researcher cannot be considered in a value-free manner. Since the researcher is a significant actor throughout the research, their values have an impact on the entire analysis process and the techniques used for this research. In essence, world perceptions, backgrounds, and cultural experiences have an impact on the researcher's approach. Thus, the axiological assumption of this study leans towards ***value laden*** as the researcher was not able to place themself free from any value, generated for this research, although the researcher understands that their involvement in this study requires the proper comprehension of a complex investigation. Therefore, the involvement of the researcher means that the reality associated with the topic area is subjective. The following section discusses the philosophical stance of this research.

4.3.4 Philosophical Stance of This Research

The research philosophy forms the outer layer of this study that develops a framework for LC implementation in the UKICI. In the context of this research, the emphasis is on the use of LC techniques in construction projects. This research comprises significant communication and interaction among the participants and the researcher; hence, in order to appropriately understand the reality of the researcher, the views of participants must be adequately examined. As the researcher's outlook was continuously influenced and socially constructed by the informants, the ontological perspective of this study was deemed to lean toward idealism or subjectivism. Moreover, the respondents involved in this investigation could have divergent features in relation to their experiences, qualifications, backgrounds, knowledge, roles and so forth. Nevertheless, such variances support the numerous perspectives provided by the participants with regards to their research subject and questions.

The respondents' demographics and experiences shape the different views that may influence their responses to the research questions. Nevertheless, this research focuses on the respondents' outlooks, what they know, feel, think and understand in relation to LC implementation in the UKICI and concerning its impact on efficiency and performance. As the researcher communicates and interacts with industry professionals who adopt LC principles in their projects, it is possible that the researcher's background and experiences may influence their interpretation and data analysis throughout the interviews. Thus, the epistemological position of this study leans towards interpretivism. Furthermore, the axiological position of the study leans towards value-laden since it is not possible to entirely detach from the researcher's potential bias and human interest. Consequently, the purpose of this study is to develop a framework to aid the UKICI to successfully implement LC principles. The following section concentrates on the research approach.

4.4 Research Approach

According to Creswell (2003), the methodological approach is vital to enable the researcher to achieve the aforementioned objectives. Saunders et al. (2016) assert that the research approach (outlined below) is classified into three categories; inductive (building theory), deductive (testing theory) and abductive.

4.4.1 Deductive Approach

A deductive approach considers that, if the properties are accurate, the results will be accurate (Saunders et al., 2012). Such a view arises from natural science, wherein rules enable the expectations of a phenomenon, represent an explanation for its origin, and envisage its existence; hence they can be measured (Saunders et al., 2012). A deductive approach enables the researcher to create a theory or model; therefore, the research design is created in order to test the theory. The acquired data is adopted to analyse the theory or theories regarding the current hypothesis (Saunders et al., 2012). There is a fundamental discrepancy among the inductive and deductive approach, where the inductive approach moves from the specific to the generic, whilst the deductive approach moves from the generic to the specific.

4.4.2 Inductive Approach

The inductive approach advocates that the scholar utilises the acquired data to investigate the phenomena, ascertaining the themes and models and developing a conceptual framework. Saunders et al. (2012) posits that the inductive approach generates a hypothesis on the basis of the analysis of the acquired data. Furthermore, the benefit of using such a method is that the origin of its context is taken into account, whereby such situations occur so that a more precise understanding of that context is enabled. Conversely the deductive approach does not focus on how people contemplate the social world and merely concerns the cause and effect interrelationship among specific variables (Saunders et al., 2012).

4.4.3 Abductive Approach

The *abductive* approach consolidates the inductive and deductive approaches. It is adopted to investigate, evaluate and elucidate connections amongst variables within a specific condition (Saunders et al., 2012). Therefore, the abductive approach focuses on moving back and forth among inductive (data to theory) and deductive (theory to data) approaches.

4.4.4 Rationale for Choice of Research Approach

Based on the aforementioned factors, this research seeks to develop a framework to aid the implementation of LC in UKICI. Thus, existing literature was investigated to create a conceptual framework that subsequently considered the real-world condition. It examined and obtained appropriate data and comprehended the organisation as well as the stakeholders' views and feelings in terms of the successful implementation of LC for an increased efficiency and improved project performance. Hence, this research adopts an inductive approach so as to achieve the aim and objectives of the study.

4.5 Methodological/Research Choice

The methodology denotes the approach to research that considers both the theoretical or philosophical assumptions, and the ways in which these inform the design of the data collection and analysis strategies. There is a difference between the methodology and methods in that the methods merely concern the data collection and analysis; hence the methods are part of the methodology. Meanwhile, the methodological choice refers to the research design. The data collection and analysis methods are categorised into two groups, namely qualitative and quantitative (Saunders et al., 2009). The former utilises numeric data based on the data collection methods, while the latter utilises non-numeric data collection methods, such as coding data from interviews during the data analysis. The quantitative method often adopts a questionnaire survey as a data collection technique and, in terms of the data analysis, uses statistical presentations, for instance tables, graphs, pie charts, and so on. Nevertheless, according to Saunders et al. (2009), "… qualitative and quantitative methods and processes are not fully independent from each other." The chosen method can be a single (mono) or multiple (multi or mixed) research design. Ascertaining the research design is a vital and complex activity as it defines the data collection and analysis process (Churchill, 1979), which means evaluating and analysing various resources to provide a logical connection between the argument and theory (Nachimas & Nachimas, 2008).

Saunders et al. (2012) outline that the mono-method refers to a single method of collecting and analysing data processes. A mono-method uses either a sole quantitative information gathering method, i.e. questionnaires with a quantitative data analysis, or a sole qualitative information gathering method, i.e. semi-structured interviews with a qualitative data analysis. Such methods are suitable for qualitative and quantitative methods. A multiple-method approach is characterised by a mixture, in which multiple data collection and analysis methods are utilised to answer the study questions. Furthermore, this approach is divided into two categories, which are mixed-method and multi-method. A multi-method approach is characterised by a mixture of multiple information gathering techniques with corresponding data analysis procedures; however, this is limited in quantitative and qualitative research. Furthermore, quantitative techniques can be adopted through the use of quantitative analysis methods and questionnaires; such processes are referred to as multi-method quantitative research. However, qualitative data may alternatively be collected through the conduct of semi-structured interviews and qualitative data analysis methods; these are referred to as multi-method qualitative research. Moreover, in the event that a multi-method approach is used, researchers cannot combine quantitative and qualitative procedures and methods (Saunders et al., 2012).

Naoum (2007) asserts that a research strategy is dependent upon the objectives and research type as well as the accessibility of the data sought. Whilst quantitative studies seek objective data, and aim to test theory to establish whether there is an actual reality, qualitative research is inherently subjective and examines a situation, emphasising its meanings, the definition of a phenomenon, exploring different views, and securing alternative notions. These factors imply that this research deploys an inductive approach; hence a mono research strategy is used to accomplish its purpose. Due to restrictions within both the existing knowledge in the field and the study type, this research is deemed exploratory. Moreover, a qualitative approach will be used to investigate the context of LC implementation factors and to subsequently create a conceptual framework for effective LC implementation in the UKICI. This will enable the researcher to explain the various facets of the phenomenon, to eliminate the amount of key alternative outcomes arising from the analysis and to verify the results (Saunders *et al.,* 2012). In essence, the purpose is to identify the situation and to explore alternative concepts rather than to test or verify the theories that already exist (Naoum, 2007). Thus, this research has adopted an in-depth survey strategy. The findings prompted the researcher to develop and standardise qualitative models for construction organisations. Holloway and Wheeler (2002) affirm that qualitative research is a concept of social inquiry that depends on how people view their experiences and the world to which they belong. The adoption of qualitative research depends on a natural approach, which seeks to comprehend phenomena in context-particular settings; for example, the "… real world setting where the researcher does not endeavour to manipulate the phenomenon of interest" (Patton, 2001). However, in a qualitative study, the findings are not the result of numerical techniques or alternative statistical techniques (Strauss & Corbin, 1998).

Jamshed (2014) argues that qualitative research is assumed to be applicable when the researcher either examines a new area of research or ascertains and theorises a prominent situation. Various qualitative techniques are generated to establish a profound and broad understanding of the circumstances through textual interpretation, which is mainly achieved through the conduct and analysis of interviews and observations. Pathak et al. (2013) posits that qualitative research comprehends research questions as idealistic or humanistic. Qualitative research is deployed to comprehend individuals' behaviours, backgrounds, knowledge, experiences, communication and interactions; moreover, it engenders non-statistical data. A research strategy that integrates qualitative research with an intervention study, will advocate enhanced attention across the disciplines.

This research endeavours to comprehend LC implementation factors in a real-life context in the UKICI. In order to achieve this, semi-structured interviews are utilised to collect the qualitative data. The qualitative data has been analysed by a triangulated approach, where the researcher made use of contrasting views and comparisons amongst the findings. This led the researcher to validate the analysed data. This research leans towards subjectivism, interpretivism and value-laden philosophies; therefore an inductive approach has been selected. The study requires the researcher to enter the environment of construction organisations in order to collect data on LC implementation, which is then interpreted and comprehended in order to subsequently create a conceptual framework for effective LC implementation. This research attempts to explore the context of effective LC implementation in the UKICI, thus an in-depth study involving numerous infrastructure construction organisations will be undertaken. The researcher intends to explore in-depth with, and enable interactions amongst, these organisations and their actions at the development phase.

4.6 Research Strategy

After the philosophy and approaches have been determined, a range of strategies is explored that are applicable to the conduct of the research. In order to ensure congruence throughout the research, the strategy needs to be influenced by the philosophical stance and research approach. Fundamentally, a strategy allows the researcher to adopt a 'plan of action' or a 'roadmap' to translate the research aims into viable outcomes (Yin, 2009; Saunders et al., 2009). A research strategy is crucial in terms of facilitating the investigator to accomplish the research aim and objectives (Remenyi et al., 1998; Saunders et al., 2012). Furthermore, a research strategy is a methodological assembly that links the research philosophy with the consequent choice of research method (Denzin & Lincoln, 2005).

Yin (2014) asserts that a research strategy has distinct features, but that a significant overlap occurs amongst them. Yin (2014) highlights the existence of three situations that determine when these strategies can be used. These situations comprise the research query type, the researcher's degree of control over real life situations, and the extent of the emphasis on current situations rather than historic events.

A research strategy is considered to be a set of actions and a design to accomplish a purpose, and thus the research query (Saunders et al*.,* 2012). Furthermore, the selected research strategy must be led by current knowledge, the study's research questions, the available resources and the philosophical grounds of the researcher. Saunders et al. (2012) categorised the research strategies into eight groups, namely: survey, case study, archival research, experiment, narrative inquiry, grounded theory, action research and ethnography. Table 4.1 presents these strategies with their features.

This study does not recommend the use of ***experiment research*** since this strategy needs the investigator to maintain total control of the phenomenon. It is predominantly applicable to quantitative research and carried out in a highly controlled context. Due to the researcher's inability to fully control the context, an experimental research strategy is discounted. Experimental studies are frequently the 'gold standard' averse to cogency of different strategies are acquired (Saunders et al., 2012). In ***archival research,*** managerial documentation and records are considered the primary information (Saunders et al*.,* 2012). According to Bryman (1989), the phrase 'archival' has historic implications that could misguide investigators, as it might also imply recent documentation. As the purpose of this study is to comprehend an actual-world situation in the UKICI, archival research could provide useful data; however, this would not deliver the desired outcome for appropriate analysis.

Saunders et al. (2012) affirm that ***ethnographical research*** is often adopted for group research and essentially uses an inductive approach. This strategy requires the researcher's involvement by observing, discussing and comprehending the unit in order to become familiar with the unit's interactions, beliefs, and attitudes and the events that shape their worlds. This allows the investigator to generate extensive cultural stories from the sample (Saunders et al., 2012), although additional time is often required in the adoption of this type of strategy, which is not possible for this study. Hence, ethnographic research is not applicable to this study. Saunders et al. (2012) state that ***action research*** is generally utilised to advocate organisational education in order to generate real-world results by ascertaining problems, and then designing, taking and measuring action. This strategy is conceptualised as “research in action rather than research about action” (Saunders et al., 2012) and is most applicable to researchers who are able to use additional time within companies to conduct the research. Furthermore, as this strategy is generally longitudinal, it is more appropriate for long to medium term research, rather than shorter-term studies. Therefore, action research is not applicable to this study (Coghlan & Brannic, 2010; Saunders et al., 2012).

A researcher may adopt ***grounded theory*** to imply a methodological form, as this strategy is an investigation method that arises from the study’s procedure (Saunders et al*.,* 2012). This theory utilises data gathering methods to collect data and the subsequent analysis process enables the creation of a model that elucidates social interactions and procedures across a broad spectrum (Bryant & Charmaz, 2007). However, this research strategy does not allow a sufficient timeframe for the researcher to spend an appropriate amount of time collecting data with the purpose of developing a model. Thus, the strategy is unsuitable for this study (Strauss & Corbin, 1997).

Narrative inquiry enables the researcher to analyse connections, interactions and socially grounded elucidations, which arise inherently from narrative stories in order “… to understand the complex processes which people use in making sense of their organisational realities” (Musson 2004; Saunders et al., 2012). The strategy is best suited to qualitative and interpretive research. However, this type of strategy is rigorous and demands a substantial amount of time. In this study, the investigator intends to examine an in-depth phenomenon in an actual-world context within the UKICI; hence, a narrative inquiry cannot be considered.

Table 4.1: Research Strategy Characteristics

Research Strategies	Characteristics
Experiment	Suitable for laboratory research rather than the field Unlikely to be related to the real world of organisation
Survey	Most frequently used to answer 'what', 'who', 'where', 'how much' and 'how many' questions Used for exploratory and descriptive research An easy to explain and to understand research strategy
Archival research	This strategy makes use of administrative records and documents as the principal source of data Allows research questions which focus upon past and changes over time to be answered
Case Study	It is suitable for research which wishes to gain rich understanding of the research context and processes Has considerable ability to generate answers to the question 'why', 'what', and 'how' Not suitable for collection data for generalisation
Ethnography	It is used to study groups It requires a longer term of field work study
Action Research	Provides in depth understanding to specific phenomena, but the literature advises using it in the education context
Grounded Theory	Has been used by many academic research studies in the building environment field Has been criticised widely due to its confusing process and time required to be completed Collecting data processes might require visiting the field several times
Narrative Inquiry	Suitable for small, purposive samples This strategy is intensive and time consuming
Mixed methods	Allows answers to questions on what, how and why Adopted to describe, explain and explore a phenomenon Allows for diversity of views to aid interpretations Allows for generalisation of the study or its relative importance Allows for both qualitative and quantitative data to be employed in a single research Allows combination of inductive and deductive approaches within a single research

Source: Saunders et al., (2012)

The above-mentioned research strategies can be utilised separately or integrated as a mixed method. Nevertheless, Yin (2014) identified three positions that help to determine the most suitable strategy, namely: the research query and type, the level of researcher control over real-life events, and the extent of emphasis on current events rather than exclusively historical events. Table 4.2 illustrates the interconnection among these situations and the five fundamental research strategies.

Table 4.2: Research Strategies Based on the Associated Situations

Strategy	Research Query Type	Control of Behavioural Situations Required	Focus on Current Situations
Experiment	How, why?	Yes	Yes
Survey	Who, what, where, how many, how much?	No	Yes
Archival	Who, what, where, how many, how much?	No	Yes/No
History	How, why?	No	No
Case study	How, why?	No	Yes

Source: Yin (2014)

Based on aforementioned factors and research objectives, the ***survey research strategy*** is most suitable for this study, since it will enable a thorough comprehension of real-life events, and help to contrast and compare the findings. The following section outlines the survey strategy.

4.6.1 Survey

According to Saunders et al. (2012), a survey research strategy is commonly deployed within business and management studies and essentially adopted to find answers to the questions of 'what', 'who', 'where', 'how much' and 'how many'. Additionally, it can be used within exploratory and descriptive research. A survey strategy enables the researcher to compare the data collected from a large population and develop a deep understanding of the investigation procedure, which advocates the creation of connections amongst variables and suggests potential causes for these connections (Saunders et al., 2012). Due to the nature of this research and its purpose to aid LC implementation in the UKICI, a survey is the most suitable strategy. Furthermore, this meets the study's limitations in terms of cost and time as the strategy does not require the researcher to gather information for an entire population but merely to utilise the sample unit that helps to acquire the results, which represent the entire population (Saunders et al., 2012).

The survey strategy is adopted to collect information from a substantial population, which will suit this study that aims to consult contractors, consultants, and clients in the UK construction industry. Surveys are not limited to particular information gathering methods; they can also use interviews, questionnaires, observations and content analyses (De Vaus, 2002). This research deploys a survey strategy, as the aim and objectives of the study demand the collection of extensive data as well as the establishment of a general concept regarding LC best practices and their implementation in the UKICI.

4.6.2 Literature Review Synthesis

In any research, the literature review is considered a critical phase. A literature review is conducted by selecting the most suitable and accessible documentation, either by using published and/or unpublished resources that are relevant to the research field and subject. Such documentation comprises facts, evidence, theories, data and studies undertaken by a number of authors (Hart, 1998). A literature review intends to ascertain the gaps in the specific research area, which advocates the creation of research queries and the identification of adequate and acceptable answers to those queries through empirical research (Eisenhardt & Graebner, 2007). A literature review advocates the generation of concepts through research and existing knowledge, which helps to develop a robust aim and objectives (Saunders et al., 2009). In addition, the synthesis of literature helps to construct a vigorous discussion that justifies the research and ascertains the fundamental challenges that may impact on the research problem. Moreover, instead of considering narrative critiques and data sources, the literature review focuses on the descriptive facets of a range of articles/journals (Gill & Johnson, 2010). This study carried out a critique of existing LC techniques and their implementation factors; it ascertained numerous gaps on the basis of the adoption of LC techniques in the UKICI. Furthermore, a synthesising literature review enables the selection of suitable research strategies.

4.6.3 Justification for Selecting Survey

Since the purpose of this research is to develop a framework to aid effective LC implementation in the UKICI, the research phenomenon needs to involve participants from infrastructure construction organisations in a real-life context in order to understand the phenomenon of LC from the project stages. The 'survey' research strategy is recommended for the exploration of broad aspects and a range of ideas with regards to the approaches and techniques of LC principles used in the UKICI. Moreover, a survey research strategy is adopted to include the research phenomenon and its associated situations. In essence, the recommendation is to explore the key challenges and barriers of LC implementation in the UKICI. As this research adopts an inductive approach, the philosophical position leans towards subjectivism, interpretivism and value-laden; thus, a survey research strategy is most suitable.

This research intends to facilitate social interaction between the scholar and the construction professionals of the UKICI; thus, individual control is not required since the richness of the data acquired is critical within these social relationships. Given that there is no requirement to control behaviour, action research and experimental methodological approaches are discounted as potential choices. Instead, this research uses 'what' and 'how' questions; therefore, the strategies of action research, ethnography, grounded theory, and history research are eradicated as they would not provide appropriate answers to these queries. As the depth of data requires an extensive investigation involving construction professionals, archival research cannot be used as a methodological approach since it requires the study of historical documentation and archives. Therefore, based on the aforementioned factors and the research aim and objectives, a survey is the most suitable research strategy to conduct this study. This enables the researcher to thoroughly comprehend the research problems, generate comparisons, contrast the results, and accomplish the research aim and objectives.

4.7 Time horizon

Saunders et al. (2012) categorised the time horizon of a research methodology under two different types, *cross-sectional* and *longitudinal*. The former investigates a specific phenomenon within a defined timeframe. The latter requires a longer period of time to acquire in-depth data and results. For this research, an academic year formed the allotted timeframe as the research was undertaken within an educational programme. The researcher aims to develop a framework to aid the implementation of LC in the UKICI.

Hence, the time horizon of this research is cross-sectional. The researcher's techniques are discussed in the following section.

4.8 Data Collection Methods

The last layer in the Research Onion by Saunders et al. considers the research techniques that comprise the data collection and analysis methods. This study deploys ***qualitative research*** to elucidate the facets of the phenomenon, to eliminate a number of crucial rational assumptions arising from the findings and to acquire verified data. The fundamental data collection methods use secondary data, questionnaires and interviews, which are outlined below.

Saunders et al. (2012) affirm that both quantitative and qualitative data can be classified as secondary data, which can also be collected from survey research and case study strategies. These data can be gathered using surveys and multiple sources. Documentary secondary data utilises recorded sources, which includes meeting minutes, transcripts of recorded talks, diaries, project reports and journals, newspapers, magazine articles, books and organisational and public records. Furthermore, documentary secondary data makes use of non-written material including drawings, films, photographs, voice and video recordings, televised programmes, the databases of the companies as well as CD-ROMs and DVDs (Robson, 2002). Such data could be analysed quantitatively and qualitatively. Nevertheless, secondary data is mainly used to triangulate findings on the basis of alternative information gathered via data collection techniques, namely interviews and questionnaires. This research makes use of ***documentary secondary data*** to inform the researcher's background knowledge and construct the research by gathering information from journals, books and conference papers, which comprises the research objectives.

4.8.1 Qualitative Methods of Data Collection

Saunders et al. (2012) state that the qualitative data collection methods focus on developing, acquiring, recording or utilising non-statistical data via direct observations and in-depth group and semi-structured interviews. A qualitative data collection method enables the researcher to gather in-depth data and information (Collis & Hussey, 2003).

An ***interview*** is a purposeful dialogue between individuals where the interviewer raises queries and the respondents provide answers to these queries. Furthermore, interviews advocate that the scholar collates data and then validates the information associated with the queries and objectives of the study. Interviews are classified into three groups by Saunders et al. (2012), namely, semi structured, structured and unstructured.

Structured **interviews** utilise questionnaires, which contain a set of standardised and predetermined questions. Saunders et al. (2012) refer to this type of interview as interviewer-administered questionnaires, while others call them quantitative research interviews as they gather and analyse statistical data. Structured interviews use a predetermined and standardised set of questions, which are often raised in a similar way and in the exact form that the questions are set. Gill et al. (2008) assert that structured interviews are advantageous if there is a requirement to clarify particular questions or when there are potentially numeracy or literacy issues amongst the participants. Gill et al. (2008) state that structured interviews merely allow for restricted participant responses; thus, they are not beneficial when in-depth data is needed for a research.

Semi-structured interviews are not standardised; thus, Saunders et al. (2012) refer to them as qualitative research interviews. Semi-structured interviews advocate that the interviewer adopts a set of pre-designed questions, which promotes a conversational style, giving the opportunity for respondents to contemplate the issues or situations they think are significant (Clifford et al., 2010). Semi-structured interviews consider particular themes, which are covered in a conversational manner; they are frequently concerned with the most efficient and effective way of exploring and understanding the inspirations behind individuals' attitudes and choices, their beliefs and behaviours and the influence of certain situations and events on their lives. Raworth et al. (2012) state that semi-structured interviews frequently allow the researcher to gather valuable and unexpected data. Furthermore, Britten (1995) and Gill et al. (2008) discuss that semi-structured interviews contain a number of crucial questions to outline the fields that need to be investigated and enable the interviewer or interviewee to diverge to pursue a concept or reply in more depth. Semi-structured interviews allow for flexibility enabling additional queries in response to what are often perceived as crucial responses (Bryman, 2004).

Unstructured interviews are considered to be informal and utilised to investigate an in-depth common field of interest. The researcher is merely required to thoroughly comprehend the particular subject that they intend to investigate; therefore, a predetermined set of questions is not required. As such, interviewees can discuss their thoughts and ideas freely with regards to the subject (Saunders et al., 2012). Unstructured interviews provide a system of conversations, which are essentially led by the respondents rather than predetermined questions developed by the researcher. Unstructured interviews are mainly used when a researcher needs to comprehensively comprehend a specific phenomenon within a certain context (DiCicco-Bloom & Crabtree, 2006). Therefore, such interview types are mainly used in ethnographic research.

Naoum (2010) asserts that interviews are crucial techniques to acquire realistic data and to understand individuals' inner perceptions. Interviews are generally conducted face-to-face, during which interviewees are asked questions by the interviewer that aim to elicit responses applicable to a specific research area. Interviews are broadly used techniques to explore individuals' knowledge and experiences as well as their opinions and behaviours, and factual concepts. Zhang and Wildemuth (2009) refer to interviews as an effective tool for a qualitative data collection, embodying one of the broadest methods in qualitative research. An interview is an interfacing system between the researcher/interviewer and the respondent/interviewee who wittingly seeks facts or investigates a specific area of interest (Wengraf, 2001). According to Yin (2009), one of the most significant data collection resources is an interview since it elicits rich and rigorous data from the interpretations and views of informants through social interactions (Blaikie, 2011). Moreover, interviews address various queries, which are considered qualitative or quantitative; in other words, interviews relate to the philosophies of interpretivism and positivism (Britten, 1995). Saunders et al. (2009) assert that the conduct of interviews helps the researcher to acquire reliable and valid information that meets the objectives and answers the research questions.

4.8.2 Literature Review

A literature review is an extensive appraisal of unpublished and published documents from secondary data sources in a specific field of interest (Sekaran, 2003). Researchers use the literature review to avoid re-inventing the same problems and events, which have already been addressed by other investigators/researchers, and to ensure that the researcher's knowledge is current. According to Bryman and Bell (2011), literature reviews are crucial in facilitating a discussion regarding the research queries and objectives. A literature review aims to achieve more than simply reproduce theories and other academics' views, and comprehend historic theories; it aims to make use of these concepts to promote a specific opinion or discussion. The literature review undertaken in this study covered the gap in knowledge for LC implementation in the UKICI, and acquired secondary data for the study. Thus, the literature review carried out comprised literature in relation to LC practices, LC implementation factors, guidance and frameworks to comprehend existing concepts and the current situation.

4.8.3 Sampling

Sampling strategies contain various tools, which advocate that the researcher eliminates the volume of information required by focusing on the information from a subset instead of every potential element (Saunders et al., 2012). In essence, sampling is adopted to standardise every feasible case from which the sample is selected; therefore, the sample volume and population need to be identified for this process. Moreover, the requirement for sampling arises if cost and time limitations prevent the investigator from surveying the entire audience (Saunders et al., 2012).

It is believed that sampling is a critical tool in selecting participants for the research. Bailey (1978) states that research entities are referred to as the *units of analysis*, which that may be an individual, group, firm, sector, city or country. The extent of such groups is referred to as the *population* and every group is known as a *sample element*; moreover, a sample is a proportion or subset of the entire population. A *sample unit* is either a single component in the population or a group of components, whilst a *sample frame* is a whole list of entire units that emerge from the sample (Bailey, 1978). For this study, this would mean the total number of consultancies, clients, and contractor organisations in UK infrastructure. The audience for this study is the UKICI; hence, the sample frame is the overall number of sample units selected for this research.

According to Bailey (1978), a successful investigator often commences with the overall population and moves towards the sample that will be significantly smaller. Sampling can be precise when it is carried out thoroughly. It is determined that a prudently chosen sample can represent accurate and precise findings rather than a number of sample units. Emmel (2013) states that sampling is often categorised into two groups. The former determines, "… an audience emerg[ing] from the sample whilst the latter is about making sure that all individuals from the predetermined audience have an opportunity for being included." (Emmel, 2013). Nevertheless, they are not applicable to sampling in qualitative research; in qualitative research, the most applicable technique for sampling is to invert the aforementioned activities and find alternative ways to evaluate them.

Research sampling is a crucial technique as it helps to avoid investigating the whole (and potentially large) population. Examining a large population requires a significant amount of cost and time; moreover, it is not certain that the results would be accurate as this process is prone to variances in the population through the passage of time, and future perceptions may be significantly different than the current or previous ones (Saunders et al., 2012). Furthermore, it may be impossible to manage the process, or the results could diverge (Emmel, 2013). Thus, sampling is an advantageous technique to capture and evaluate the population in a specific timeframe (Bailey, 1978). In addition, the other benefit of adopting a sampling tool is its exclusivity; if participants are made aware that they are in a particular unit and that their identities will be protected and kept anonymous, there is a higher chance that they will participate. According to Saunders et al. (2012), the two methods for sampling are non-probability (judgmental sampling) and probability (representative sampling), which are outlined below.

4.8.3.1 Probability Sampling

This is often adopted in survey research designs and the samples are chosen from the audience by a uniform probability (Saunders et al., 2012). In essence, probability sampling advocates that the researcher undertakes a statistical evaluation of the characteristics from the sample population, which helps to accomplish the research questions and objectives. Saunders et al. (2012) suggest that probability sampling techniques have five subsets, which are: systematic, multi-stage, stratified random, simple random, and cluster sampling. In this approach, the probability of the sample selections is acknowledged. These subsets are outlined as follows:

- *Random sampling* is the most frequently used probability sampling type. Random sampling means that the entire analysis group or sample group have the same probability of selection for the sample. This applies to every member from the sample unit despite discrepancies in their features (Saunders et al., 2012). Thus, the sample selection is often made legitimately when the sample form includes the unit; hence, the use of random sampling has significant advantages.

- *Systematic sampling* is selected when the researcher does not intend to use random sampling. When random selection is preferred in a sample unit, the 1/*k*th are selected, where k is a continuous figure that may be randomly selected by the investigator. This leads the investigator to acquire a systematic sample (Saunders et al., 2012). Nevertheless, Bailey (1978) suggests that, due to accuracy, using simple random sampling is more appropriate than systematic sampling.

- *Stratified sampling* considers the members of the sample frame, who are divided into divergent units that do not overlap and are also called strata (Bailey, 1978). This type adopts a systematic or random sampling tool to choose the sample from the stratum. In addition, Bourdeau (1953) posits that this type of sampling is applicable when specific fields are selected and samples are sampled randomly, whilst Tongco (2007) mentions that such processes are similar to purposive sampling when samples are selected randomly through a purposive sample.

- *Cluster sampling* allows the researcher to select samples from clusters of the population; this may be used in various phases (Saunders et al., 2012). Bailey (1978) asserts that cluster sampling is often adopted where the development of a sampling frame is impractical or impossible, and the sampling groups are sampling components. Cluster sampling enables the researcher to save cost and time; however, it may be more likely to lead to inaccuracies due to multiple sampling phases. All individual phases could have cumulative probability errors; hence, the results could be an inaccurate representation of the population.

4.8.3.2 Non-Probability Sampling

Non-probability sampling is not dependent upon a numerical system and the selected sample's probability from the audience is unknown (Saunders et al., 2012). The selection of sampling strategies depends upon the subjective judgment of the investigator.

Furthermore, the investigator potentially needs to use single or multiple non-probability sampling designs in conjunction with the study questions and research design selection, in order to identify a sampling frame. Tongco (2007) mentions that non-probability sampling techniques comprise systematic sampling, where the initial point is random. In comparison, every successful sample has a clear gap from the initial sample and every sample is uniformly positioned. According to Saunders et al. (2012) non-probability sampling comprises five techniques, namely purposive/purposeful, dimensional, quota, convenience and snowball sampling. These are detailed as follows:

- *Convenience sampling* arises from convenience. In this technique, the most suitable or nearest, or most adjacent group is selected without disturbing those that are distant or impractical to reach. This type of sampling leads to cost and time savings; however, the accuracy probability is low (Bailey, 1978).

- *Quota sampling* is considered akin to stratified sampling, but the key difference is that the entire stratum needs to be uniform and the main units are within the whole audience (Bailey, 1978).

- *Dimensional sampling* is assumed to be akin to quota sampling, albeit the form of this sampling is multidimensional, and the variables and measurements are predetermined. From this, a mixture of these measurements is chosen (Bailey, 1978).

- *Purposive/Purposeful sampling* is a non-random tool that is a purposeful selection from the population as qualities are possessed by the informant. This tool is also referred to as judgment sampling and is mainly appropriate to studies focusing on a culture or sector where not every member is known (Tongco, 2007). In essence, this sampling type is particularly applicable for documenting events that not all members are able to join, nor have experienced or witnessed (Zelditch, 1962). Hence, interactions should be conducted with experts rather than random individuals from a sector or culture (Bernard 2002; Tongco, 2007). For instance, not every organisation in the UKICI has implemented Lean Construction. Therefore, there is a requirement to interact or interview construction organisations that have looked at or implemented LC practices. Purposive sampling leads a researcher to use their discretion, knowledge and skills of the population in order to select the most suitable respondents to answer the research questions and meet the objectives (Bailey, 1978; Emmel, 2013).

- *Snowball sampling* occurs from the researcher's interaction with their networking groups to acquire a higher volume of respondents; in this approach, the researcher asks the respondent to suggest other individuals who are qualified to contribute to the research, thus a snowball effect is created (Bailey, 1978). There are probabilistic and non-probabilistic snowball sampling types based on the researcher's judgement as to whether random sampling is to be adopted.

Based on the aforementioned factors, purposive sampling is most applicable technique for the context of this study since the researcher can choose events that can provide an insight into realistic and logical approaches and practices to LC in UKICI. Tongco (2007) asserts that this tool provides the best outcome, where a researcher investigates a specific cultural domain alongside well-versed and experienced specialists. The bias in this technique is its productivity; however, it remains rigorous regardless of whether it is verified through random probability sampling. A purposive sample is essential to achieve the quality of information required; hence, the researcher must ensure the respondents are reliable and competent.

4.8.4 Qualitative Research Sampling Strategies

In qualitative research, sampling techniques are divided into three categories, which are theoretical sampling in grounded theory, purposive sampling, and purposeful sampling (Emmel, 2013). It is debated that these techniques could be adopted interchangeably and could construct each other.

4.8.4.1 Theoretical Sampling

Theoretical sampling is fundamental to grounded theory, as the theory is created through experimental research into the social environment (Emmel, 2013). Nevertheless, Emmel (2013) states that, as the basis of grounded theory continually develops, the investigator frequently asks what units or sub-units one turns to in order to gather information and for what theoretic aim. Therefore, theoretical sampling within grounded theory could not be ascertained prior to the study and could not be apportioned to an entity, individual, firm, research tool or documentation. The investigator is required to be entirely receptive to the evolution of theory and should not allow biased perceptions to obstruct the research stream while theories are emerging (Corbin & Strauss, 1997). Moreover, Charmaz (2014) affirms that theoretical sampling is about investigating applicable information to improve the emerging assumptions. Theoretical sampling fundamentally attempts to elaborate and refine groupings that constitute the researcher's theory. A researcher undertakes theoretical sampling to develop the entities of their groupings until no other entities emerge.

4.8.4.2 Purposeful Sampling

Although this type of sampling has been addressed under non-probability sampling, purposeful sampling is outlined more precisely within this section. Purposeful sampling is dissimilar to theoretical sampling as the researcher's discretion and previous and current knowledge in the research area influences the research strategy. Emmel (2013) asserts that purposeful sampling focuses on selecting rich data through rigorous cases, which advocates that the researcher has best insight into the research objectives and questions and is able to persuade the research audience. Patton (2002) refers to this strategy as pragmatic sampling and considers it a facet of grounded theory; however, in contrast to theoretical sampling, purposeful sampling evaluates who or what to sample in relation to the research objectives and the particular research audience (Emmel, 2013). This evaluation, or purposeful sampling, is influenced by pragmatic and realistic judgements rather than theoretical categories with purpose of operating what is logical, documenting precisely what happened, why it happened and what the findings are (Patton, 2002). Furthermore, the rationality and richness of purposeful sampling depends on acquired in-depth data by developing a deep understanding of the questions and objectives of the study (Emmel, 2013).

This research adopts a sampling strategy as it enables researcher to select and evaluate rich and rigorous cases. The sample selection is qualified as UK infrastructure construction clients, contractors, and consultant organisations since they meet the research criteria of possessing adequate knowledge and experience to provide the researcher with sufficient and accurate data, to answer the research questions, and hence the objectives. The information acquired from these cases is valuable as they provide an in-depth insight (Emmel, 2013).

It is imperative to consider that the random sampling techniques of stratified sampling and quota sampling could be utilised to select cases, although purposeful sampling diverges from probabilistic sampling. However, this approach should not be generalised, as the intention is to investigate cases that provide credible, in-depth findings (Emmel, 2013). Nevertheless, Emmel (2013) summarised purposeful sampling strategies within six categories (shown in Table 4.3):

Table 4. 3: Purposeful Sampling

S/N	Strategies
1	First, researchers make judgements before, during, and after sampling about what to sample and how to use the sample in making claims from their research.
2	Secondly, judgements are made with reference to what is known about the phenomena under study. This includes recognising that much can be learnt from exploring the ways in which phenomena are described through variables, categories, and insight from both quantitative and qualitative research.
3	Thirdly, based on what is learnt before the research starts and as the research proceeds, researchers are strategic in selecting a limited number of cases toward producing the most information that is usable.
4	Fourthly, researchers are aware of who the audience for their research will be and choose sampling strategies that will produce the most credible results for these audiences.
5	Fifthly, these decisions are always constrained by resources, an important consideration but one that should be addressed only after the first four themes are considered. Qualitative researchers would always like to sample more, but have to make choices with reference to time to do fieldwork, budget, and their capacity to analyse the data they collect.
6	And finally, there are quite different logics to qualitative and quantitative sampling strategies. These differences are exemplified in the purpose of the purposeful sample.

Source: Emmel (2013)

According to Table 4.3, the sampling strategy is segregated into six phases with regards to the sample size. A number of authors promote that the sample volume should be a proportional figure while other authors state that the sample volume does not directly have an impact on the research. However, this depends on the researcher’s ability to persuade the audience with cases that are accessible.

4.8.5 Purposive or Theoretical Sampling Strategy

In this sampling strategy, the work of the researcher is crucial to the progress of the study. Emmel (2013) asserts that,

> *... purposive or theoretical sampling techniques consider explaining actual phenomena [that] needs more than reliable oblivious experience and happenings that in fact ... need direct liaison among theory and empiric stories within [an] interpretative and inductive strategy of sampling.*

Tongco (2007) states that, for a purposive/purposeful sampling strategy, the investigator needs to have knowledge of the research area prior to sampling the population so that well-versed and faithful respondents can be found in the most efficient way. Subsequently, the researcher needs to determine the themes and to ascertain individuals/organisations that are willing and capable of providing information by virtue of their experience and knowledge (Bernard, 2002). Tongco (2007) adds that the respondent needs to be well-versed, with the theoretical standard of the sample population. According to Guest et al. (2006) and Allen (1971), in order for a researcher to select the most appropriate and qualified respondents that fit the purpose of the research, a number of certain criteria must be determined.

In order to answer the research question/s of this study, the researcher needs to select in-depth cases with rich information from the respondents, which provide the best insight into the context of this research. Therefore, the companies comprising clients, consultants and contractors with experience of implementing Lean Construction in the infrastructure industry are selected. A thorough examination of these cases will help to answer the research questions; hence, the most applicable sampling technique is purposeful sampling. As the complex rationality and virtue of purposeful sampling is based on a profound evaluation of data rich cases, it enables the investigator to answer the research questions, and is deemed to be the best sampling strategy for this study.

4.9 Data Analysis Method

The data type determines the data analysis process, whether statistical or non-statistical. Hence, the data analysis methods are divided into two categories, namely qualitative and quantitative methods. This research utilises qualitative method, which is outlined below.

4.9.1 Qualitative Method

According to Saunders et al. (2012), qualitative data is considered to be non-statistical and has not been quantified; moreover, every research strategy can use it as a product. Saunders et al. (2012) and Denscombe (2010) assert that the data analysis process consists of five different methods, and these are: content, thematic, grounded, discourse and comparative analysis.

Content analysis is referred to as a methodical technique that helps to acquire concepts and views, which are determined in advance and the information is formed through the transcription and coding of the expressions that are compressed into themes. ***Thematic analysis*** is an approach that is remarkably inductive, wherein the themes are extracted from the collected information and the researcher does not impose these themes. ***Grounded analysis*** makes use of classification and codes for the gathered data so as to acquire concepts and theories from the meanings through the data. ***Discourse analysis*** relies on conversations, including the participants' ways of communicating and interacting, and what convinces these individuals to interact. In this type of analysis, the conversations are analysed as a performance as opposed to a state of mind. ***Comparative analysis*** focuses on contrasting information gathered from various respondents until no further event or issue occurs; this kind of analysis relates to thematic analysis.

Content analysis is a broadly used method or a tool for qualitative research. The purpose of this method is to elicit rich and credible data from text or images that are either explicit or implicit and design this information through methodical theories before making valid judgements and interpretations (Colorado State University, 2014; Krippendorff, 1989, 2004; Kualtunga et al., 2007). According to Joffe and Yardley (2004), content analysis is advantageous as it is capable of systematically studying significant volumes of raw information. Furthermore, the quantification of qualitative data can also be undertaken by a content analysis (Kulatunga et al., 2007; Vismoradi et al., 2013).

Kulatunga et al. (2007) states that content analysis can be divided into four techniques. The first technique is the word-count, where the researcher counts the occurrence of ascertained and assumed words that frequently occur and demonstrate the significance of the words. The second technique is a conceptual content analysis, where the researcher examines the texts or sets of texts for the presence and frequency of the ascertained themes or theories (Colorado State University, 2014). These themes or theories may emerge from the data or could be pre-determined from the literature. The third technique is called relational analysis, where the links amongst the themes or theories emerging from the text are analysed (Colorado State University, 2014). The last technique is referred to as referential content analysis, where the researcher examines the texts based on their fundamental meanings and interprets this information with their judgement.

Content analysis is also referred to as coding (Bailey, 1978), and is the most applicable data analysis method for this research due to the purpose of the research questions and the size of the data that needs to be analysed. This type of analysis promotes the examination of informants' replies with various concepts to provide profound statements that are crucial to the study. As the purpose of this research is to develop a framework for the implementation of LC in the UKICI, the published documents related to LC principles and its implementation factors, and the knowledge and experience of the informants were investigated. Given the inapplicable and restricted functionality of the word-count and relational analysis techniques, this study utilises conceptual content analysis to provide an insight into LC implementation in the UKICI.

4.9.2 Coding of Data

Naoum (2007) asserts that coding the data with regards to the themes and concepts is the most efficient and effective way to analyse open-ended questions and promotes the elimination of high-volume information in order to determine a few generalised responses. Equally, Bailey (1978) asserts that content analysis or coding,

> *… is a structured document-analysis technique in which the researcher first constructs a set of mutually exclusive and exhaustive categories that can be used to analyse documents, and then records the frequency with which each of these categories is observed in the documents studied.*

In this research, open-ended questions were coded after the data was gathered in accordance with the context of this research. As this study entails contrasting phenomena rather than a descriptive analysis method, and the purpose is to provide a broad-spectrum of the situation that emerged from the cases, the inferential analysis method is adopted (Miles & Huberman, 1994). The researcher uses a mixture of unreduced texts, tabulating, and/or pie charts from the coded sections in order to analyse the data. Moreover, to ensure appropriate analysis and sufficient discussion, every query was taken on its own merit by primarily elucidating the purpose and significance by setting out the questions, and subsequently examining the answers. The coding was carried out using NVivo10 software.

During the analysis of the pilot study, the researcher experimented with a manual analysis of the transcript and by using NVivo 10 software. The latter was selected since it is proven to be an appropriate tool in managing the interview transcription and in aiding the execution of the content analysis. The extent of the categories/nodes and coding created during the analysis process is enormous; hence the use of specialised software was appropriate. NVivo 10 assisted the coding process by ensuring that it was systematic and precise. Despite the limitations in the graphic presentation produced by the software, the researcher accepted this, with the intention of integrating it with other available software.

Coding is the process whereby the data collected is interpreted and defined by the researcher, and represents an important step in the research process (Robson & McCartan, 2016). The analysis process began with the familiarisation with the raw data. The audio recordings of the interviews were listened to repeatedly until the researcher was accustomed to them. Documents were read and re-read to understand the context. The next step was to categorise the data through the process of coding, namely by organising and sorting the raw data (Kohlbacher, 2006).

The categories used in the analysis were a combination of pre-determined and open. Pre-determined categories were identified during the familiarisation stage through the documents that referred to LC principles and their implementation factors, while the open categories emerged from the data analysis. Both were created as nodes in NVivo 10. These nodes were important in classifying the data into meaningful categories. Through the process of coding the text into relevant categories, sub-categories emerged as more refined categories were identified; these were sub-nodes in NVivo 10. The process of coding the raw data into nodes and sub-nodes depended on the interpretation of the researcher. The codes were identified for the potential and relevance of the raw data to existing or new categories. In NVivo 10, the process involves the researcher examining each interview transcript for relevant text and patterns that fit any category, and are then assigned under the respective nodes and sub-nodes.

These processes were undertaken repeatedly; similar relevant texts from other respondents were examined, coded and collated under existing or new categories until the subject crystallised to address the research objectives. The analysed data were then presented and arranged in a consistent order as illustrated in figure 4.2.

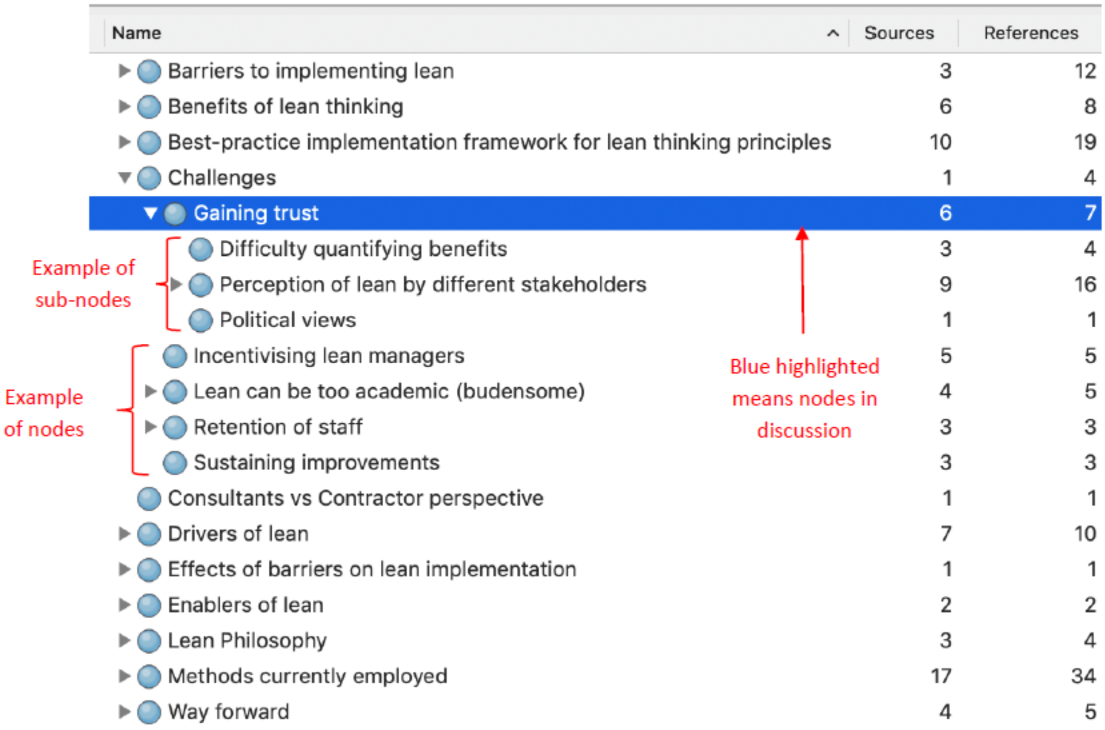


Figure 4.2: Data Presentation Example via NVivo 10

The result of the analysis corresponds to the purpose of examining LC implementation in the UKICI context through the experience of the actors involved. The results were then used to develop a framework that aimed to promote effective LC implementation in the UKICI through considering best practice.

4.10 Rationale for the Choice of Research Methods

As previously discussed, the research is designed to acquire in-depth knowledge and concepts through semi-structured interviews, and therefore adopts an inductive approach. Hence, a qualitative research strategy is employed to achieve the specified objectives and the aim of this study. In other words, a qualitative method is adopted for the data collection and analysis within the interpretation and presentation process of the study.

Based upon the aforementioned factors, the use of a semi-structured interview technique best fits the purpose of this study as it enables the most flexible atmosphere to investigate the most applicable fields of interest to this study. Consequently, semi-structured interviews were utilised as the principal data collection method. Deploying semi-structured techniques advocates that the researcher investigates cases thoroughly and profoundly, as it requires the application of fundamental queries within a flexible atmosphere and varying queries to clarify any vagueness in the responses. As this study was undertaken within the confines of a survey strategy, the semi-structured interview was the most suitable method to accomplish the aim within the timeframe required. In addition, this method encourages interviewees or respondents to express their ideas and perceptions on the basis of their knowledge and experiences in the UKICI, and most importantly in the field of LC. The interviewees/respondents were chosen, through their organisation, to respond to the questions on the participant information sheet or the invitation letters presented to their organisations. The respondents' backgrounds varied from the roles in the companies to the amount of years of experience on that role within the company. To further acquire various concepts considering the cases under investigation, 27 expert views or opinions were sought from both public and private sector organisations including clients, contractors and consultants in the UKICI. The managers or directors were ascertained and approached for the semi-structured interviews and they were contacted and issued with a research participant consent form, as required by the University of Salford's research regulations. Once the respondents confirmed their participation in the research, the interviews were arranged. Prior to the interviews, the participant consent form was read out to check for understanding and agreement. Each interview was carried out in English and was recorded in accordance with the contents of the participant consent form. A total number of 27 interviews were conducted.

In this research, secondary data was gathered through a documentary survey to determine the background information and develop a conceptual framework that considered real life events in order to examine, collect related data and develop an understanding of the concepts and views of informants who have experience and knowledge of LC implementation. The documentary survey addressed the research objectives.

A content analysis was used to analyse the collected data, due to its methodical strategy in acquiring concepts and views, which were determined in advance. The data emerged from the transcriptions and the coding of the texts emerged from the semi-structured interviews, which then leads to the generation of the themes. The content analysis was conducted using NVivo10 software, which utilises word-based and code-based techniques. This tool enables the investigator to efficiently code the high volume of transcripts and to utilise questions to identify themes for the data. The collected qualitative data was transcribed, coded and then analysed thematically. The research outline and overview are given in Tables 4.4 and 4.5.

Table 4.4: The Outline of Research Methodology Adopted

Research Methodology	Type	Choice
Research Philosophy	Epistemology	Lean towards Interpretivism
	Ontology	Lean towards Subjectivism
	Axiology	Lean towards Value Laden
Research Approach	Inductive/Deductive/ Abductive	Inductive
Research Strategy	Survey	Survey
Research Method Data Collection	Qualitative	Secondary Data - Documentary Survey Semi-structured Interviews
Research Method Data Analysis	Qualitative	Content Analysis via NVivo

Table 4.5: Accomplishing the Research Objectives: An Overview

Research Objectives	Research Strategy	Research Techniques	Data Collection and Analysis Method
Objective I	Literature review of research documentation on Lean Production and Lean Construction	Documentary Survey	Qualitative
Objective II	Literature review Survey	Survey: Semi-structured interviews with 27 industry experts	Qualitative
Objective III	Literature review Survey	Survey: Semi-structured interviews with 27 industry experts	Qualitative

Objective IV	Literature review Survey Expert Opinion	Survey: Semi-structured interview with 27 industry experts	Qualitative
Objective V	Literature review Survey Expert Opinion	Semi-structured interviews with 19 industry experts	Qualitative

4.11 Validity and Reliability

In research, the significance of acquiring accurate data and valid findings is an important focus (Creswell & Miller, 2000). Reliability considers the way in which a study produces precise outcomes in research. Since this research acquires qualitative data, the researcher needs to consider several validity and reliability issues that could arise during the data collection process (Sutter, 2011). According to Golafshani (2003), reliability and validity consider the removal of prejudice in qualitative research. Furthermore, Yilmaz (2013) asserts that reliability and validity can be achieved by fulfilling specific requirements during the data collection and analysis processes.

Gillham (2005) and McNeill and Chapman (2005) advocated the application of a reliability test. The former affirms that a test can be reliable when it generates precise outcomes after re-testing. Equally, the latter asserts that reliability is about acquiring precise and similar outcomes once two different researchers have utilised the research method in two different situations. In contrast, validity refers to the truthfulness of collected information as well as the interpretations from the results (Neuman 2014; Suter, 2011). The technique for validity testing varies based on the research type, whether it is qualitative or quantitative. In qualitative research, validity entails facets of power in the data, the extent of the data, its truthfulness, neutrality and its triangulation; in comparison, in quantitative testing, validity is tested on the basis of measurements, or sampling error measurement.

Nevertheless, generalisability focuses on the possibility of extrapolation, namely whether the results from the samples can be extrapolated to an enlarged unit. It may not be easy to demonstrate generalisability, as the purpose of qualitative research is to acquire the ideas, concepts and outlook that comprise the subjective responses from the informants/respondents. Nonetheless, Finlay (2006) pointed out that depending on the depth and power of the information, the researcher can transfer the findings from the samples, which could be applicable to the study.

Moreover, Lincoln and Guba (1985) established a measurement criterion for qualitative research, which comprises the test for conformability and dependability as well as the test for credibility and transferability. Conformability seeks to determine whether the study results are aligned with the results of the same study yet adopting another method. Triangulation is known as a type of conformability test in qualitative research. Dependability deals with the occurrence of events that led the investigator to acquire results and if these events can be retraced to produce an exact conclusion. Credibility focuses on logical results while transferability focuses on the way the results were acquired and whether they are applicable to another study (Lincoln & Guba, 1985).

Conformability, dependability, credibility and transferability can be acquired through various techniques. The techniques briefly outlined in the following paragraphs comprise of discrepant/negative information, utilise rich descriptions and member checks (Creswell, 2003), peer debriefs (Onwuegbuzie & Leech, 2007), in-depth methodology descriptions, and an examination of previous research to frame the findings, and triangulation (Shenton, 2004).

Creswell (2003) refers to *member checking* as a strategy to examine the credibility of results acquired in qualitative research through issuing the final document to the informants from the sample unit to ascertain the accuracy and validity of the findings. This research adopts a member checking strategy to evaluate the findings' credibility as it enables the informants to determine if the results are valid and reflect reality. Furthermore, the strategy of using rich descriptions of the results advocates that the researcher perceives the respondents; furthermore, outlooks and associated views with their experiences and knowledge, and such strategies also contribute to the credibility of the research findings. Presenting discrepant or negative information encourages the researcher to perceive the findings from other viewpoints, which is crucial to this research.

According to Shenton (2004), an in-depth methodology tests conformability to assess whether the research method is explained thoroughly and whether the research methodology leads to the results. In this study, the research process has been explained in detail through the research philosophy, methods, techniques, strategies and data collection and analysis. Peer debriefing validity has not been adopted in this research as it is described by Lincoln and Guba (1985), as a,

> *… process of exposing one's self to disinterested peer in a manner paralleling an analytic session and for the purpose of exploring aspects of the inquiry that might otherwise remain only implicit within the inquirer's mind.*

Lastly, the validation approach of examining previous research to frame the findings is deployed in this study, where the researcher strengthened the results through the literature review and demonstrated that the findings conformed to previous results. This approach was outlined within the research methodology and data analysis chapters.

4.12 Ethical Approach to the Research

As part of the requirements for a doctoral thesis at the University of Salford, it is the duty of the researcher to maintain the ethical standards set by the University. An application was submitted to the College of Science and Technology Research Ethics Panel, and approval was granted to conduct this research. The approval letter is attached as Appendix A. Guided by the research ethics, at all times the researcher is expected to perform their duty to responsibly use and share the data collected, respecting the anonymity and confidentiality of the respondents and preserving the privacy of the data.

4.13 Summary

This chapter highlighted the importance of the research methodology to a research thesis, outlining the research philosophy, approaches, strategies, data collection methods, and techniques adopted. Careful consideration was given in order to select the most appropriate philosophical stance, the research approach, strategy, method, techniques, time horizon and data collection method. The philosophical stance leans towards subjectivism, interpretivism and value-laden with regards to its epistemology, ontology and axiology as social phenomena are generated by social actors. These actors' relationships with the phenomena are dependent upon the bias perceptions of the phenomenon that may be induced by biased opinions and values. Thus, this study is inductive, qualitative and exploratory. Additionally, as this study is undertaken from the empirical to the conceptual level, in essence, grounded theory has been embedded in the research (Corbin & Straus, 1997; Emmel, 2013), whilst the deductive approach commences at the conceptual level and finishes at the empirical level. The research strategy used is the survey as the purpose of the research was to gather rich data and to have a broad spectrum regarding the concepts of the implementation of LC in UKICI.

The infrastructure construction organisations were chosen by means of a purposeful sample and stratified sample strategy. The sample consists of clients, consultants and contractor organisations within the UKICI. A purposeful sampling strategy evaluates the sample frame selected for the research concerning the research aim and objectives and the particular respondent unit.

As for the data collection technique, semi-structured interviews using open-ended questions were adopted, since such techniques enable the researcher to develop a deep understanding of the study area and to collect more profound and accurate information. The content analysis was the data analysis technique adopted through using NVivo 10 to code the data to ascertain the concepts and themes, validated findings and ideas, and ultimately promote the development of a LC implementation framework for the UKICI. Lastly, validity has been achieved via the aforementioned validation strategies that present discrepant views, rich descriptions, member checking, in-depth methodology descriptions, an examination of previous research to frame the findings and the conduct of triangulation. Next chapter outlines the research findings.

5 CHAPTER FIVE| DATA ANALYSIS AND PRESENTATION

5.1 Introduction

This chapter presents the data, as reported by the respondents, and the analysis. The sole purpose of this study is to investigate how companies in infrastructure construction implement lean principles and best practice in infrastructure construction in the UK. With the aid of NVivo10, the study identified an exhaustive list of themes from the data collected, which gave an overview of lean implementation practice in infrastructure construction. The themes are as follows: Lean philosophy, barriers to Lean implementation, benefits of Lean implementation, challenges, effects of barriers, enablers, drivers, best practice, methods currently employed, and the way forward. It is important to note that the analysis and discussions will be especially pertinent to infrastructure construction in the UK.

These themes will be discussed in the following sections, but first, the backgrounds of the research respondents are presented in Table 5.1. It can be seen from the table that the respondents have, on average, eight years of experience in general Lean knowledge, and more than six years' experience in the application of Lean in infrastructure construction in the UK. It can also be seen from Table 5.1 that all the research respondents have some form of formal Lean training. This is a satisfactory level of experience considering the newness of Lean in the construction industry.

Table 5.1: Background of Research Respondents

CODE	TITLE	COMPANY ROLE	EXPERIENCE		
			General Lean	Infrastructure Lean Years & Training	
CDHE01	Lean Technical Manager	Client	11	11	Six Sigma black belt
CDSK02	Performance Manager	Contractor	8	5	Lean Training
CDBC03	Programme Controls Manager	Contractor	11	11	Six Sigma black belt
CDAO04	Lean Manager	Consultant	31	13	TPS, Lean greenbelt
CDEM05	Quality Insurance Manager	Contractor	6	6	Lean Practitioner
CDML06	Senior Project Manager	Design Consultant	6	6	Lean Champion

CDAK07	Transport Consultant	Consultant	4	4	Lean and Six sigma
CDNR08	Project Manager	Client	3	3	Lean Practitioner
CDCT09	Performance Manager	Contractor	20	4	TPS and Six sigma
CDMM10	Quality Leader	Consultant	12	12	TPS and Six sigma
CDHE11	Director of Lean	Client	7	7	Six Sigma black belt
CDCP12	Project Manager	Contractor	4	4	Lean Practitioner
CDAK13	Practice Manager	Consultant	5	5	Lean Practitioner
CDNR14	Black-Belt Candidate	Client	0.3	0.3	Six Sigma black belt
CDCH15	Collaborative Planning Lead	Consultant	7	7	Lean Practitioner
CDAM16	Quality Manager	Contractor	13	13	Six Sigma greenbelt
CDCT17	Project Manager	Contractor	7	7	Lean and Six sigma
CDSK18	Process Quality Manager	Contractor	12	1.4	Six Sigma greenbelt
CDMS19	Lean Coordinator	Contractor	2	1.3	Lean Practitioner
CDCT20	Lean Leader	Contractor	7	7	Lean Practitioner
CDAO21	Performance Manager	Consultant	5	5	Lean and Six sigma
CDCL22	Lean Manager	Contractor	7	7	Lean Practitioner
CDAD23	Solutions Consultant	Consultant	7	7	Lean Training
CDCL24	Business Improvement Manager	Contractor	10	10	Lean Training
CDCL25	Associate Director	Contractor	2	2	Lean Training
CDBB26	Continuous Improvement Director	Contractor	6	6	Lean Training
CDCL27	Operations Manager	Contractor	1.6	1.6	Lean Practitioner
	AVERAGE		**8.0**	**6.2**	

The research conducted a robust interview with 27 lean managers and practitioners in the infrastructure sector from whom rich and informative responses were received, which satisfied many of the study's queries on Lean implementation in infrastructure construction. Figure 5.1 presents the distribution of respondents by their roles in the industry. The choice of respondents was based on their relevance and activeness as members or actors in infrastructure construction.

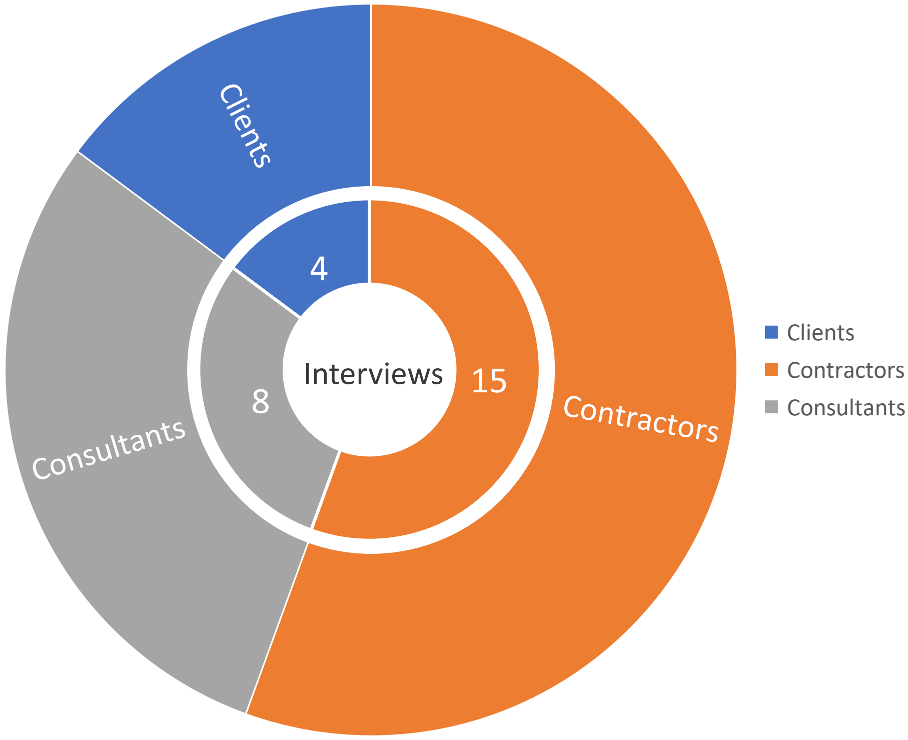


Figure 5.1: Interviews with Lean Practitioners in Infrastructure Construction

It is evident from Figure 5.1 that the majority of the respondents were members of contractor organisations, eight were from consultancy companies, and four were from client organisations. The research revealed that the two most dominant clients in the infrastructure industry are: Highways England and Network Rail. It appears that every contractor and consultancy company in the study work exclusively, or in part for one or both of these clients in the study.

5.2 Lean Philosophy

Lean is a way of thinking and acting. According to the Lean Enterprise Institute, the main driver of Lean Thinking is to maximise customer value while minimising waste (Howell & Ballard, 1998; Liker, 2004); in other words, to create more value to the customer with fewer resources. Furthermore, Liker (2004) and Womack and Jones (1996) perceive waste as "anything that absorbs resources but creates no value". This ultimately means understanding the customer's values and creating the perfect system of processes to avoid waste, and maximise values.

At Toyota, the philosophy of TPS is to eliminate all Muda (overproduction, waiting, transportation, over-processing, inventory, unnecessary movement, unused creativity and defective products) (Liker, 2004). In this study, all the respondents demonstrated a very good understanding of the Lean philosophy, its overall objective, and its potential value creation in infrastructure construction. This understanding is summarised in the following quote from respondent CDAO04, who is the Lean Manager for a Lean Consultancy Company.

> When people say to me 'what is Lean', I always have three answers. First of all, it's a philosophy, it's a way of thinking, and Lean Thinking, whether it is a manager, supervisor, technician, designer of construction or a construction worker, it doesn't matter, whatever level, Lean Thinking just quite simply says, 'can I do this a little better tomorrow? Can I do it a little bit better next time?' And that philosophy is what it is all about… the purpose is to increase customer value, capacity and business performance through the use of Lean philosophy, tools and techniques.

The study revealed a peculiar trend of thinking, or philosophy, among the respondents, which is directly associated with their leadership position in their respective companies, and most importantly, their Lean training. This philosophy is that, (1) everything can be improved, (2) there is waste everywhere, and (3) the process, not people, represent the problem. With this thinking, they are able to approach a problem with an appropriate attitude (see Figure 5.2). The respondents demonstrated a high-level understanding of Lean as a process that not only concerns the elimination of waste in the production process, but also develops creative, smarter, and more sustainable solutions. These are the characteristics that Koskela (2000), and Hines et al. (2004) emphasised were of prime importance. CDCT17 captures this understanding as they explain their company's Lean philosophy;

> … it is not just about productivity and getting rid of waste, and being faster and faster, it is about doing it better. It is also about delivering smarter solutions, which is where the manufacturing car industry has developed more reliable products.

The respondents displayed excellent knowledge of Lean leadership and business improvement capability as they have embedded Lean into their culture and into all improvement plans, including safety, people, manager, client, and so forth. Many have encouraged employees to become even better problem solvers by deploying and organising

Lean problem solving and process improvement techniques to deliver targeted improvements.

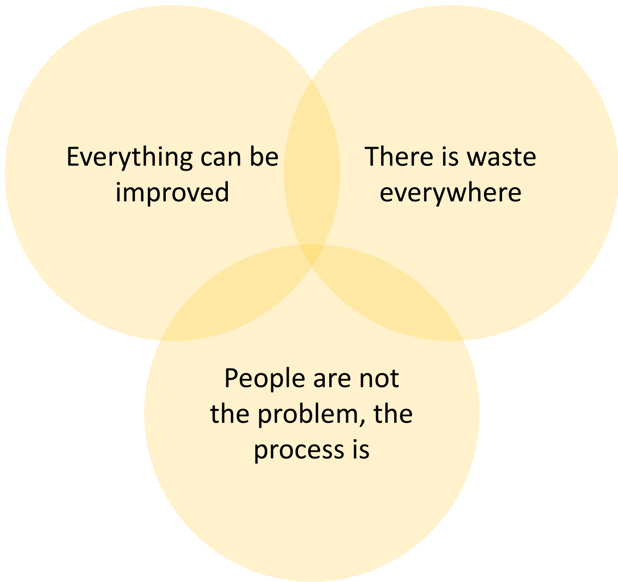


Figure 5.2: Lean Philosophy in Infrastructure Construction

5.2.1 Everything Can Be Improved

"It doesn't matter how good you are, you can still be better." (CDCT09).

Internally, looking at the way things are done in the office can help in making improvements. This principle is embedded in the essence of value-stream mapping, which aims to improve processes by generating an efficient process map that helps to eliminate non-value-added steps. According to Liker (2004), value stream mapping leads to the comprehension of a holistic as well as an enhanced view of the process, which helps in generating improvement strategies for projects aimed at minimising non-value-added activities. The respondents emphasised that, by mapping the processes of procurement, invoicing, design, meetings and so forth, non-value adding activities are eliminated, and the processes are made more efficient.

An organisation can apply Lean in both its offices and construction sites, because there are practical ways of gaining improvements in all activities. However, the current state of construction is fraught with waste throughout the process. Waste in the construction processes can be considered under the different waste classifications given by the Toyota

Production System (TPS) (Ohno, 1988) that were improved upon by Liker (2004). These are: (1) overproduction, (2) waiting, (3) transportation, (4) over processing, (5) inventory, (6) movement (7) defective products, and (8) the waste of unused employee creativity (Macomber & Howel, 2004). For example, often design in construction is undertaken multiple times throughout the life of a project. This results in waste through overproduction, over processing, and waiting. Not only is the project started with incomplete designs, but there are also multiple variations along the way. This causes a lot of wastage in the process, which is unlike manufacturing where the design is finalised and remains unchanged throughout a particular product line (Gao & Low, 2014). The objective in construction is to develop a 'Lean design'. Lean design concerns doing a design once, getting the drawings and design right the first time, and then building it right the first time.

Respondent CDCT09 asks the question, why are there no production techniques that can satisfy all projects? He advocates the standardisation of construction processes. This is supported by Highways England (2017), who state that major construction, "activities are repetitive and so opportunity exists to standardise the steps and understand the constraints and enablers" in the processes. Respondent CDCT09 stated that standardisation is the future of construction. It is, however, impossible to avoid some issues in construction. For example, redesigns are often unavoidable as site circumstances sometimes dictate the final output (Egan, 1998; Latham, 1994). Furthermore, structures are very different from one project to another. Thus, the production rate (or the time needed to complete a segment of the structure) even on similar types of structures is different because there are other variables unique to the site and location. However, maintaining a philosophy that 'everything can be improved,' is the most appropriate attitude when problem solving (Liker, 2004).

5.2.2 There is Waste Everywhere

If everything can be improved, by implication, there is waste everywhere. A quick map of the whole process reveals the non-value adding activities (Liker, 2004), which can then be eliminated (value stream mapping). For example, the Lean Manager of Lean Consultancy Company, respondent CDAO04, states that, not only is this a useful starting point, but it should be the philosophy that every contractor operates. According to Liker (2004), the value stream maps aid the comprehension of improvement strategies of projects aimed at minimising non-value-added activities.

5.2.3 People are not the Problem, the Process is

Respondents were quick to point out that, more often than not, managers hold their staff responsible for the inefficiencies in the process when set objectives are not achieved, which creates fear in people. In contrast, a manager who is a Lean Thinker understands that people are the problem solvers, and not the problem. If teams are not performing, it is not the team that needs improvement, but rather the process; thus, the process is not performing, which produces negative results. The Lean Manager of a Lean Consultancy Company, respondent CDAO04, states:

> You have got to stop blaming people and you have got to remove fear. This philosophy and culture to me, is your starting point. You have got to get people saying, 'yes we can improve tomorrow.'… And you have got to remove the barriers to preventing that. And this barrier can be fear. When you have got an environment that people can say, quite openly, 'things are wrong, we can do better than this.' When you start getting that, you can start improving processes… I do not know anybody who gets out of bed in the morning and says, 'I am going to go to work and I am going to do a bad job.' Nobody says that. If you have got your best people, in a very broad process, the process will beat them. So, help your people and look at your processes and get your people to improve the process. Because your people are the problem solvers, they are not the problem.

The Lean Manager's explanation captures why this philosophy is so important. When people are perceived as the problem, they fear making a mistake. Often, they cover up inefficiencies in the process for fear it will be attributed to them, and so, no improvements are made. It is imperative that line managers adopt the philosophy, 'People are the problem solvers; they are not the problem. The process is the problem'. It therefore means, that the industry does not matter (construction or manufacturing); if good employees are employed in a bad process, more often than not, the bad process will undermine the efforts of the employees.

5.3 Barriers to lean implementation

Table 5.2: Response to Barriers of Lean Implementation in Infrastructure Construction

Barriers	Client	Contractor	Consultant	Total	%
Conflict of interests	1	1	1	3	11%
Competing improvement models with supply chain	2	2	1	5	19%
Construction is not manufacturing	3	5	1	9	33%
Contracts		11	4	15	56%
Lack of forward thinking from supply chain	3	1	1	5	19%
Cost of implementation	2	14	7	23	85%
Language barrier		2	2	4	15%
Project members limited knowledge of lean	1	9	4	14	52%
Resistant to change	4	15	7	26	96%
Unwanted pressure due to transparency	1	3	1	5	19%
Lack of top management commitment	1	7	3	11	41%
Lack of knowledge transfer	1	3	2	6	22%

Figure 5.3: Barriers to the Implementation of Lean in Infrastructure Construction

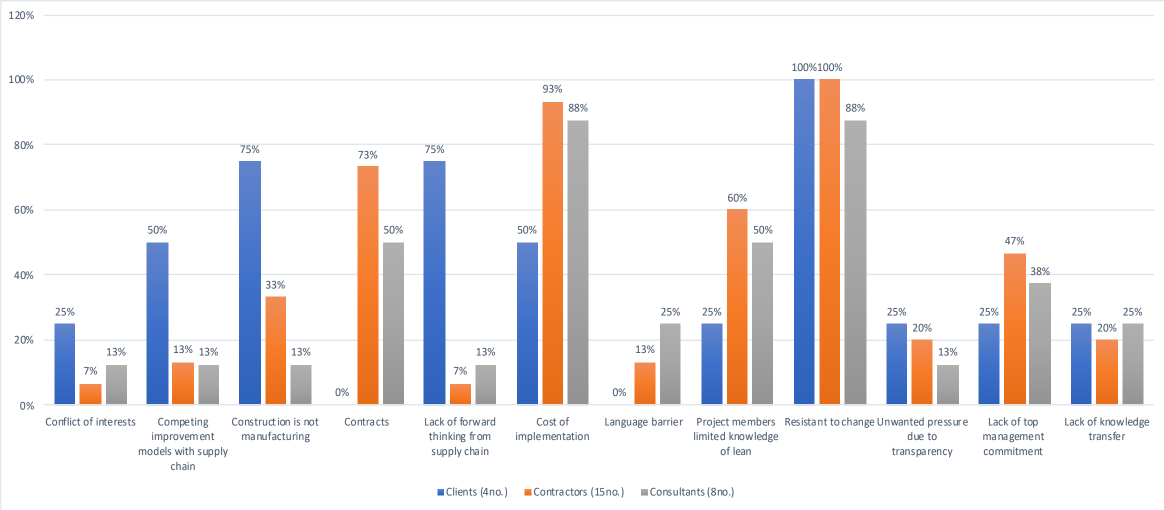


Figure 5.4: Group Responses with regards to Lean Implementation Barriers

For the barriers to Lean implementation in infrastructure construction, responses were categorised by the respondent's group or company role (i.e. client, contractor, and consultant). The number of responses as well as the percentages for each group can be seen in Table 5.2, and Figures 5.3 and 5.4. The different groups, tended to hold the same views regarding a barrier, if mentioned. Those who did not feel strongly about any barrier simply did not mention it in the interview. For example, contracts represented one particular barrier that was mentioned by 73% of the contractor organisations; this was affirmed by 50% of the consultants in the study. However, the clients did not mention this as a barrier at all; they did not see this as a problem, which was perhaps because the clients have all the power. The contracts are drafted by the clients and imposed on the contractors. However, this sample suggested that contractors are not happy with the contractual relationship.

Clients were found to put more emphasis on barriers such as; resistance to change (100% of clients), a lack of forward thinking (75% of clients), and the difference between construction and manufacturing (75% of clients), while contractors emphasised barriers such as; problems with the way contracts are designed (73% of contractors), the cost of implementation (93% of contractors), and resistance to change (100% of contractors). Consultants, on the other hand, particularly noted the industry's resistance to change (88% of consultants), the cost of implementation (88% of consultants), and project members' limited knowledge of Lean (50% of consultants). See Figure 5.4 for more responses and percentages.

5.3.1 Conflicts of Interests

Both Latham (1994) and Egan (1998) documented the UK reported on the inefficient, fragmented, and chaotic nature of the construction industry. Furthermore, three respondents in this study demonstrated that the industry feeds on this chaos. In the opinion of many contractor respondents, it is better to extend a project, and even extend it, than to finish early. They argue that it is counter intuitive to finish the project early when there is likely to be a gap between the current and the next project. Therefore, a conflict of interest arises, which is, to finish the project early, and lose your workforce, or extend the project to close the gap between projects.

Fees are also a significant factor. According to the contractors, if a contractor is offered a choice between two jobs, one of which lasts one year, and the other two years, the contractor would probably take the two-year contract because this would mean a secure cash flow for a longer period. Lean Thinking, on the other hand, encourages the contractor to find efficient ways of finishing the project in half the time and at half the cost. Although, the client sees a ‘reduction of programme duration’ as a good outcome (as should the project team), the contractor does not entirely see it as a benefit, as it means a two-year commission can be reduced to just one year; therefore, a conflict of interest arises. For example, Highways England’s collaborative mapping, or look-ahead planning, aims to reduce the duration of programmes i.e. the time taken to complete a project (Ballard, 2000; HE, 2017). Therefore, the interest of the contractor is in conflict with the ‘time reduction’ objective of using Lean construction.

Similarly, the findings of Aziz et al. (2016) showed that there was a lack of motivation and commitment to the Lean implementation process amongst the HE supply chain. Therefore, there was a need to rectify that contractually, to incentivise implementation through raising both the level of the stakes and the liability for the client and SMEs. In addition, Aziz et al. (2016) pointed out that SMEs lack the motivation to implement Lean in the HE supply chain because of a lack of clear goals and incentives for systematic Lean implementation. For contractors to achieve optimum performance on a project, their objectives or interests need to be aligned to the client’s overall strategic goals. The unwillingness of contractors to lose fees associated with the project duration serves as a barrier to Lean implementation.

This leads to resistance to any change that affects the bottom line performance on the project.

It is important to note that clients are aware that some contractors have this pattern of thinking. For example, respondent CDHE01, who represents a client organisation, demonstrates his understanding.

> If you are a contractor, you probably find that the job in reality should finish early. But do you lose your team in this period? No, what you do is move slowly and extend the finishing of one, so it is nearer the next one and the men just move over. So, it's a mess, and we have got a huge challenge on our hands.

To avoid this type of behaviour, which undermines the Lean process, it is therefore, imperative to align the contractor's interests with those of the client. This study can extrapolate from Hearn (2017), who shows that when contractors can see how their interests are met, secured, and contribute to the goals of the client organisation, they are more engaged and motivated. Rather than thinking only about how their objectives can be achieved and cascaded to the contractors and the supply chain, clients should also think of how to align the contractor's interests with theirs so as to keep the contractors engaged and motivated within the Lean process.

On the other hand, the client's approach or motivation to promote Lean can serve as a barrier to Lean implementation, because Lean tends to be measured in monetary terms. Some client systems expect the contractor to produce monthly efficiency registers, where they are expected to declare monetary savings. The client then expects a percentage of that money back. Respondent CDCL22 calls it a "pain and gain mechanism" where the contractor does all the work to produce some savings, and the client takes a good percentage of them. This system dis-incentivises the contractor from adopting a system that short-changes them. CDCL22 demonstrates his point:

> So, we have implemented visual management, collaborative planning where we are planning the traffic management programmes. Therefore, we've saved that money (forecasted savings), then we have to declare that money on HE's system (the client). They operate contracts, which work in a pain and gain mechanism. So, if they've seen that we are saving money, and we're declaring figures, they expect a percentage of that money back. Some

> of the savings in the lean world are not really tangible, they are based on, well, if they hadn't have done this, this is what we think it would have cost looking at the data, rather than typical savings somewhere.

Therefore, the respondent indicated that the savings made, are usually not actual or real, but forecasted based on assumptions made; for example, through streamlining the process using visual mapping and Collaborative Planning. The complaint of this contractor is that, although the monies are assumed savings, or at least, not yet realised, they still have to return actual money to the client against these savings. Needless to say, some contractors and consultants see this as problematic. One consultant (respondent CDCH15) explains that their company does not get credit for reducing design costs and in fact, this is not beneficial to his company. CDCH15 explains that;

> … if the contractor or material supplier can do their stuff cheaper, they can put the savings in their back-pocket. If we do that, it tends to go into the back-pocket of our client. So, he is happy, but my commercial men are not. So, that is one (barrier) and you can see why it affects implementation.

5.3.2 Contracts

Another barrier, mentioned by 15 respondents (comprising 11 contractors, and 4 consultants), is contracts. Respondents raised a number of issues with the current state of contracts in infrastructure construction. Firstly, the nature of the contracts restricts freethinking, where opportunities to try different things are limited by contractual stipulations, which consequently, have a negative effect on Lean implementation. In addition, the stipulated payment structure influences behaviour; for example, if a fixed fee contract is used for a design, the design consultants tend to do whatever they can within that fixed fee and to issue the design as quickly as possible, in order to get the project built. However, is another type of contract is used, this may influence the creation of a different kind of design, which could reduce all costs, such as a reward and incentive-based contract (see Table 5.3). Therefore, it is important to ascertain whether clients are willing to explore other types of contract that may cost more but give more in value to their projects. However, this is unlikely because most clients prefer the predictability of fixed cost contracts. Therefore, contracts can be a barrier to driving the right behaviours.

Table 5.3: Contracts' Rewards and Incentives in Lean Construction

Action	Relationships	Reward and incentives	Suitable Contract
Time and cost efficiency savings Innovation	Client – Contractor	Profit sharing Bonus Knowledge contingency pay Non-financial rewards	Fixed Price Incentive Fee (FPIF) or Cost-Plus Incentive Fee (CPIF)
Time and cost efficiency savings	Client – Consultants	Commission Non-financial rewards	Fixed Price Incentive Fee (FPIF)
Time and cost efficiency savings Innovation	Contractor - Subcontractor	Profit sharing Knowledge contingency pay Bonus Non-financial rewards	Fixed Price Incentive Fee (FPIF) or Cost-Plus Incentive Fee (CPIF) or Labour-Hour and Time-and-Materials contracts
Time and cost efficiency savings Innovation	Contractor – Employees	Increase in wages Bonus (cash or stock) Non-financial rewards (e.g. recognition or promotion)	Salary + incentives
Time and cost efficiency savings Innovation	Subcontractor – Labourers	Piecework pay Increase in wages Knowledge contingency pay Bonus Non-financial rewards	Labour-Hour and Time-and-Materials contracts

Secondly, the clients have all the power, which means that some contractors in the supply chain feel squeezed and are left with impossible choices. In other words, they are forced to take an unfavourable contract and operate with little to no margins, or not take the work and risk going out of business. For example, Highways England's suppliers (contractors) have reported that HE is continuously tightening its budget every year, which makes them reluctant to adopt Lean; they subsequently feel they are doing so much for less. Respondent CDAO04, reported that their company's morale is low; their team has lost its motivation and it is now difficult to manage employees, because instead of a team working hard, and getting work out, they are worried about budget cuts. CDAO04 also stated that his company is losing its best people to their competition because they cannot pay them. Furthermore, respondents report that the short-term nature of some contracts brings about adversarial practises that undermine the Lean implementation process. Aziz et al. (2016) note a similar finding; they show that the short-term relationship in infrastructure construction encourages adverse relationships that lessen motivation, prevent trust, and reduce collaboration.

Furthermore, the “payment per shift” set-up of most contracts does not encourage increased efficiency in infrastructure construction; for example, Tier 2 or Tier 3 pays per crew, per shift. If they are paid at £1000 per shift, they would be unlikely to do the work in half the time, which could lead to the client cutting shift times, and this implies less pay next time. One respondent captured this in the following comment:

> We have contractual disincentives. It (the contract) doesn’t incentivise you to do continual improvement. Commercial barriers are payments for works per shift. If I always just paid you for a shift and it didn’t vary, if I pay you £10 per shift, there’s no incentive for you to work quicker or smarter. So, none of us win. Also, we pay for work done. By that I mean, the longer you take the better it is for you. You want to spend as many days as you can, doing something for me and not doing it in the most efficient manner.

How contracts are written and enforced poses a huge barrier for Lean adoption in infrastructure construction. If the clients continue to tighten contracts (as some respondents in this study have reported) or continue to squeeze the budget year after year, and continue to demand unrealistic efficiency savings, this does not afford contractors sufficient overheads and profits to adopt a Lean culture without resorting to adversarial practices to increase their earnings, which potentially undermines the underlying concept of Lean culture. Lean practitioners need to convince people that Lean Thinking is a good way of doing things and that Lean is beneficial to them. Therefore, contracts are one of the barriers to Lean implementation.

5.3.3 Competing Improvement Models within the Supply Chain

Five respondents mentioned that they used other improvement systems before being introduced to Lean (see Figure 5.3). When trying to implement Lean, it is not uncommon to find that an organisation has put in place an improvement system that they trust to be efficient. The respondents commented that Lean was just one approach from a variety of continual improvement models. Therefore, Lean adoption must complement the existing improvement models employed by the company. For example, some contractors have adopted the European Foundation for Quality Management (EFQM), which is an excellence model that ensures management practices are optimally organised for continuous improvement and that the intended organisational strategies are continuously delivered. Lean adoption should be an addition that fortifies efficiency rather than encourages the complete abandonment or dismantling of an existing successful model.

Some contractors have the false impression that, if they adopt Lean, they have to abandon other existing good practices, like Six Sigma. The Six Sigma/DMAICT model is well known in construction, but not widely used, as the majority of respondents believe it is more suited to manufacturing. Respondents CDCT09, CDBC03 and CDAO04 have the opinion that Six Sigma is meant for repetitive work, and construction does not repeat several processes a thousand times. For example, respondent CDBC03 recollects:

> I applied DMAIC for my certification and I never applied them again… we have now divorced ourselves from it, we kind of said DMAICT is great but Lean is more practical.

They perceive the implementation of Lean following on existing systems as an additional burden that might disrupt the company's stability; therefore, this serves as a barrier. Respondent CDHE01 articulates this barrier as follows.

> When I engage with each of my five key suppliers, the majority of them have business-operating models that do not fully encompass Lean. If they would only see that Lean was not a standalone activity, but it is actually a business operating system. So, I would go to a company, invariably say on a yearly basis. I would say to them "let's get the audit or assessment underway". What would they say to me "we do not do Lean, we do continuous improvement." But it is exactly the same as Lean methodology.

5.3.4 Construction is Different from Manufacturing

Nine respondents pointed out that Lean principles developed in the manufacturing industry may not be easily adaptable to construction (see Figure 5.3). Manufacturing is characterised by the mass production of a single product (which has a finished fixed design), in a steady environment. But in construction, no two projects are ever the same; even if the design is the same, the environment constantly changes. A variety of reasons contribute to this phenomenon – the site location, the nature of the site, weather, and the changing project teams, which account for differences in projects and mean that people are constantly having to think on their feet. Lean traditionally originated and has since flourished within manufacturing; for example, through the Kanban systems of the Toyota production system (TPS). The system is designed to stop the production line as soon as something goes wrong, when the problem is fixed, and the production line is started again; however, there is not the same production control on construction sites. A Kanban system is hard to implement in construction, as the industry is general, traditional, and highly fragmented due to the involvement of many subcontractors. Therefore, it is extremely difficult and sometimes inefficient, to halt the whole construction process when something goes wrong, as multiple subcontractors are usually executing processes simultaneously.

In addition, Lean is difficult to implement in construction because there is less repetition within the process. Projects are unique, bespoke, and less repetitive in nature; moreover, designs are unique, reflecting the creativity of the architects and designers. Due to the lack of design for manufacture and assembly, as found in the automotive or manufacturing sector, construction has a lot of issues as many aspects are bespoke. Respondent CDSK18 comments on the nature of the industry:

> We have a lack of repetitive nature; we do not have a lot of repeatability in the work which we deliver. Across the projects we try to identify repetitive work. For example, in mechanical and electrical work which we do within business… We have a factory, which we try to assemble modules there after having identified some repetitive work. So, it is the lack of repetitive nature of work. It is one of the barriers.

The main obstacle, however, is people's view of Lean as a process purely from manufacturing; they struggle to see how it applies to the construction industry and as a result do not become engaged or committed to the process. The reality is, there are processes that are repeated in construction, and can be standardised. Furthermore, there are procedures that can be streamlined, and workplaces that can be organised. Construction professionals only need to realise that Lean principles are transferrable and adoptable to existing systems. For example, in electrical engineering, controlled panels, are designed and built off-site in a more controlled environment, then delivered and installed on site. The underlying principles are transferable to construction, but this is not obvious to some people in the construction industry, which hence, represents a barrier to Lean implementation.

5.3.5 Lack of Forward Thinking from Supply Chain

A lack of support from sub-contractors was mentioned by five respondents as another barrier in the implementation of Lean in infrastructure construction. This ties into the aforementioned lack of motivation and commitment. Although the client has all the power, it becomes very difficult to achieve commendable Lean improvements when the supply chain returns to old practices as soon as the client 'looks away'. Aziz et al. (2016) shows that, while the client can integrate Lean into its procurement and contractual processes, this infers to the members of their supply chain, 'you do lean, or you won't work for us'; however, forcing the supply chain to implement Lean does not guarantee their motivation and commitment. For example, respondent CDHE01 from Highways England, states their frustration with some suppliers:

> The only disappointing thing for me is that we have some of these suppliers who work for us, who do Lean. And they will do Lean on our roads, but they will build a similar road for a local authority and use no Lean skills whatsoever. It's bizarre because they could save everyone so much money.

Unfortunately, some people do not see the value of Lean. According to the black belt candidate from Network Rail, CDNR14, subcontractors and suppliers think Lean is a common-sense issue. They do not necessarily see the benefit of introducing a Lean expert to make changes, as not all employees feel comfortable with the prospect of an outsider intervening in such a way. In such cases of resistance, the supply chain needs to be shown or reminded of the benefits of Lean. They need to be advised of the need for patience in the process, which will develop with time. The client company and its employees need to buy into Lean, and employees need to enjoy the process, whilst the process must deliver time savings, ease work, provide better quality outputs, certainty of delivery, and so forth. If they do not see the benefits, Lean will not work. The client is looking for better value; increased capacity, better quality, increased value, and ultimately, less cost. If the client does not see value in the process, they will stop it. The contractor who is implementing the Lean process on site, wants more profit; it is therefore about the bottom line. Without profit, the company goes out of business, so, if undertaking lean does not produce more profit, it makes no economic sense to continue with it. Respondent CDAO04, states;

> …Lean should win you more work, give you more market share, save you money, and increase your bottom line. If that does not happen, companies will stop doing it whether they are small or big. They will say, 'I tried that, it cost me money. It did not make it better'.

5.3.6 The Cost of Implementation

An overwhelming number of respondents (23) affirmed that the cost of implementing Lean is a barrier. The cost of implementation can take three forms; time, money and personnel, which raises questions as to who bears the cost of a Lean implementation. Further issues arise such as, whether the client should bear the costs as an upfront investment as they will receive the savings overall, or whether the designer should cover the costs because they will receive the savings, or whether the cost should come out of the contract. Some respondents made the point that they are so busy, that finding the time and resources to make Lean changes is difficult. To make Lean changes, it is imperative to have a dedicated person who can coordinate its delivery. Furthermore, such appointments have a cost element. According to the Senior Project Manager of one of the major construction companies, CDML06, "… it is surprising how much, from an administrative perspective, managing Lean on a big job can cost." According to CDML06, "when you start implementing Lean, the number of administrators to support the Lean implementation can result in a large administrative team." He stated that, on their current job, his company has about 27 people on site to manage Lean delivery. Consequently, he asked; "Is Lean a full time role for somebody? Can we afford it full time?" In summary, his question was; "is the client prepared to fund the Lean delivery, or is the contractor responsible for it?" It is evident that the cost of implementation can be a barrier to implementing Lean since the debate on who to bear the cost has not been finalised.

Furthermore, Lean often requires a frontloading of investment, where the company invests time, money and resources in terms of training or introducing a Lean training resource, which often seems like adding cost to a project. Some organisations cannot afford to implement the change. For, example, a small business owns an old printer which takes one minute to print one page, the business is advised to become Leaner by buying a new laser printer, which prints one page in ten seconds instead of one minute, hence saving the company time. They might not have the funds available to implement the Lean improvement, so cost can be a significant barrier. Respondents CDCP12 and CDAD23 comment respectively:

> It costs money to become leaner. In the first place, you have to put in something to get something out. To train people costs so much money, in addition to the training costs you have also got staff who are not doing any

> work. So as a business training hits them twice. Once is when you are not getting any work out of that staff when you send to training, and then second is when you've got the training fees to pay. It is very expensive.

> In terms of the cost of training, we do not like that at all. It is expensive. To put the Lean professional or expert on a job site for a day or two is not cheap. And people sometimes have a hard time seeing the value of that… it is much harder to prove out the value of Lean and show time and energy saved, so it is hard to sell it because, sometimes people want to see hard data that proves, conclusively, that this is worth time and money.

The size of organisations or tighter margins can make Lean changes, training, and equipment upgrading difficult. Not only does the company have the direct cost of training and equipment, they have the indirect cost of time and money affecting the actual work of staff, which could mean a loss of money. Therefore, the costs can increase substantially for a small company or a company struggling with tighter margins. More so, as Lean benefits are not immediate, as they take time to materialise. According to respondent CDMS19:

> The profit margins are always tight, especially within infrastructure. Lean implementation is a bit of a risk, it involves short-term investment for long term benefits so very often the money will be spent getting consultants in and getting people trained up. Something quite expensive, and you reap the benefits further down the line. Obviously, the studies show that it will be beneficial, but it does just require that small leap of faith to take on that investment.

The indirect cost of training is a barrier because the cost and amount of time people have out of their regular functions can result in a loss of profit. For example, a Six-Sigma yellow belt (a Lean practitioner who reviews process improvements) takes only two days of training, which may be bearable for a company to allow in terms of the time needed for day release for training. However, for the black belt level, the company has to support that person across two years, which can result in a lot of time away from profitable company functions.

On the other hand, when respondents CDCT17 and CDAO21 were asked whether their companies see the 'cost of implementation' as a barrier to Lean implementation, and they stated, respectively, that it is not necessarily an obstacle because:

> As a company we have put workshops on Lean. We employed a specialist consultant who ran a number of workshops for us. I do not believe that the cost of training is a barrier. Our company certainly sees that it is an investment to achieve a long-term saving. Having everybody within the company understanding the Lean principles outweighs the cost of providing that training. So, no I do not see it as a barrier.

> [The] cost of training is a barrier, but it is not massive. If you do enough of Lean and if your business cases work you would do an investment straight away there, you then probably recoup the cost of training definitely within the first year or so, so cost should not really be a barrier, for us it never has been. The attitude of people is probably more of a barrier than the cost of training really has been.

It is evident that, while some people see cost as a barrier to implementing Lean, others, see it as an investment. Having the right attitude, as respondent CDAO21 indicated, is imperative for a successful Lean implementation.

5.3.7 Language Barrier

Another major barrier to Lean adoption, as reported by four respondents, is the 'language of Lean'. It was asserted by the respondents that some Lean terminology and phrases, including the Japanese terminologies, such as muda, mura, kaizen, genchi genbutsu, or the non-Japanese phrases, like Just in Time (JIT), can discourage staff interest who are not familiar with Lean. Respondent CDMM10 elaborates on this.

> What I found in the techniques we are using up here, particularly in the Manchester area is, there are operatives in our workforce who they do not like the Japanese nomenclature. So, they do not like us to use the Japanese names. If you introduce it as a common-sense idea and explain in common sense principles, they go like – 'that is brilliant', but as soon as you use some jargon to describe it they go – 'that is Japanese stuff I am not interested'. And then they do physically shut off. So, we have gone away from using the Japanese words and Toyota words.

Respondent CDEM05 also found that people look at Lean as a "black art" because it has been defined by Japanese terminology. Therefore, people are discouraged, not only because they do not understand the language and terms, but also because they feel their culture is under threat of change and a new one imposed. Therefore, according to respondent CDEM05,

> … if you start saying (to the staff), ‘what I expect to see is you getting up and doing an Ishikawa Diagram’ and start talking about Kaizen principles, then they just switch off. But if you go to them and say, ‘what I want to know is how can we do this job better, what ideas have you got, what thoughts have you got?’ They’ll come out with them left, right, and centre.

Furthermore, in the client organisation, there are often people who do not understand the construction industry language, as most have come from other industries. They are often good project managers but do not really understand the particular challenges of the construction industry. Moreover, they do not have the experience to understand the language of Lean Construction.

The language of Lean is one of the biggest barriers; therefore, the finding shows that it is important that Lean managers communicate with workers in the language they understand in order to encourage their engagement. Respondents generally indicated that the Lean language generally used in Toyota Manufacturing should be adapted to the language of the people using it. Moreover, it was felt that construction should not use the Toyota manufacturing system language, but rather that it should use simpler language that people within construction can understand. Thus, instead of ‘Ishikawa Diagram’, the phrase ‘Fishbone Diagram or Cause and Effect Analysis’ could be adopted, which means the same thing.

5.3.8 Project Members Limited Knowledge of Lean

The respondents commented that a lack of Lean production knowledge amongst the project team is often considered the biggest barrier to achieving results on Lean construction projects. Since the project team is comprised of many agents from different companies, the level of Lean education or competence will differ; as such, individuals with little to no Lean education will require training to bridge the competence gap between the project team members. Thus, 14 respondents were quick to point out that these varying levels of Lean knowledge can cause delay. Furthermore, within infrastructure construction, because the project team is only brought together for the duration of one project (which may be as short as two years), every time a new project is started, a new project team is formed again. Therefore, everyone is re-educated, which can be quite challenging. Respondents CDSK02 and CDBC03 commented on how this barrier affects their project team, respectively.

> From an education perspective we don’t have everybody at the same level so there is a lot of terminology and a lot of language that we use which key people in the organisation do not have the same understanding about what the language actually means.

> Imagine you have a problem that you need to solve, and your team are experienced in their roles and they understand the Lean terminology, when you say to them, ‘ok we need to - let’s do a fishbone’. Everyone understands what you are about to do, and you do not have to explain that to anybody. And I find that when you say something, people would already understand what that is. They would already start to think about what they can do because they are trained. I find that to be really useful because now we have a common language.

When project members are not knowledgeable about Lean on a project that Lean principles are being implemented, it can lead to miscommunication and/or misunderstanding. According to respondent CDAO04, “… lean is a reputation. And reputation is like integrity, one mistake and it is gone.” It is imperative that people receive proper training before becoming members of the project team.

5.3.9 Resistance to Change

Construction is an old-fashioned industry that is resistant to change (Egan, 1998; Latham, 1994). This is the biggest barrier to Lean implementation in infrastructure construction and all respondents affirmed this. According to respondent CDBT03, “… people do not like change. They are scared of change.” As a result, pushing people out of their comfort zone forms a barrier. Other respondents in contractor organisations reflect an attitude of ‘if it’s not broke, don’t fix it’. Findings suggest that people are still new to the idea; they do not understand it and have not been taught about it. They feel that everything is fine; they do not need to change how they work. That is one the biggest hurdles facing Lean adoption within infrastructure construction today. Respondent CDAD23 states that “Traditionally, we find that older people are a little less computer savvy, as they have been doing their job the same way for 20-40 years. They are not very interested in change. It would be hard for them to change.”

Therefore, the Lean manager has to be prepared to work against resistance, which is inevitable; they must keep pushing and not be discouraged. Respondent CDAO04 states that, “You have got to be enthusiastically disappointed.” Therefore, the Lean manager has to be patient:

> People are very stuck in their ways of thinking. It is not like people do not like change, it is that change challenges people, and it gets them out of their ruts. A lot of people are stuck in their ruts with certain types of thinking with certain practices and changing thinking challenges those. And then you find that it’s quite difficult.

The challenge is to change people`s paradigms, as well as their routines, and how they see things. Changing the culture requires a major investment in change management from top management. This entails, first, creating awareness amongst staff as to the difference that Lean can make to the current state of affairs, and to identify the improvements they could affect from their processes. However, complacency also drives resistance, particularly when management feel they are already doing well. Staff can assume that, not only do they not need the proposed Lean changes, they feel they do not need an outsider coming in to disrupt their existing system. To address complacency, Kotter (2002) recommends creating a crisis by establishing a sense of urgency. For example, Highways England created a crisis for its supply chain by making Lean implementation compulsory. This established a sense of urgency for subcontractors and suppliers to make Lean changes, which resulted in increased efficiencies and savings. According to the Lean technical manager, CDHE01, “the best attitude to the supply chain’s resistance to change is perseverance.” He also states:

> As a client, every one of our suppliers will say to us, ‘we wouldn’t have done Lean if it wasn’t for you, the client.’… But the thing is by them telling me that, I must not live in a fool’s paradise thinking they are going to eventually see the light, because I don’t think they will for some time to come. So, I am going to continue to lead them for as long as it takes.

A few respondents also confessed that they did not adopt Lean on their own volition, but because the client made it compulsory, and as such, they needed to demonstrate Lean capabilities through certification. Thus, in order to win work, contractors need to show that they are certified in BS1100, for example. According to respondent CDCP12, fierce competition in the UK construction industry, has forced them to put Lean at the forefront of their activities, demonstrating Lean certification in order to satisfy their client.

5.3.10 Unwanted Pressure due to Transparency

Five respondents mentioned that some members of the supply chain do not appreciate the pressure that Lean-requirements place on them. The transparency that Lean principles demand is unwelcome by some contractors and suppliers. One respondent commented, "Hiding things is easier,". However, when they have to produce set objectives at a collaborative meeting, in front of all the project team members, inefficiencies can be exposed, which can cause embarrassment. According to respondent CDHE01;

> A lot of the people do not like the transparency, because when I say, "Charlie, did you do this" and he sound terribly sorry "mm… I haven't done it." But that's just not good enough. This transparency and exposure and shaming is not liked by some of our supply chain. And we have had suppliers stop doing this Collaborative Planning, and not want it on this site because they don't like the transparency. Because it's nicer to keeps things hidden.

The collaborative planning lead, CDCH15, also recognises this issue and comments:

> If you are running a project, and you are an experience project manager, you have been running projects for 30 years. You are not necessarily going to want some consultants staring over your shoulder looking at how you do what you have been doing for 30 years.

Therefore, Lean managers, when faced with such attitudes, must try to get the people to realise and accept the value of honesty and transparency, because, knowing when things go wrong is the only way to make them right. By hiding failures, no one can offer solutions to the problem. On the other hand, it is important that people do not feel they are watched all the time. Lean should give people a feeling of empowerment and emancipation, and there must be a balance between accountability and empowerment. Too much control from senior management leads to fear, and fear leads to mistakes, which defeats the purpose of Lean. Furthermore, it may also lead to contempt towards senior management, which may lead to a breakdown of relationships that would make collaboration impossible.

5.3.11 Lack of Top Management Commitment

Lean is heavily dependent on leadership, and so, when there is a lack of top management commitment, it is practically impossible to implement Lean. Indeed, 11 respondents emphasised that a lack of commitment from top management would serve as a barrier, because people work and behave how their boss expects them to work and behave. Therefore, management has to lead by example. Change in this case, must be top-down. Respondent CDAO04 emphatically warns that, if the management team is not committed, then employees will not be committed. “It just will not happen … What is needed is senior management to buy into Lean, so they can drive the implementation. Lean without real effort particularly for senior management will not be successful.” According to the quality leader, CDMM10, an already profitable company will find it hard to see reasons why they need to implement Lean since they are already doing well. He states:

> If your company is performing quite well and making a few million pounds profit every year, and somebody comes in and says you need to be more efficient, ‘you might make an extra couple of grand every year.’ It is a big thing for you, because you are already profitable. So, there is a certain amount of, not negativity, but buy-in, from the people to actually adopt those techniques. “We are already doing very well, why do I need to do it another way, why should we change” there is that kind of attitude. It is down to resource.

Respondent CDSK02 also comments:

> In terms of the barriers from senior management, they are not committing to sponsoring the project management improvements within the business. With time, people don’t understand the importance of improvements and lean thinking, and therefore it limits our ability to make progress.

To convince management, it is important to show savings in terms of numbers (namely, real money saved). For example, this can include capturing and quantifying how adopting collaborative meetings will provide savings through, for example, the designer imparting their knowledge to the contractor. Management are more open to suggestions that will save money and increase profitability. However, sometimes it is difficult to quantify the savings, but an attempt must still be made to do so. Without that, some members of top management will remain unconvinced, which could affect an effective Lean adoption process.

5.3.12 Lack of Knowledge Transfer

Another significant barrier is knowledge transfer, namely capturing the lessons learnt and sharing the knowledge. There are lessons to be learnt on every Lean implementation, especially for new comers. Knowledge transfer is about capturing Lean best practices and then disseminating that knowledge to other design offices and construction sites. According to six respondents, knowledge transfer is one of their biggest difficulties, in particular, how to disseminate good practice. Quite often, on construction projects, different companies use slightly different formats from one another. Thus, capturing good practice and effectively defining the processes and procedures becomes difficult. Therefore, it is imperative that all project team members are tasked with recording best practice in their respective areas. Respondent CDEM05 was also asked how the lack of knowledge transfer affects their projects. He states:

> It affects us because there is a lot of probably good learning that does not get captured and it is not shared. So, then you find lessons learnt do not get learnt, six years down the line somebody will go and do a scheme in the same area again and commit the same mistake. Because somebody has not bothered to log it down and communicate.

One of the major reasons why knowledge transfer in construction is difficult is the lack of repetition in construction as projects are unique and seldom are processes repeated. In manufacturing, various processes are repeated over and over again. However, in construction, or design, if there are one hundred processes, some might only be repeated once or twice, and as such, lessons are lost. Therefore, people do not feel the need to capture lessons learnt from processes. Nevertheless, one respondent understood the need to capture lessons learnt. They stated that it is imperative for their company to capture "what went wrong, and what went well" so as to guide how they should do things next time. Respondent CDML06 states:

> We produced a spreadsheet and we have got loads of trackers to capture information, which is stored for next time we do a similar job like this. Not that someone start from scratch and spend a lot of time putting a tracker together.

Highways England, on the other hand, has a system where all improvements and efficiencies identified and delivered using Lean are recorded on a Benefits Realisation Capture Form (BRCF) and Knowledge Transfer Packs (KTP) and uploaded onto the Highways England Lean Tracker, where they are shared with Highways England staff and their supply chain. Another best practice method for tracking lessons learnt is the use of BIM software, which not only captures project processes and procedures, but also, hosts a library of project elements, which can be used on future projects. With BIM, there is a lot of IT data management; therefore, a data manager is required who ensures that the right information is disseminated at the right time.

5.4 Lean Benefits in Infrastructure

Table 5.4 and Figure 5.5 show the Lean benefits identified by respondents as the most important. The benefits of Lean have long been documented and the benefits that it brings to infrastructure construction are not different from the general benefits attributed to Lean in other disciplines. Cost and time savings, improved collaboration, increased efficiency, increased safety, and good reputation and reliability are some of the benefits recognised and enjoyed by respondents in this study.

Table 5.4: Lean Benefits in Infrastructure Construction

Benefits	**Frequency**
Cost and time savings	27
Improved collaboration	24
Increased efficiency	8
Increased safety	16
Reliability and reputation	9

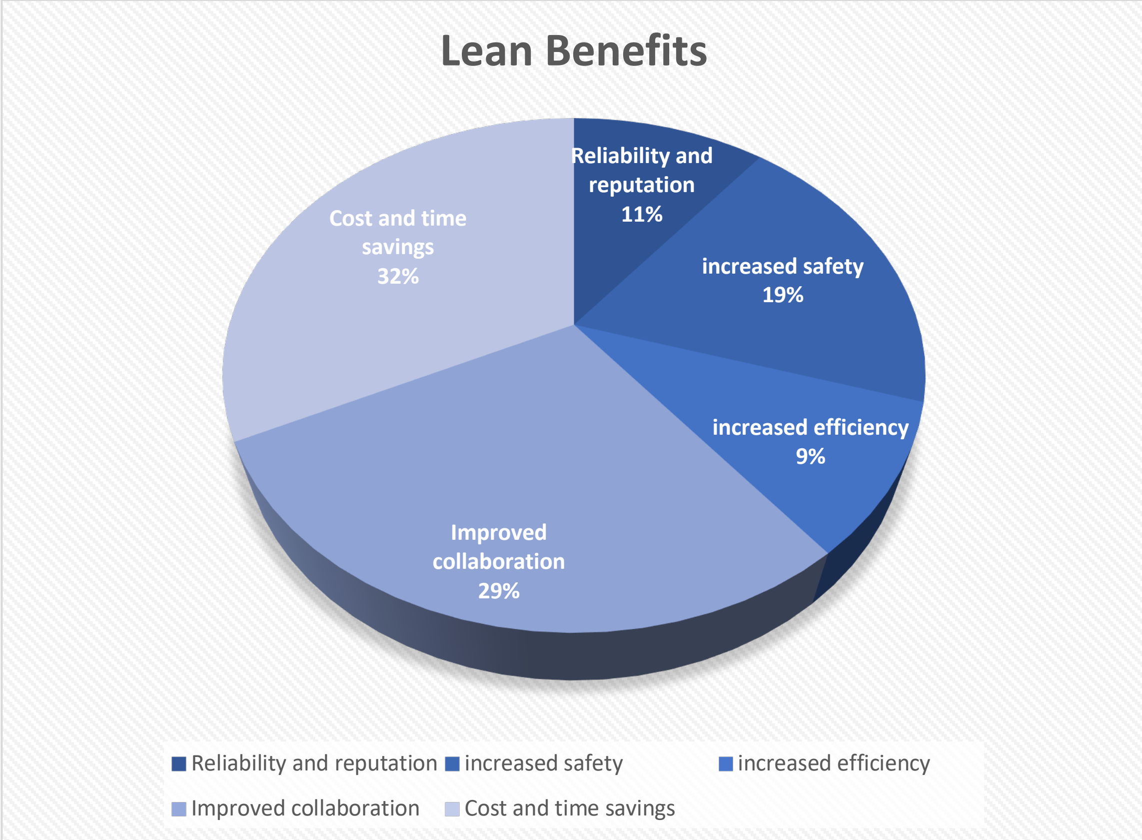


Figure 5.5: Lean Benefits in Infrastructure Construction

5.4.1 Cost and Time Savings

The most common demand of lean implementation, is to save the time and cost of the project, and all respondents affirmed this. Costs and time are saved as a result of the increased efficiency that Lean brings to streamlining the process. For example, by using collaborative systems, collaborative programme and collaborative planning, the best options are put forward, and the time needed to complete an activity or project is reduced. Therefore, one can associate cost savings to doing things right the first time and saving time and cost on repeated work. Respondent CDHE01 commented that, since 2009, his Lean team generated £110 million worth of audited Lean genuine savings. According to respondent CDBC03, within eight weeks of his team implementing Lean on a tunnelling project, their productivity increased by 40%, posting a savings of around 30 million dollars. However, he argued that there is an over-emphasis on cost savings and profitability and less patience to allow an effective programme to develop to its full potential. If the Lean programme does not post savings immediately, the client can see it as a failure.

5.4.2 Improved Collaboration

The respondents emphasised the importance of collaboration in their responses, and 24 of the respondents stated that Lean brought about improved collaborative working on their projects. Lean not only improves the relationship and knowledge sharing between the project team members, it also improves the business relationship with the client, which actually works in favour of the contractor when bidding for new work. With Lean Thinking, working collaboratively with the supply chain increases efficiency, as there is improved communication and a sense of common responsibility to achieve the project objectives. People share knowledge, best practices, and avoid repetition by not having to 'reinvent the wheel'. The knowledge then benefits the industry as a whole. In other words, instead of the contractors competing with each other, they share knowledge and collaborate; hence, they work efficiently. Technology, such as BIM, is currently the best platform to introduce collaborative working. Collaborative planning has been monumental in the improvements reported by the respondents as it relates to infrastructure construction in the UK. Respondent CDCT17 reports how collaborative planning changed their perspective on how they do things in their company:

> It (collaborative planning) improved our overall programme understanding, that is, everybody on the project improving their understanding of Lean. I think it allows us very much to focus on the key deliverables within our design and production management and ensure that we are directing our efforts at the most important work.

5.4.3 Increased Efficiency

Eight respondents mentioned that they have benefited from increased efficiency after implementing Lean on their projects. Cost and time savings are possible only with increased efficiency. In terms of eliminating waste, Lean increases efficiency. It reduces re-work due to defective work, by reducing inefficiencies. In addition, with collaborative planning, there is a more positive culture in the way people interact. It improves shared knowledge, reduces stress and increases awareness and the engagement of those involved. Respondent CDAO04 confirmed that the introduction of visual management whiteboards, performance measure dashboards, collaborative planning, weekly production meetings and set internal targets, project productivity increased. He states:

> Scheme delivery programme improved from 59% to 89%. Weekly reliability tests completion from 63% to 75%. 75% of staff said working practices have changed for a positive way. 59% reported improved communication. We calculated nearly £700k savings, by 20% reduction in design time.

5.4.4 Increased Safety

On infrastructure projects, safety is of the upmost importance. According to 16 of the respondents, their primary goal as a company is the safety of their workforce over everything. Unfortunately, fatalities happen on the road and rail networks, which is usually where workers are exposed to live traffic. Lean can reduce the time of exposure for workers to live traffic, where things are completed quicker and more efficiently, or where the work is executed at times when traffic is minimal. Therefore, the less time that workers are on the road, the greater the potential improvement and safety, and the reduced risk of serious injury. For example, respondent CDEM05 affirmed that one of their drivers is 'safety', "so the more we can do that, that makes the job more efficient and therefore the guys do not spend so much time out there exposed to danger."

5.4.5 Reliability and Reputation

With lean, efficiency is increased and therefore, time and cost are saved which in turn increases profitability and the client is happier. The satisfaction of the client usually improves the contractor's reliability and reputation in the industry as whole. Nine respondents recognise the effect of Lean implementation on their companies' reputations. For example, respondent CDCT09 emphasised the need for value creation for the client by meeting their needs and objectives. With infrastructure construction (roads and rails construction), although the client is usually the government, the end user is the public. Therefore, a good execution of work creates a good reputation in the public eye, and hence greater credibility. Respondent CDAT13 states:

> We are designing the roads and rails for the public and if they see a lot waste, that is not good. So, it is spending less tax payer's money, getting things built in the timeframes we promised, better knowledge sharing, more standard practices, standard ways of working, standard products, less bespoke staff that is going to be cheaper, and better reliability in what we deliver.

5.5 Lean Challenges in Infrastructure Construction

Table 5.5 and Figure 5.6 refer to the challenges in infrastructure construction following Lean implementation, as noted by the respondents. The challenges are similar to the barriers, but do not impede Lean implementation; instead, they only slow down progress. The most common challenges faced by respondents in this study are: difficulty in gaining the trust of the supply chain, and confusion on how to incentivise Lean managers and team members to give their best to the programme. Furthermore, Lean can be considered too academic; there can be difficulty in retaining staff after they have undergone Lean training, and lastly, sustaining the improvements made from Lean implementation can prove challenging.

Table 5.5: Challenges of Lean in Infrastructure Construction

Challenges	Frequency
Difficulty gaining trust	13
Incentivising Lean managers	5
Lean can be too academic (burdensome)	7
Retention of staff	6
Sustaining improvements	3

Figure 5.6: Lean Challenges in Infrastructure Construction

5.5.1 Difficulty Gaining trust

Thirteen respondents mentioned that they were experiencing difficulty in gaining the trust of their supply chain after implementing Lean because there is still no widespread acceptance of Lean. In addition, many respondents report that the majority of suppliers have business operating models which do not fully encompass Lean, and so they object to the new Lean systems. This is a challenge because the subcontractor (supply chain) companies affect the construction process. Subcontractors that are small companies, (i.e. the individuals doing the work at the construction site) need to buy into Lean because they have the true impact on the process. Therefore, it is necessary for the supply chain to realise that Lean is not a standalone activity, but rather a business operating system that has a proven track record of success in multiple industries. Respondent CDBC03, a new Lean manager in his company, shares his perception on the reason why the employees on construction sites are hesitant to trust new Lean managers.

> You are seen as an outsider who is coming in. And the fact that you are ruffling feathers… When you are there people are kind of hesitant to help

> you out because they don`t really trust what you are going to be doing with the information.

Furthermore, employees wonder if there's a greater risk of redundancy through more efficient working. Lean has negative connotations amongst many employees in infrastructure because it has been used in some of the other industries to make people redundant. For example, respondent CDNR08, recollects a time when the NHS used Lean to remove jobs, and called it 'streamlining'. He recollected that after the NHS downsized using Lean, people in infrastructure construction felt that they would also risk job loss if Lean were introduced to their sector. In addition, some see Lean as an added workload to their daily tasks, instead of reducing their workload, because people are left processing far more paperwork.

This is a common reaction, which is why it is important for Lean managers to first build relationships with "the men on the ground", using the words of respondent CDNR08; in this way, they will be more receptive to change. CDNR08 advises that, if Lean Thinking is to be implemented correctly, "you have got to bridge that gap" between the administrative and managerial employees and the employees working on construction sites. Bridging that gap is difficult and the challenge is to build trust. CDNR08 states, "you need to build trust to narrow that gap and that trust is not there when you start, and it takes time to build it. It takes successes, it takes wins, it takes repeated conversations to achieve that."

5.5.2 Incentivising Lean Managers

Five respondents stated that people need to be incentivised to take part in implementing the Lean improvement programme(s). At the moment there are not enough Lean managers and leaders to make a big impact. According to respondent CDNR08, the "lean journey can be a lonely place. It can be quite a sacrificial journey because of the resistance to change from the men on the ground." This was affirmed by respondent CDMM10 who stated that, because Lean is fairly a new way of thinking in the construction industry, there is currently just not enough Lean practitioners or Lean experts within the industry. As a result, there is a lack of motivation and commitment to the process. Small wins can serve as a motivation to keep going but they would need many small wins. For example, setting financial, quality, or safety targets that, when met, provide those short-term wins may be sufficient to give people confidence that a Lean programme is accruing some benefits. In addition to small wins, financial incentives and rewards can motivate the right people to get work done in the most effective and efficient manner.

5.5.3 Lean can be too Academic (Burdensome)

Another challenge mentioned by seven respondents is that Lean can be too academic, instead of practical and simple. For example, undertaking a detailed analysis on productivity using excavator bucket sizes can become an unnecessary burden since excavation lasts only a short amount of time. In manufacturing, conducting the analysis is necessary as the process is repeated multiple times.; however, in construction, most activities are executed only once and for short periods of time. Respondent CDBC03 explains:

> Construction is not like manufacturing, where the same process is constantly repeated. Whereas for us, we are doing earthworks and earthworks only last three months. You do not have time to go through a full process. In fact, you just have to learn to deal with work sometimes without data … So really, making the process too burdensome is unnecessary. It has to be fit for purpose.

Respondent CDBC03 argued that things have to be more practical and fit the context. He also argued that meetings must be kept at a minimum especially during the first weeks of construction until significant Lean results have been achieved. The research findings show that the Tier 1 infrastructure companies regularly use Collaborative Planning, which results in a plethora of meetings that people have to attend. All 27 respondents attested to the fact that, in these process improvement meetings, team members can become disengaged at weeks 1, 2 and 3, because they are getting called into too many meetings, and by week 6, the meeting room is empty. Therefore, making Lean more practical than academic could raise enthusiasm and improve the ongoing commitment of employees on site.

5.5.4 Retention of Staff

One of the major crises that Lean managers are facing in infrastructure construction is retaining staff that they have trained in Lean. Six respondents were particular about this challenge as it not only discouraged them, but it detracted from the improvements they were trying to make. Respondent CDMM10 stated his frustration in the interview: "You train somebody, and they leave. So, you are back at square one again. Time is a constraint considerably because everyone in here is working to virtually 110% capacity.” It can therefore be frustrating, given the investment in time and resources for training, is undermined by issues with staff retention. Furthermore, project teams are only brought together for the project duration, which may be as short as two years. As such, every time a new project is started, a new project team has to be setup, and everyone has to be educated in Lean all over again. This can be challenging to the Lean managers.

5.5.5 Sustaining Improvements

Another challenge faced by respondents is that of sustaining improvements, namely implementing discipline to maintain improvements, and ensuring that the new Lean culture is maintained throughout the company. CDAO04, who is a Lean consultant, stated that “There is nothing worse than getting improvements and then walking away and coming back and it is dropped again”. According to respondent CDCP12, Lean is an ongoing exercise. Lean managers have to pay attention and flag every sign of old habits resurfacing, otherwise, “as time goes by, people slowly revert back to the old method of working; bad habit takes a long time to get rid of.” Respondent CDCH15 states: “I have spoken to various people from other industries, they all said that to do Lean properly it takes 20 years plus.” Therefore, to guard against reversion to old ways, CDAO04 recommends embedding Lean into the management systems routines, aligning improvements to the business need, and using Lean tools and techniques to complement existing practices. Complementing existing practices ensures that the change is not monumental but incremental where people can easily adopt the change without having to completely overhaul their processes.

5.6 Drivers of Lean in Infrastructure Construction

The drivers of Lean Thinking in infrastructure construction are people, governmental bodies, or institutions that influence industry actions or industry direction, which are not exclusive to safety, and efficiency, but rather incorporate them. The research findings show that the benefits of Lean, competition in the industry, the direction of the industry, technology, and the client or government drive Lean in the infrastructure construction in the UK (see Table 5.6 and Figure 5.7).

Table 5.6: Drivers of Lean in Infrastructure Construction

Drivers	Frequency
Benefits	27
Competition	16
Industry	20
Technology	6
Client/Government	24

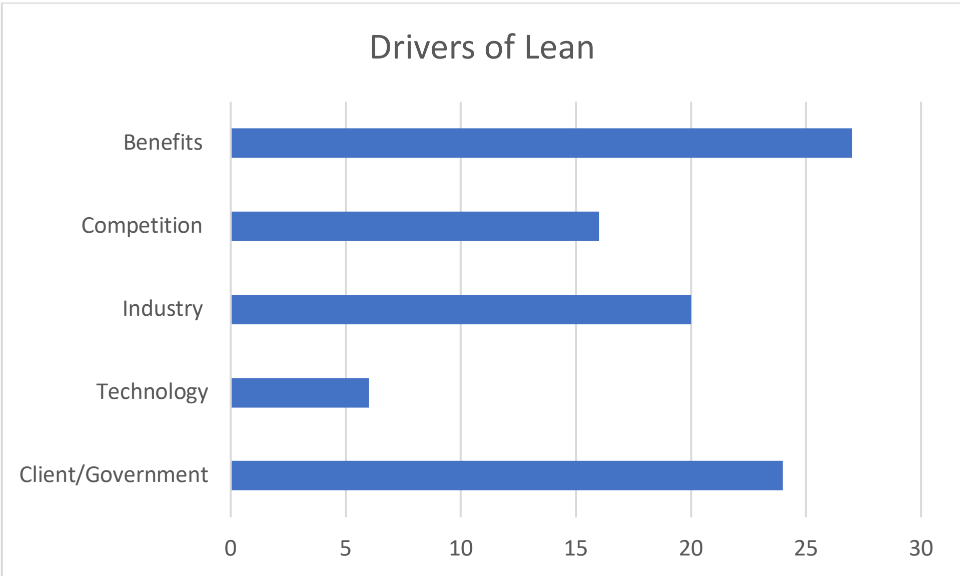


Figure 5.7: Drivers of Lean in Infrastructure Construction

5.6.1 Benefits

The benefits of Lean can be seen as drivers, which was confirmed by all 27 of the respondents. The key driver is financial rewards.; if a construction company is convinced that it is going to get a higher return by using Lean, then it will be more likely to adopt Lean. In other words, if they believe that it will help them work twice as fast, be twice as profitable twice as frequently, then it is easier to convince the contractor to adopt Lean. However, respondent CDBC03 criticised the emphasis on profitability instead of the Lean programme itself; he called it 'an immature Lean implementation" because the contractor is pressured to provide savings. However, he also stated that,

> … if you've managed to get a single project completed, that's made you money for the year then everyone is off your back. Whereas if you are not

> making money, you might have a great programme, but it seems a failure. So, it`s all about profitability; or increasing profit through efficiencies.
>
> Because people want to get a lot more value for their money and cost… you need Six Sigma and Lean that shows you how to do things more efficiently and eliminate the waste from the process. (CDNR14)

Other benefits, such as increased efficiency, safety, collaboration, and reliability and reputation, are also driving Lean Thinking; according to respondent CDNR14, this is because "… the market rewards companies that stand out". Other respondents testified to actually getting more work because of their Six-Sigma programme. Therefore, companies want to improve the way they do business, by continuing to look at ways that they can apply Lean tools and techniques to improve their processes, behaviours, and culture.

5.6.2 Competition

The other driver influencing Lean implementation in infrastructure construction is competition. Overall, the UK construction industry has become more competitive than in the years before the recession. Coming out of the recession, the government became quite stringent with ambitious targets for driving efficiencies through their supply chain. Sixteen respondents mentioned that, due to competition in the industry, companies adopt Lean to secure a competitive advantage over other companies operating in infrastructure construction. This is because the government is looking to save money and Lean has a reputation for saving money and increasing profit. This sentiment is also shared by consultants; for example, respondent CDCH15 stated:

> If we want to be the consultant of choice, Lean has to be part of the service… It is about the reputation of our organisations. It is about being the people they (client/government) want to have on their side… Lean certainly within our organisations is, a means to an end, and as a means to get-in to do the work.

In addition, respondent CDSM19 was asked why, in their opinion, do these drivers influence the implementation of Lean Thinking in their company in the UK construction industry. CDSM19 affirmed that it is about "winning work in the future and making money now." Similar comments from other respondents included, "It is essentially, a way to beat the opposition, become better at what we do, beat the competition" (CDBB26).

> We are not doing lean because we want to do Lean, we are doing Lean because we need to do Lean to demonstrate that we are able to be collaborative, we achieved the right certification and we can win work. Some work, we will lose straight away by just not being certified; for example BS1100. Because there is so much competition in the UK construction industry we are having to do lean at the forefront of what we do and meeting the right certifications of Lean in order to satisfy our client. (CDCP12)

> At the moment competition between rivals means that we have to look at different ways of delivering our services cheaper and more effectively to client. So … we have created automation, we have created great standardisation on models we use across organisation and looking at the way we captured the value we add to client. (CDAK07).

5.6.3 Industry

Twenty respondents suggested that industry institutions are also driving the implementation of Lean in infrastructure construction. The industry institutions, along with the government drive are influencing its implementation by incorporating Lean into standards and raising awareness in the form of seminars, conferences, and forums around the UK. As a result, increasing numbers of organisations are starting to adopt Lean, and more organisations are collaborating to deliver projects through alliances and joint ventures, instead of delivering projects by themselves. The supply chain also plays a big role in bringing Lean to the ground works on site. Hence, with increased awareness and education, companies will be starting to recognise the benefits of Lean and making use of the same approaches, whilst the supply chain will subsequently start putting it into action. Respondent CDNR08 shares their view on how some individuals in the industry are making an effort to change the infrastructure environment to become leaner.

> I think they are also committed individuals who want to make a difference. Committed individuals within the construction industry who want to make this happen, who see the benefits of Lean, who see what has happened in manufacturing. They are what I call believers. They believe this would make our country better if we did more for less. Those individuals are definitely drivers and they make it happen.

5.6.4 Technology

Due to the nature of Building Information Modelling (BIM) technology, activities can be executed in a Lean fashion. Six respondents recognised the areas where BIM helps their company to be Leaner; for example, BIM helps minimise the number of clashes during the construction phase. During the design and construction, conflicts, problems, and issues, are inevitable. With BIM, the design is reviewed quicker and better solutions are developed faster, such as moving floors, changing structures, and re-laying earthworks, than on a 2D drawing. A normal 2D design review process could take months because all project team members need to view the drawings. With 3D, BIM, and the visualisation of all the components, people can look at a design quickly and make decisions and approvals quicker. In addition, the ability to visualise the project in 3D helps the client get a better understanding of what the final output will look like.

Furthermore, BIM enables the attachment of detailed information to every building component and to store it in one place for the use of all project team members; this enhances communication, integration and collaboration. Respondent CDML06 states:

> With Lean, and particularly BIM, … we can work collaboratively. It is far easier to visualise what you are building if you have got a 3D model than 2D design. You are going to get far more efficient designs, far less rework, far less misunderstanding from stakeholders, more buildable solutions that are going to improve health and safety, a far better record when you come to build or do alterations in the future. So, you have got better information from the start and the client has a far better understanding of what they are getting at the end of the day and the whole process is improved massively.

According to CDML06, if undertaken effectively, BIM represents the way forward. It is now used on all major projects and the government is driving BIM competence, for which the minimum competence level required from contractors during tendering is Level 2. It is a tool and a structure in which to supply an optimal design and an implementation, from conception through to demolition. Furthermore, although it is not Lean, but it is a platform on which Lean thrives. Moreover, like Lean, people are also reluctant to accept BIM as a technique, and so, project leaders also have to demonstrate the benefits of BIM.

5.6.5 Client/Government

In infrastructure, the government is the main client, and its demands with regard to efficiency and cost-savings are increasing. It wants faster, cleaner roads, and more punctual trains for half the cost; furthermore, in the government and regulatory environment, waste is becoming less acceptable. Therefore, contractors have to show they have a Lean system that reduces waste and cuts costs but improves quality and customer satisfaction. Twenty respondents stated that the government is a major driver of Lean in infrastructure construction. Respondent CDCH15 states:

> [The] government is a driver. [The] government has clearly got a Lean agenda; I do not think they understand what might be achieved through it yet, but they have got an idea of what it is. So that is gradually affecting client behaviour.

However, according to respondent CDCH15, some clients usually have no idea how much influence they have. If the client does not ask for efficiency, they will probably get a longer design period and a bigger fee from the designers. Other clients, however, are mature clients and understand the magnitude of their influence on the industry. For example, CDHE01, who is a client representative, states:

> The thing from our point of view is, we are a client, so we have a big influence and we are determined to the get the rates down. We reckon we are paying potentially at least a half more than what we should be paying on rates. It is massive. We have just got to keep going, we will not stop.

Furthermore, the client/government is now inserting Lean requirements into contracts; therefore, every contractor that wants to work for the government must demonstrate Lean efficiencies in their processes. Respondent CDAO04 states:

> There is business pressure from the client under new contracts. The new contracts strongly state you must understand the philosophy of Lean. You must apply it to improve business and make efficiencies. So, when we start bidding to win contracts, we better be able to demonstrate that we are doing it… If it had not been for the client saying, 'you must', then it would have been extremely difficult to change our minds. That gave the impetus and strength to push it through. By doing it and people have been seeing the benefits in terms of quality, cost, delivery, safety, and moral, now the motivation is becoming intrinsic. We are doing it because we understand it, because we want to do it. It makes sense.

5.7 Lean Tools Currently Employed

Like the Toyota tool kit, Lean tools can be combined or used separately to achieve effective and efficient processes in the construction process. The research findings show that there is a plethora of Lean and improvement tools currently employed by companies in infrastructure construction. However, ten tools are most commonly employed by infrastructure construction companies to implement Lean, which are, in order frequency; Collaborative Planning, Visual Management System (VMS), DMAICT/Six Sigma, 5S or 6S, Value Stream Mapping, Elements of TPS (such as Kaizen, Gemba, Andon and Kanban), Root Cause Analysis, HELMA, BIM and Last Planner (see Figure 5.8). Figure 5.8 shows the total number of responses to each Lean tool or technique. It is important to note that the tools are not used in isolation but in conjunction with each other to achieve Lean results; for example, 5Whys, and collaborative planning can be used within Six Sigma in the DMAICT stages. The findings of this research, with regards to Lean tools and techniques in infrastructure construction, reflect the findings of Tezel et al. (2017).

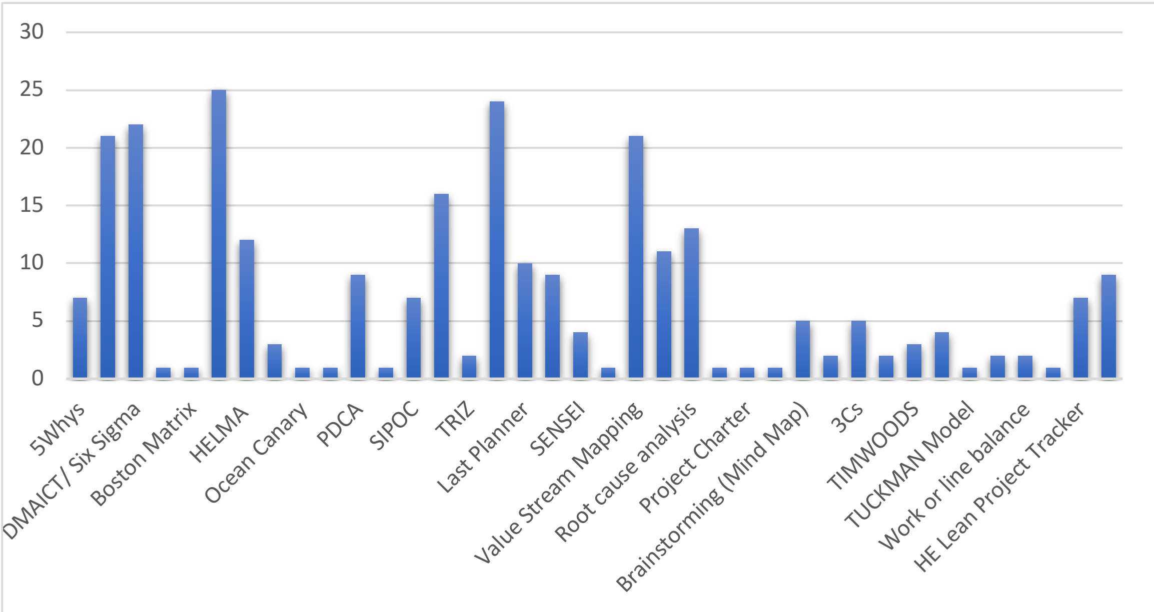


Figure 5.8: Lean Tools Currently Employed by Respondents

- **5Whys**: - used to determine the root cause of a problem or issue by repeatedly asking the question 'why'.

- **5S**: - 21 respondents affirmed the use of the 5S technique in their workplaces to help standardise their activities in a systematic way in order to eliminate or reduce waste. They also use the technique to control and improve their processes on site (Spoore, 2003). On site, 5S enables infrastructure companies to sort materials and tools by keeping only what is needed at the time; to set them in order (straighten) for ease of use; to clean up (shine) and to make perfect materials and tools. Finally, 'standardise and sustain' processes enable the sorting, straightening, and shining, which is second nature to people on site, while bringing about system improvements (Ogunbiyi, 2014).

- **Six Sigma: -** Six Sigma, is probably one of the most popular Lean techniques in the workplace. At the heart of Six Sigma is the DMAICT model, which stands for: define opportunity, measure performance, analyse opportunity, improve performance, control performance, and transfer knowledge. It is popular in infrastructure construction, but not currently used widely by infrastructure companies, as the majority of respondents believe it is mostly suited to manufacturing. Twenty-two respondents also affirmed the use of this technique in their workplaces. Six Sigma, as defined by iSixSigma (2018), is:

> … a disciplined, data-driven approach and methodology for eliminating defects (driving toward six standard deviations between the mean and the nearest specification limit) in any process – from manufacturing to transactional and from product to service. The statistical representation of Six Sigma describes quantitatively how a process is performing. To achieve Six Sigma, a process must not produce more than 3.4 defects per million opportunities. A Six Sigma defect is defined as anything outside of customer specifications. A Six Sigma opportunity is then the total quantity of chances for a defect.

Respondents CDCT09 and CDAO04 gave their opinion on why Six Sigma is not widely used by infrastructure companies; "Six Sigma is not quite prominent in construction because we do not make several components, we are not doing things 1000 of times to add that." Other comments also affirmed the fact that Six Sigma is widely known but not widely used:

> We do not do a lot of Six Sigma because that is more on a manufacturing basis; it is more about tightening up on the quality to that nth degree. In construction the quality is always, the tolerances are so wide in many aspects, it is much more difficult… so taking it down to the Six Sigma level is less applicable. (CDMM10)

> We've hardly done any Six Sigma. There is nothing that we do a million times. So, Six Sigma is all about one in a million that goes wrong. There is nothing that we do in terms of Lean - Six Sigma is a waste of time. (CDCH15)

> I applied DMAIC for my certification and I never applied them again… we have now divorced ourselves from it, we kind of said DMAICT is great but Lean is more practical. (CDBC03)

- **Collaborative Planning and Collaborative Programming**: - this is the most used tool in infrastructure construction. Almost all the companies in this study (25 respondents) stated that they use Collaborative Planning on their projects (See Table 5.7 for examples of the comments). According to Highways England (2017), "… Collaborative Planning is about contractors and sub-contractors working together to improve productivity and reduce time and cost." The study found that most companies adopting Lean start out with the Six Sigma – the DMAICT route of undertaking Lean interventions. This is because Six Sigma is the most popular tool in the industry. However, more recently Collaborative Planning has become the key technique utilised throughout the UK infrastructure construction industry. Table 5.7 suggests widespread acceptance of Collaborative Planning in the industry.

Table 5.7: Respondent's Comments on Collaborative Planning

RESPONDENT'S CODE	COMMENT
CDAO21	"The main thing that everyone is doing at the moment, I would say, is Collaborative Planning. There seems to be an awful lot of focus on Collaborative Planning."
CDCL27	"… things like Collaborative Planning we have seen real benefits, sort of, immediately after implementing it. And now that we have had quite a few successful Lean projects and things like that, people really understand the benefit of doing it."
CDSK18	"My understanding is Last Planner is way more similar to Collaborative Planning, but Collaborative Planning is a little bit more detailed."
CDCH15	"… nobody has seen a tool better than using Collaborative Planning…My priority in the next six months is to train more people to do Collaborative Planning more. And I expect to be doing that, extending that into other sectors of our business."
CDCH15	"We have applied Lean improvement, we have applied visual management, but we have found in our business that the thing that has made the biggest difference is the use of Collaborative Planning. And that's what I have spent most of the last 4 years doing."

CDHE01	"… we are really big into Collaborative Programme Planning. Collaborative Planning is the way"
CDAO21	"Collaborative Planning is not just about getting together, and planning, it is a lot more than that. It is about forward planning, and looking forward a week, what is coming up, whether we have got the right materials, right machines, resources, information in place."
CDHE01	"… initially most companies, when they got involved with Lean, went down the DMAICT route …but now Collaborative Planning and Collaborative Programme are the two key techniques that we are using within, not only us, but throughout the UK Construction Industry."

Collaborative Planning encourages inclusive behaviour. It makes it easy to work with others and creates a more positive culture in the way people interact. It improves shared knowledge, reduces stress, increases the engagement of people by establishing some visual control systems for work group, and encourages work groups to solve problems on a weekly basis. Highways England has taken the lead in Collaborative Planning and the facets associated with it, such as; 5S, 5Whys, DMAIC, Visual Management, Plan, Do, Check, and Act (PDCA) cycle, and so forth. According to respondent CDAO21, who is a performance manager, Collaborative Planning, is not only about getting people together and planning, it is about forward planning – looking forward a week or two weeks, to what is coming up, whether the right materials have been procured and scheduled for delivery Just-In-Time (JIT), and whether the right machines, and necessary resources are in place. He affirmed that together with the supply chain, they endeavour to create a twelve week forward looking plan, and then try to protect the plan by forward looking and making sure everyone is committed to it. Collaborative Planning is also about performance checks – looking at the percentage of planned work achieved that day, or week, and the things that have not been achieved, including why were they not achieved. From this, reasons are captured so that corrective measures and performance improvement measures can be put in place.

When asked, 'what is the best practice implementation framework for LT for your organisation in the UK context', respondent CDHE01, from a client organisation stated that:

> I think the best practice framework is combination of Visual Management and Collaborative Planning, which is what we do on site… In terms of the

contract, all the contracts were more adversarial, so by making them more collaborative you get a far better working environment that everybody is pulling the same direction to deliver a good quality product on time and within the budget.

- **Highways England Lean Maturity Assessment (HELMA)**: - HELMA is the Lean Maturity Assessment Toolkit designed by Highways England and provides an organisation with the structured means to assess their annual Lean performance, in relation to the implementation of a Lean culture in the organisation. The objective of the process is to highlight where actions need to be taken to make improvements and to use this information to help drive the Lean adoption process (Highways Agency, 2012). HELMA is mainly deployed amongst HE's supply chain to assess their progress in Lean adoption. On an annual basis, HE's Lean team visits the Tier 1 suppliers and asks them to measure their performance on the HELMA. There is a list of 19 questions, which are scored on a scale of 0 to 4 (where 0 is low and 4 is high). According to HE (2018), the main areas of assessment are:
    - The integration of Lean in the business strategy
    - Lean leadership and engagement
    - Deployment management/Lean infrastructure
    - Understanding customer value
    - Understanding the processes and value streams
    - The use of methodologies and tools
    - Organisational coverage, activity and capability
    - Performance improvement/benefit realisation and delivery
    - Lean collaboration, climate and culture
    - Supplier maturity

- **Toyota Production System (TPS)**: The Toyota Production System (TPS) is a Lean philosophy that comprises a variety of tools through which to eliminate waste, achieve the best possible efficiency, increase safety, empower people, and encourage a culture of continuous improvement. TPS incorporates many tools; however, those used by the respondents in this study are: Just-In-Time (JIT), Kanban, Gemba, Ishikawa diagram (Fishbone diagram), Kaizen, SENSEI, visual management and **WORMPIT** (waiting, over production, rejects, motion (excess), processing (over), inventory, and transportation).

Visual Management Systems received 24 responses, while **Last Planner**, **Value Stream Mapping**, and **BIM** had 10, 21, and 11 responses respectively. This indicates that Lean leaders have more work to do in educating the industry on the benefits and gains of these Lean tools (BIM, value stream mapping, and the last planner system). Other techniques are seldom used, as they feature low responses. The **5Ps** (product, price, place, promotion, and people), is remarkably effective at helping companies with strategic decisions in order to satisfy customer needs, whilst **8D** and the **AD problem-solving** technique aim to identify, correct, and eliminate recurring problems in a process. The **Boston Matrix** also had one response; this is a marketing tool that allows a company to measure itself against its competition, which helps in strategic decision-making. The Boston Matrix is seldom associated with Lean but is used in business improvement models. Meanwhile, the following had low responses and were mostly unknown to contractors and consultants in this study: **Pareto** (80 - 20 rule); **PDSA** (Plan-Do-Study-Act) for improving processes; Quality Circles; **SENSEI** (the mentor support for leaders); **SIPOC** (suppliers, inputs, process, outputs, customers) for documenting a business process from beginning to end, and **TRIZ** (Theory of Inventive Problem Solving) for problem solving.

More recently, people in the industry have recognised **BIM** as an effective Lean tool in that it encourages collaboration, saves money, reduces duration of projects, and so forth. Using BIM is another way of developing value for the customer and it has become one of the leading best practice tools. This was affirmed by respondent CDCT09, who stated, “BIM can become a very good Lean tool because you can virtually see the value and customers outcome, which is best practice.”

5.8 Challenges facing collaborative planning

- Lean leaders have to train people to handle plan changes, because the conditions today might be different to the conditions yesterday. For example, for every project, there is a different project team, who also have to be trained in collaborative planning. Therefore, changing conditions, environments, and personnel can represent obstacles to Collaborative Planning.

- It is impossible to hold Collaborative Planning meetings when nobody, or only a handful of people, turns up to meetings. Collaborative Planning means getting the right people to communicate and give their inputs, so the project can be planned efficiently. According to respondent CDCT09, people are not available because they have so many meetings to attend, or because the site is completely different than a lot of people's offices; for example, it may be hundreds of miles away from the location of those concerned. This can represent a challenge in the execution of Collaborative Planning. In addition, the transparency that comes with Collaborative Planning is unwelcome by some contractors and suppliers. According to respondent CDHE01, their experience showed that a lot of the people do not like the transparency that comes with Collaborative Planning, because it exposes their inefficiencies. Therefore, many suppliers stopped attending the meetings, and refused to welcome it on their site; this represents a significant challenge for the implementation of Lean.

- Having the right technology to support Collaborative Planning is also a big challenge. The use of video conferencing serves as a useful tool that makes up for differences in geographical locations. However, this technology is still being developed and not completely tailored for construction sites. Therefore, the absence of the right technology can be a challenge for Collaborative Planning.

5.9 The Implementation of Lean in Infrastructure Construction: Best Practice

5.9.1 Leadership

The best practice implementation for Lean in construction organisations must start with leadership (see Figure 5.9). Creating a culture of 'Lean Thinking', where every employee in the company has a mindset of continuous improvement, ought to be the vision and mission of infrastructure companies. It is certainly the vision of Highways England towards its supply chain. Hilbert (1998) and Ahlstrom (1998) state that the core principle managers need for the successful implementation of Lean is leadership. This culture-changing leadership involves motivating employees to buy into project goals, to proactively reduce waste, and to recognise how they can positively impact the project. It is characterised by; an improvement culture, self-development, employee training, Gemba (shop floor management), and customer focus (Dombrowski & Mielke, 2014). Leaders must exhibit a continuous improvement mindset and behaviour in order to influence and motivate employees to do the same. This study assumes the competence of the leadership and therefore the responsibility of success rests solely on the leadership. For a smooth transition and culture change, Lean must complement existing best practice rather than replace or compete against it, leaders must remove fear and make things simple for their employees and supply chain who are being introduced to Lean, leaders must capture knowledge for discrimination, and finally, ensure the training and development of staff in continuous improvement, which is of utmost importance.

Figure 5.9: Lean Best Practice for Implementation

Any organisation interested in implementing Lean needs to have a good strategy for performance and that strategy needs to focus around leadership, which includes the training and development of staff. The leadership strategy for Lean implementation must be embedded with a philosophy of; making things easy, supporting existing best practice, removing fear (being brave in implementing change), and improving the capabilities of staff through training and development. Within that engine for improvement, is training staff in the various Lean tools and techniques, such as Collaborative Planning, Visual

Management, 5S or 6S projects which are for work-place organisations, and DMAICT projects. Finally, it is important to ensure knowledge sharing by capturing the benefits and learning throughout the process, so the wheel does not have to be reinvented for future projects. Furthermore, leaders have to self-educate in order to increase their capabilities, direct the team, and pass down knowledge to their counterparts and subordinates. Awareness courses, foundation courses, training on specific tools, like Collaborative Planning, DMAIC, or 5S, are very good avenues for self-education. This builds the Lean leadership culture in the organisations.

Lean is heavily dependent on leadership in driving and sustaining its implementation. Respondents are reported to have faced some difficult situations where people were resisting the Lean instructions by the Lean managers. Respondents particularly commented on SENSEI, which is a technique in which a neutral independent Lean Sensei (a Japanese word meaning master, or mentor) is appointed to shadow the Lean leader on site. Some of these Sensei are very experienced Master Black belts (Six Sigma) who would Sensei (mentor) the Lean managers; this would entail sitting with and motivating them, and giving them pointers on what to do to be successful. This leadership strategy requires the following: self-education, education of others, driving continuous improvement, and vision. Sensei was pioneered and driven by the Toyota Production System.

The respondents comment that, early on, it is important to select someone as a Lean champion, and preferably someone from senior management who can break through barriers. When any blockers or constraints meet a Lean initiative, the senior champion can more easily defend the initiative, so that it continues to thrive. From this it is possible to build capability, and process improvement, and manage the success. The leader should try to establish some visual management systems in the business process and track progress through collaborative planning. These meetings must be regular. Regular meetings must be held around an improvement or performance board to discuss team performance, identify concerns and opportunities, problem solve, and improve the process.

Furthermore, a Lean practitioner must be part of the project team from the planning stages, namely from the time of inception. The current strategy is reactionary, where they wait for the problem to occur and then call in a Lean practitioner to solve the problem after the fact. In such cases, the Lean practitioner was never part of the team mobilised to the construction site. Contractors should not wait until they are far into a project and running behind schedule before involving a Lean expert. If Lean experts are involved from the planning stages, issues can be addressed before they developed into something that will cost time, money and resources to correct. Therefore, Lean practitioners must be part of the project team from the inception.

The success of any initiative revolves around the leadership. Respondent CDEM05 opined that people are reluctant to adopt Lean because managers are not recognising their roles as Lean leaders.

> "I think there is a lack of Lean leadership. That is one of the critical things at the moment."

Other contractors also pointed out that engaging staff/employees to undertake Lean can be very difficult. Some employees are reluctant to find efficiencies and savings as they are of the impression that undertaking Lean and its increasing efficiencies may lead to job losses, which could include theirs. Therefore, Lean practitioners have to educate employees that the process is not necessarily about cutting staff and resources, but about identifying areas where resources can be better deployed. Respondent CDAO04 states that, in order to streamline processes when implementing Lean, it is important to ensure that employee redundancy is a last resort; this is due to the negative effect it can have on their future involvement in Lean projects. If it affects them negatively, they will be reluctant to be involved next time. Respondents affirmed that some contractors refuse to undertake Lean, as it has not worked out favourably for them in past projects. Respondent CDCT17 states that the forward-thinking contractors, on the other hand, "cannot afford not doing Lean" because it is the best way to deliver for their clients and reduce the overall cost of the contract. In other words, for them, Lean is best way to provide value for their client.

5.9.2 Lean Must Support Existing Best Practice, Not Disrupt It

As much as lean benefits are well documented, implementation must not disrupt other existing best practice already built by the company. In other words, Lean must support existing best practice, not disrupt it; for example, this includes best practice safety on site, like the Zero Harm policy in the top Tier 1 construction companies, or the three million hours accident free accumulated by a Lean Consultancy Company. Implementing Lean changes on a project must not jeopardise this progress, but instead should make them better. Lean should not have a negative impact on company atmosphere either; it must support a greater consolidation of the new and improved culture, and positively impact on the business. If the Lean manager ensures this, people will be more engaged; they will be better problem solvers, and hence, they will have less waste, more profit, bigger market share, and offer better value for their customers.

5.9.3 Make It Simple

Make implementing Lean principles simple and easy for people to apply is important. This involves giving them the tools and techniques that makes work easier day by day, so they are happy and open to implement further changes. Respondent CDAO04 suggests that showing the company the benefits of Lean, particularly for line workers, and then building capability through training and executing some improvement activities. Finally, using the success experienced to promote more activity is also key.

5.9.4 Remove Fear

The respondent findings also emphasised that the process must be void of fear, or to *remove fear* by realising that people are the problem solvers, not the problem. This shift in approach would liberate workers to innovate, make mistakes, and revaluate until they refine the processes. The respondents state that leaders must place emphasis on discovering solutions to what goes wrong, rather than who makes the mistake. This entails changing the culture by encouraging staff to renew their minds, to see problems as opportunities, and so, to be quick to point out problems, so they can be solved. From the study, it was evident that respondents encourage their staff to speak out without fear as their inputs are valuable. Respondent CDAO04 illustrates this:

> I just trained 60 people. I told every single one of them, ‘I do not mind if you are telling me that it is wrong, that it is red’. If it’s red, it’s red. I do not want bad notes, but I do not mind bad notes. What I do not want, and I do not accept, is bad surprises… If there is something wrong just say so. We have enough expertise, enough knowledge to sort any problem out.

5.9.5 Knowledge Capture

Although contracts are one of the biggest obstacles at the moment, they are also one of the biggest drivers of Collaborative Planning. According to the Lean coordinator, CDMS19, "contracts are evolving, and frameworks now include a collaborative requirement." The industry is starting to recognise that the most successful projects are those where knowledge is captured and shared. Moreover, best practice is now being shared between projects. A successful tool that aids collaborative planning and knowledge sharing is the 'Lean project tracker' that is driven by Highways England (HE). With HE Lean-project tracker, contractors are required to upload their inputs onto the tracker which all principle contractors have access to. For example, if information on traffic management is required, they just type in TM or traffic management on the tracker, and several different projects will emerge that have already been conducted. This has provided an opportunity for Highways England's contractors to avoid re-inventing the wheel every time and has led to millions of savings both in time and cost.

5.9.6 Create Awareness

The construction industry has a history of being slow to change. Therefore, a proactive approach has to be undertaken, in order to create awareness of the benefits of Lean construction for business, and for the industry; for example, running seminars and small interactive workshops that explain what Lean is and how it works, scheduling training for staff, and attending Lean conferences, getting people engaged in Lean improvement projects, explaining why they need it, and how it is going to improve the way they work and make their job easier. Respondent CDCL24 recommends training all staff members in at least the basics of Lean principles so that everyone is carried along with the project execution. He states:

> We've put our executive board and the senior management team on Lean training courses. That is our entire executive board and our entire senior management team. And we are also engaging with the next level down with our managers. I would say about the last 6 years, we have had about 750 people go through continuous improvement, or process improvement or Lean-type training. This year we will be close to 500 in just one year alone doing Lean awareness training. And we have budget from our chief executive to invest in training our wider workforce on Lean Thinking … We actually want to make sure that every employee has almost introductory level of Lean Thinking as a bare minimum.

Also, at the centre of awareness raising is the client, who must know what they want, and/or get what they want, by asking the contractor to work efficiently. If the client does not drive the change, it is unlikely to happen, because the contractors are going to do exactly what the client is asking for. Therefore, if the client does not ask for Lean, it is highly unlikely that Lean would be implemented, because breaking through the industry's resistance to change is a real challenge.

Institutions like the Lean Construction Institute (LCI), Construction Excellence, European Network of Construction, Lean working group, and social media platforms and Lean Construction blogs, are playing a part in creating greater Lean awareness in the construction industry. As Lean becomes more widely recognised, and people start contributing to Lean knowledge, it will grow and the people adopt it will grow as well. The aim is for Lean to become normal, and just the way people work.

5.9.7 Drive Commitment and Motivation

One of the most crucial aspects of Lean implementation is gaining commitment, especially, from top management. Senior management and executive management need to 'buy into' Lean. In order to convince top management, they need to see examples of successfully implemented Lean delivery. At first, it may be difficult to convince senior management, hence, it is imperative to ensure that they are engaged with the process by allowing them to see examples of the increased efficiency, increased profit, time and cost savings that are possible with Lean. According to several respondents, leadership commitment and buy-in is absolutely crucial to the success of Lean implementation. Respondent CDMM10 emphasises the importance of leadership. They state:

> … the lessons for us are leadership absolutely vital, our clients particularly must deploy it strategically. If you do it in a half-hearted way or the leadership has not bought into it and you just have little islands of success, it will not just join up, it does not work.

The second important action is train staff in Lean principles and implementation by giving them the tools and opportunities to apply the lessons learnt. This is important because training gives people the knowledge they need to change their behaviours.

The company has to be careful with training; it has to select the right people who would stay and apply what they have learnt, otherwise, money, time, and resources are wasted. Therefore, it important to choose committed and motivated individuals to train. According to one respondent in the study, a very good indication of the right individuals (persons) who can be good advocates of Lean are those who stay at the end of a Lean presentation, seminar, or workshop to talk about things they want to improve or what they want to get involved in. From this indication, management can start to develop a network of likeminded individuals who can drive a Lean culture. Therefore, it important to train and motivate people because only then can they deliver results for the business. After training, it is important to immediately start on a mini Lean project. The newly trained staff have to remain engaged and be given the opportunity to apply what they have learnt on projects where Lean can be used to capture learning. Essentially, this means providing infrastructure to support the Lean implementation strategy.

5.9.8 Manage Expectations

Five respondents emphasised the importance of managing expectations. According to the Programme controls manager of CDBC03, people ultimately think that the Lean leader has a silver bullet that can fix the problem instantaneously. On the contrary, when applying Lean on a project for the first time, it may not go as anticipated. It is imperative to manage the expectations of the newly trained Lean staff. The savings promised might not be realised on the very first project. Conversely, it is possible that losses may be incurred in time if not in cost. This is because the project might experience slowed progress due to hitches as it would take some time for staff to get used to the new Lean processes, which involves a break from routine and old culture and exposure to a new culture. It may also involve new technology, like BIM, which would require a period of familiarisation.

The Lean technical manager for one of the client organisations, CDHE01, recalls leading an enthusiastic group of trainees involved in implementing lean on a project that did not end successfully. When he was asked why the project did not go well, he stated, “we did one project and it wasn’t the best. We had inexperienced Lean people despite being trained during the project, and they were taking a long time. We hadn’t really thought about the amount of effort that was going to be required to support them. So that was huge.” Thus, this experience impacted on the morale of the group.

Furthermore, there can be change fatigue, or initiative fatigue, which make it hard to implement further new programmes when previous attempts have not yielded positive results. Initial high expectations become a challenge when implementing Lean, especially when expected results are not realised. Respondent CDAO04 stated that a slow start should be expected because "the change is massive. But it will take off" with time. He also mentioned that, when he joined his previous company the transition to a Lean culture took seven years.

5.10 The Current Concerns of Lean Implementation in Infrastructure Construction

1. The current nature of contracts and fees in infrastructure construction serves as barriers to achieving the optimum efficiency on site. With the ever-shrinking yearly contract budgets, clients tighten spending, and the continuous demand for savings by clients, mean that contractors are cut thin on their margins, which makes the contractors reluctant to adopt Lean. The morale of the team is affected by tightening budgets, which results in a lack of motivation and commitment from the integrated project team and supply chain. The lack of motivation makes it difficult for the Lean manager to coordinate the team, because they are worried about not getting paid. The findings show that some contractors are forced to operate at the limit of their margins, which sometimes results in a loss of talented people. Should clients continue to tighten the contracts or continue to squeeze the budget each year, and continue to demand for challenging efficiency savings, it will not afford contractors sufficient overhead and profit to adopt a Lean culture without introducing adversarial practices to increase earnings. Clients have a key part to play; the recent collapse of Carillion demonstrates how contractors will indulge in very poor behaviours. The client/government is also culpable by going for lowest cost tenders and taking tough commercial lines. The objective is to have an equitable contract that encourages the supply chain to bring about efficiency savings, and to leave behind the adversarial culture, in order to adopt the collaborative culture of Lean.

2. Through the contract, the supply chain can be made to adopt Lean and create efficiencies. A strategy used by one to the leading Tier 1 construction companies is to

let all the members of the supply chain know that demonstrating Lean savings is a requirement for working with HE. This policy has forced the major Tier 1 and Tier 2 companies to adopt Lean improvement strategies. However, care must be taken that contracts do not force contractors to bear losses, as this may become a huge barrier to the adoption of Lean in the long run. Real incentives only come if they are correctly written into the contract. If contracts are written correctly, they drive the right kind of behaviours. Forward thinking clients are ones that design contracts for the outcome behaviour and not the outcome cost.

3. Fees are also a significant factor in determining the degree of efficiency on projects. If a contractor is offered a choice between two jobs, one of which lasts a year, and the other two years, the contractor would probably take the contract with a longer duration, because they secure a cash flow for a longer period. Lean thinking, on the other hand, encourages the contractor to find efficient ways of finishing the project in half the time and at half the cost. Although the client sees the 'reduction of programme duration' as a good outcome (as should the project team), the contractor does not entirely see it as a positive outcome, because it means a reduction in their income. Therefore, the interest of the contractor conflicts with the 'time reduction' objective of using Lean construction; for example, Highways England's collaborative mapping or look-ahead planning aims at reducing programme duration (HE, 2017). For contractors to achieve the optimum performance on a project, their objectives or interests need to be aligned to the client's overall strategic goals.

4. Getting commitment from the client or their representative requires contractors to fulfil their promise by protecting the client's interest. That means executing the wishes of the client outlined in the owner's project requirement (OPR) to their full extent. Clients may be reluctant to corporate with a contractor if the contractor is known to miss deadlines or for poorly executing the works stipulated in the contract. In other words, the client's motivation for collaboration with such contractors is significantly reduced. This can affect collaborative planning, and hence, the Lean implementation objective.

5. Furthermore, the "payment per shift" set-up of most contracts does not encourage increased efficiency in infrastructure construction. For example, Tier 2 or Tier 3 traffic management are paid per crew, per shift. If they are paid at £1000 per shift, there is no

incentive to do the work in half the time when that can lead to the client cutting the time of the shift, which implies less pay next time. The unwillingness of contractors to lose fees associated with the project duration serves as a barrier to Lean implementation. This leads to resistance to any change that affects their bottom line performance on the project. To avoid this type of behaviour, which undermines the Lean process, it is therefore, imperative to align the contractor's interests with that of the client. This study extrapolates from Hearn (2017), which shows that, when contractors can see how their interests are met, secured, and contribute to the goals of the client organisation, they are more engaged and motivated. The nature of contracts has to change; there has to be reward and gain for everybody in the process.

6. The unequal sharing of pains and gains also poses a problem to Lean implementation. Some client's systems expect the contractor to produce monthly efficiency registers, where they are expected to declare monetary savings. The client then expects a percentage of the money returned. The respondents called it a "pain and gain" relationship, where the contractor does the work to produce the savings, and the client takes an inequitable percentage. Furthermore, some contractors complained that, although this is assumed savings (not yet realised) generated through visual mapping and waste elimination, they have to give back a significant percentage of the savings in 'actual monies' to the client; therefore, some contractors see this as problematic. Similarly, consultants also see this as problematic as savings tend to go into the "back-pocket of our client …and not shared amicably" (CDCH15). Thus, the client is happy, but the consultant and his team are not. This system dis-incentivises both consultants and contractors from adopting a system that short-changes them.

Due to the evidence concerning a lack of motivation and commitment, which results in a shallow and partial implementation or a complete rejection of Lean in the infrastructure sector, there is a need for a framework that captures all Lean values as well as the benefits and incentives for everyone involved. The research findings show that the problem is not the absence of Lean implementation frameworks in infrastructure construction, but one that ensures the effective and efficient implementation of the Lean principles, driven by commitment and motivation.

5.11 Summary

The research set out to explore the best practice implementation principles of Lean in infrastructure construction in the UK. The research found several themes that encapsulate the Lean Thinking and adoption by construction companies, consultants and clients in infrastructure construction. The findings show the existence of strong barriers to Lean Thinking and Lean adoption in the infrastructure sector. Such barriers are: the conflict of interest that exists for contractors choosing between efficient working and their commissions which increases with longer work periods, and the tightening of contracts which dis-incentivises contractors from giving their full commitment to the process. This is evidenced by the lack of motivation and commitment of contractors to the Lean implementation process. Further barriers include: the cost of implementation, clients' and contractors' resistance to change, the lack of commitment from top management, project members' limited knowledge of Lean, language barriers, unwanted pressure due to transparency. Respondents also offered their own opinions on the benefits, challenges, drivers and philosophies of Lean Thinking and implementation. Moreover, the findings showed that there are a plethora of tools and techniques utilised to facilitate Lean implementation. However, the overwhelming majority of respondents emphasised that 'Collaborative Planning' is the most useful technique for the implementation of Lean Thinking in infrastructure construction.

6 CHAPTER SIX| DEVELOPMENT OF FRAMEWORK

6.1 Development of Framework

The research findings showed that the problem in infrastructure construction processes is not the absence of Lean implementation frameworks, but an absence of a framework that ensures motivation and commitment to the implementation process. In other words, a framework that ensures people give their full commitment to the Lean process and remain motivated throughout the project duration. The current nature of contracts and fees in infrastructure construction serves as a barrier to achieving optimum efficiency on projects. The RIBA Plan of Works presents a suitable frame upon which to illustrate the unique process of Lean implementation developed by this research. Figure 6.1 shows the framework developed using the research findings and shows the necessary factors that must be present in order to drive the right kind of motivation and commitment from all members of a project team.

6.2 Consider Contracts

At the beginning of a project, the client must choose a project manager with Lean knowledge to lead the project execution. The formation of the contract starts at the strategic definition, and brief preparation stage, where discussions are held with the client to produce a statement of need and project brief. The statement of need describes the owner's project requirements (OPR), with regards to the quality of work, cost, duration of contract, and the nature of the project, and so forth. The OPR needs to be clearly defined, specific, measurable, and realistic (Raj, 2018) with regards to time frame and cost. The OPR should be part of the contract and form the basis of agreement with the supply chain. It is recommended that the client's lead consultant is an experienced Lean practitioner who can coordinate the project team and other supply chain members in a collaborative planning manner to achieve Lean results.

The chosen contractor is then met to agree with the terms and conditions. This allows the contractor and supply chain to create project objectives that help to achieve the client's objectives as no objective will represent a significant incentive if they are forced and unrelated to the supply chain's underlying personal aspirations. Lean contracts must be equitable and fair to all parties involved, namely, beneficial to both the client and contractor and/or the supply chain. This is why the term 'agreement' is key to the contract. The supply chain must not feel marginalised; excessive squeezing of the supply chain reduces their motivation for collaboration, and innovation, which in turn negatively affects the project. Many of the respondents reported that a significant number of contractors in the industry are working towards the situation where collaborative working will be a win-win situation for both the client and supply chain. Currently, they report that the pain-and-gain dynamics are due to the way contracts are written. When contracts incorporate the right incentives to contractors and other involved parties, they will focus more on the final product (working hard to add value) rather than on maximising the most money for themselves or for their employer. With the right incentives and rewards, the supply chain will be more motivated, committed and focused.

According to Designing Buildings Wiki (2018), one of the biggest advantages of lump sum contracts, is "there can under certain circumstances be a greater margin for profit for the contractor", which then provides maximum incentives for contractor efficiency. Although, NEC 3 Options C, D, and E may not the best contracts to drive performance improvements on construction contracts, they are appropriate for design contracts.

The supply chain on the other hand can increase enthusiasm and commitment from the client by showcasing innovation that saves money and time for the client. The client retains control of the contract by using competitive tendering and can dictate proceedings and terms. However, the 'lowest cost' should not be the driving factor; rather, it should be 'best value'. Contract terms that are equitable to everyone involved drives the right kind of commitment and motivation to achieve the owner's project requirements. Figures 6.2 and 6.3 show how the different factors that comprise the Lean framework would operate or flow within a construction project process.

After drafting the owner's project requirements, which are outlined in the brief, the Lean manager must immediately begin to prepare the project schedule as well as assemble the right project team. Most infrastructure clients, including Highways England, and Network Rail who participated in this study, are drivers of Lean, and in fact, require their supply chains to be Lean certified. Hence, they understand the need for an integrated project team as well as collaborative planning/working. All the terms and conditions of such collaborative working should be outlined in the contract by the client and Lean manager, which is later presented to, and agreed upon by all parties within the contract. It is therefore important that the project brief accurately represents the client's desires so that the concept design stage is productive and ultimately client satisfaction can be achieved.

6.3 Align Objectives

The concept of Management by Objectives (MBO) in an organisation, aims to improve performance by aligning company goals with the individual goals of managers within the organisation so as to motivate them and create a spirit of oneness with the company, where they feel that achieving the company's goals and targets, also means achieving their own goals and aspirations as well (Farcas & Vuta, 2015). According to Spinner (1992), management by objectives can facilitate optimum efficiency because:

1. You have a goal so you know whether you are on the right track.
2. You can access results throughout the course of the project
3. By regularly assessing the performance of your goals, you are up to date with the project
4. You will perform with maximum effectiveness by knowing what goals the project requires and how well you are performing in relation to these goals.

This research fuses the MBO principles with Lean construction in order to reshape the managerial system and address the current problems facing Lean implementation in infrastructure construction in the UK. Properly implemented and rigorously applied management by objectives (MBO) will address underlying problems, through tightening contracts, fees, conflicts of interest, and motivational issues facing Lean implementation in infrastructure construction. In this research, the relationship dynamics in construction lie between the clients and their supply chain (which includes the contractor). Since Lean, is about collaboration, transparency, and unity, it is important that there is no ambiguity about the project objectives, which should ultimately reflect the client's objectives (OPR). Therefore, OPR must be clearly defined, specific, measurable, agreeable, and realistic (Raj, 2018). In order to fairly and accurately assess a performance, key performance indicators (KPIs) must be collaboratively developed. This may be the OPR itself or derived from it and agreed upon by the members responsible for achieving the stated goals. According to Raj (2018), the only goals that will be achieved, are those that are clearly defined and agreed upon, which consequently leads to an easier buy-in because the person(s) responsible for accomplishing the goal contribute to its development.

Some subcontractors may be concerned as to why they need to complete the job quicker if they are paid per shift. To avoid this problem, early on in the project, the Lean leader could use Failure Mode and Effect Analysis (FMEA). Here, the Lean leader invites the most appropriate people to a meeting, including clients, contractor, subcontractor organisations in order to hold a frank and honest conversation and negotiate. The workshop could be facilitated by the Lean leader or by an external person so that there is no conflict of interest associated with the contract. The project areas needing discussion are; targets, barriers, challenges, what is achievable, incentives and rewards related to performance (which may or may not be monetary). These then need to be agreed and incorporated into the contract.

The client sets their goals and the contractors develop strategies to achieve the client's goals. This means aligning the interests of the contractor and supply chain to the interests of the client. This allows the supply chain to establish rewards related to performance, which can be negotiated with the client. Together with the Lean practitioner/lead, they can identify these incentives and motivations. Money is a good motivation to people, an opportunity to take on more work, which would result in a higher turnover, and can be a good motivating factor. Moreover, reputation and recognition can be excellent motivating factors to some contractors.

The supply chain should be allowed to create project objectives that contribute to the achievement of the client's objectives. No objective will be a significant incentive if they are forced choices that are unrelated to the supply chain's underlying personal aspirations. It is essential that the supply chain's interests are aligned to the OPR or project charter and communicated across the whole project, so that everybody knows exactly what the objectives of the project are. The brief must contain a clear statement of project objectives, clearly identified stakeholders, and clearly outlined key risks associated with the objectives. Both the client and contractor/supply chain objectives must be aligned. In that way, there is enthusiasm, motivation and focus on achieving both short and long-term targets.

Infrastructure clients are usually knowledgeable; therefore, they, or their representatives, must provide guidance, monitor Lean performances, provide SENSEIs (mentors), and remove barriers to achieve set objectives. With MBO, the integrated project team and the supply chain is highly motivated as they feel part of the project goal setting and adopt a sense of responsibility for the goals. Aligning objectives also brings a sense of accomplishment, achievement, recognition, and self-worth to the contractors and supply chain (Lloyd, 2018). Because of Collaborative Planning and regular contact and communication between the client and the supply chain, MBO helps to build and strengthen relationships; it builds an atmosphere of respect and trust, improves the quality of decision-making and problem solving, and encourages fairness in performance evaluation.

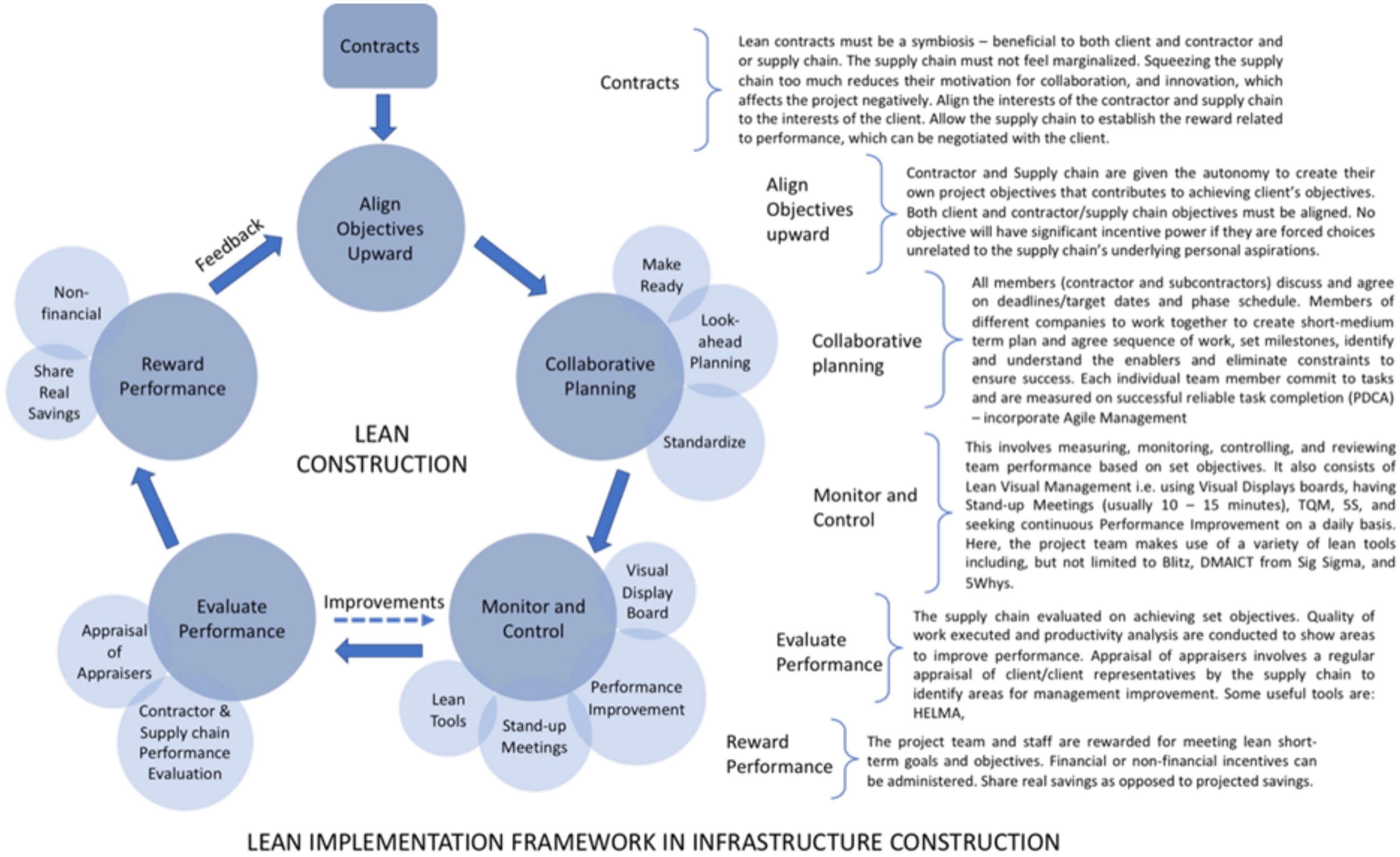


Figure 6.1: Lean Implementation in Infrastructure Construction

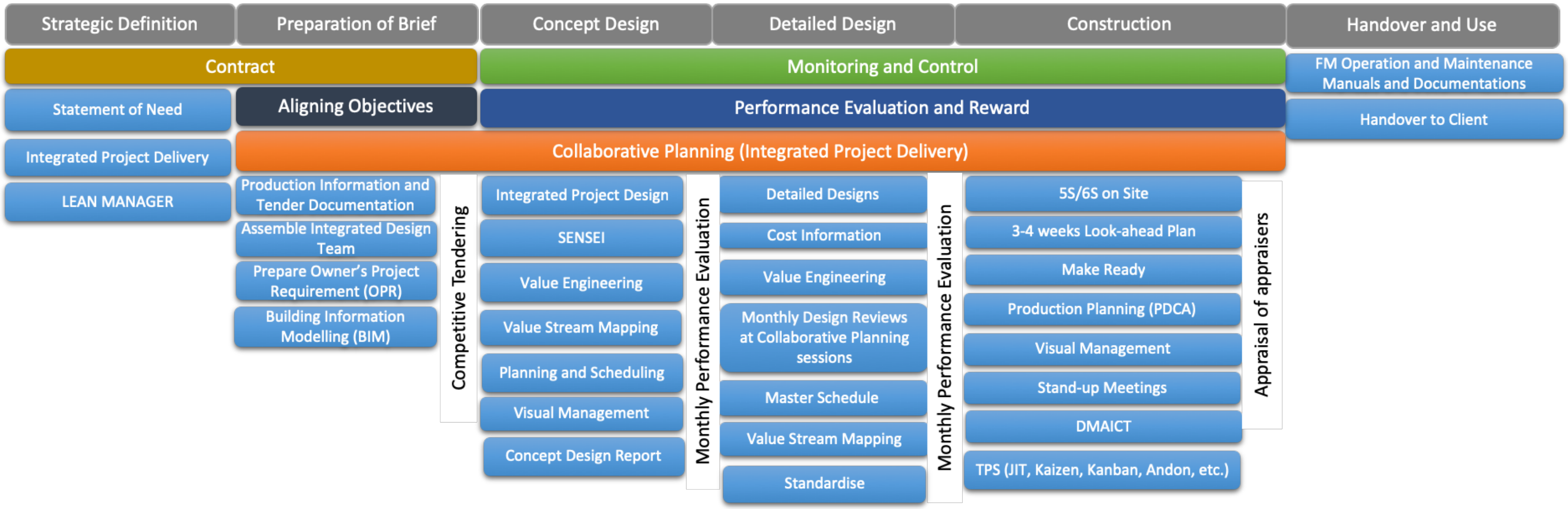
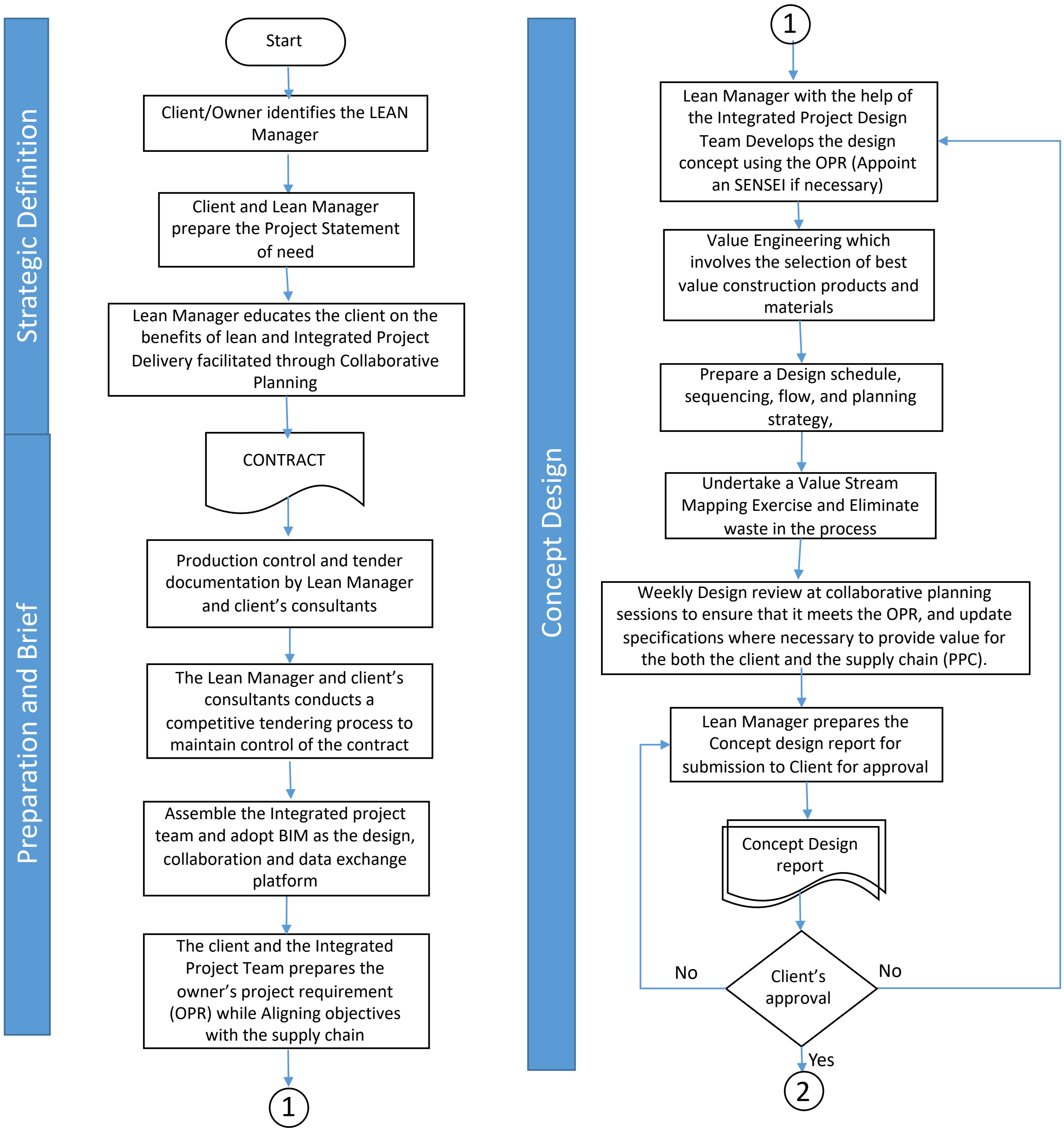


Figure 6.2: Lean Implementation on a Construction Project Process from Strategic Definition to Handover and Use


Strategic Definition
Preparation and Brief
Start
Client/Owner identifies the LEAN Manager
Client and Lean Manager prepare the Project Statement of need
Lean Manager educates the client on the benefits of lean and Integrated Project Delivery facilitated through Collaborative Planning
CONTRACT
Production control and tender documentation by Lean Manager and client's consultants
The Lean Manager and client's consultants conducts a competitive tendering process to maintain control of the contract
Assemble the Integrated project team and adopt BIM as the design, collaboration and data exchange platform
The client and the Integrated Project Team prepares the owner's project requirement (OPR) while Aligning objectives with the supply chain
1
Concept Design
1
Lean Manager with the help of the Integrated Project Design Team Develops the design concept using the OPR (Appoint an SENSEI if necessary)
Value Engineering which involves the selection of best value construction products and materials
Prepare a Design schedule, sequencing, flow, and planning strategy,
Undertake a Value Stream Mapping Exercise and Eliminate waste in the process
Weekly Design review at collaborative planning sessions to ensure that it meets the OPR, and update specifications where necessary to provide value for the both the client and the supply chain (PPC).
Lean Manager prepares the Concept design report for submission to Client for approval
Concept Design report
No
Client's approval
No
Yes
2

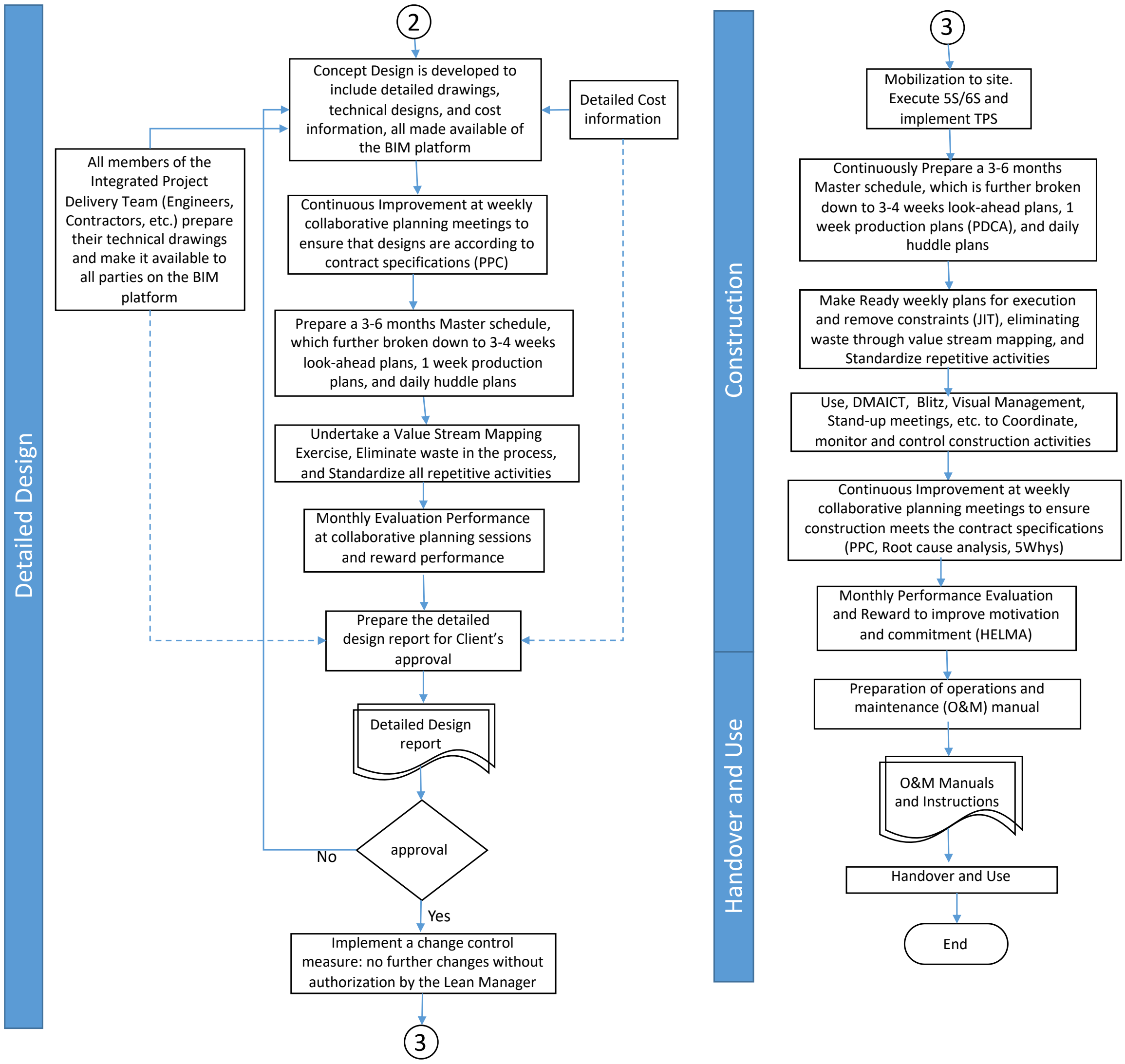


Figure 6.3: Flow Chart of Lean Framework Implementation

6.4 Collaborative planning

The findings of this study showed that the most referenced method currently employed in infrastructure construction for the implementation of Lean Thinking is Collaborative Planning. A statement by respondent CDMM10 succinctly captures this emphasis.

> "For me the jewel in the crown, the cornerstone, is Collaborative Planning"

Collaborative Planning, also known as the phase scheduling approach, allows the integrated project team (client, contractors, designers, M&E engineers, facilities managers, sub-contractors, and so forth) to work together to improve productivity, reduce time and cost, and ultimately improve the project completion reliability (HE, 2017). Some big multi-team projects involve teams in specific departments with the responsibility of delivering one type of function, such as; a road team, a structures team, a technology and improvements team, and so forth. Moreover, a road team could be made up of, road designers, road builders, suppliers, and so forth. It is therefore imperative that this approach is incorporated in any Lean implementation framework. The approach allows all project stakeholders to make collective decisions and identify best solutions to the problems under consideration (Ballard, 2000; Pasquire et al., 2015). It has been shown to reduce the amount of re-work, reduce and eliminate waste, improve communication between all parties on a project, and increase the reliability and timeframes of programmes. It is the platform on which all other Lean tools and techniques will flourish on a construction project.

After the brief is prepared, the infrastructure client and the lead consultant (who is also the Lean manager), should prepare the tender documents and conduct a competitive tendering process to assemble the integrated project team, and adopt Building Information Modelling (BIM) as the design, mode of communication, coordination, collaboration, and data exchange platform upon which Lean will be facilitated. Building Information Modelling (BIM) has proved to be very efficient in construction, and in fact, contractors are required to have a minimum of Level 2 certification for public works. The major infrastructure clients are from the public sector; therefore, they are in a good position for increased efficiency and productivity. BIM does not only enhance collaboration and data exchange, it also allows for clash detection, design interoperability, and for the rapid identification and correction of deficiencies, errors, and inaccuracies. Although the framework appears simple, it is important that a lot of thought and time is invested into each stage. Consequently, the more that trades on a project grow, the more complex it becomes; hence, the more systemised the process needs to become. Therefore, technology like BIM can be used to automate the process and improve the work place.

Collaborative Planning requires a substantial commitment on the part of the client, and the Lean manager to drive to idea through the supply chain. The Lean manager is responsible for ensuring that the atmosphere in Collaborative Planning sessions are interactive and work properly, where members feel free to give their opinions without fear of criticism. The Lean manager must coordinate the team members and ensure that they communicate effectively and efficiently.

There is an overwhelming consensus amongst respondents in this study that collaborative planning should begin as soon as possible. This study recommends that Collaborative Planning begins at the 'brief preparation' stage and continue throughout the concept design, detailed design, construction and hand over (as shown in Figure 6.2). At the moment, there is no a consensus on how many times in a week Collaborative Planning meetings should be held. Some respondents proposed weekly meetings, and a few suggested three Collaborative Planning meetings a week, while another group emphasised the need for daily collaborative meetings. However, more respondents suggested a weekly programme than three times a week or daily meetings. On the basis of the findings, the recommendation of this research is to set aside one day in the week for collaborative meetings. However, at least a stand-up meeting of 15 minutes must be held every morning. For example, during design, the design team could meet on a weekly basis to hold collaborative meetings but hold daily stand-up meetings to discuss daily targets. The collaborative meetings should be facilitated by a Lean practitioner, who together with the supply chain, work through the processes and develop a plan by following a four-step procedure:

1. Discuss the previous weeks' activities and assign reasons and codes on incomplete activities; discuss why things did not happen as planned (percentage plan complete).
2. Run through plans for the next week, discuss any future key dates coming up in the next four weeks, and plan backwards from that point, to develop a plan ensures that the deadlines are met.
3. Discuss concerns, blockers or constraints, and opportunities.
4. Produce improvement solutions to improve productivity.

Set aside an entire day each week for collaborative planning, which will involve people from the programme management office (PMO), namely the; design team, asset team, subcontractors, sponsors (client) and so forth. Everyone gets together in the meeting room to go through the project, and the value stream mapping of activities, which aids in the early detection of problems within the construction process and earlier on within the actual scheme. It also identifies bottlenecks, such as earning approvals, pricing, and so forth. Collaborative Planning should start at brief preparation stage, and continue through to design, construction, and close out. It allows for effective project communication and a better project flow without much conflict as a result of waste identification and elimination.

It is a good method for systematically monitoring and recording progress, analysing work in progress, placing mitigation measures for any work not completed, deploying continuous improvement, and improving motivation and commitment.

All members (contractor and subcontractors) discuss and agree on deadlines/target dates and phase schedules. Members of different companies work together to create short to medium term plans and agree the sequence of work, set milestones, identify and understand the enablers and eliminate constraints to ensure success. Each individual team member commits to tasks and is measured on successful reliable task completion. Value stream mapping can be utilised at the beginning of this stage.

6.4.1 5S/6S

According to the contractors in this study, the first thing to do after moving to site is to implement 5S technique. The integrated project team must deploy **5S/6S** (sort, straighten, and shine, standardise, sustain, and safety) after taking control of the construction site. This is imperative because unorganised and messy sites could result in delays, which implies that the team will not deliver the tasks as promised. Messy sites can make it difficult to find the information, cause the improper filing of documents, miscommunication, misplaced instructions, and accidents. In order to protect against accidents, many contractors have added a sixth ‘S’ for safety. This ‘S’ ensures that everyone on site is held to high standards of health and safety.

6.4.2 Production Planning and Pull Planning

Production Planning is a form of pull planning where milestones are set, and work is planned backwards from the set target. It is the means by which the project team manages information, labour, and materials in order to achieve an efficient delivery (HE, 2017). Production Planning is a weekly endeavour under the umbrella of Collaborative Planning. According to respondents, Production Planning is the safest, quickest, and most reliable way to get reliable plans because it involves every member of the integrated design team. Respondents affirmed that production planning forces a buy-in and commitment, so that people actually execute the works they have promised. The evidence show that it motivates all members of the integrated project team as well as the client, it encourages engagement and greater involvement, and gets members to take more ownership of the plans so they feel they are more part of the process. They feel invested in the success of the project, like their contributions have worth and have helped to achieve the contract requirements.

Using the **master programme** as a baseline programme, a schedule is produced for the next three to six months. The team discusses the activities and generates delivery solutions for a **three-four-week** phased schedule. According to respondent CDAT23, the tradition of spending months to produce a two- or three-year master plan is unproductive, and a "waste of time" and effort, due to the fact that things change constantly as the project progresses. The plan tends to look different after a year. He states:

> The further away you plan, the further away you are from your target, and the harder it is ahead. It is a complete waste of time trying to do that… So, in doing **production planning**, we have a lighter, thinner master schedule and we spend more time doing **pull planning**, and safe planning and it is saving money.

He confirms that the most efficient method is to continuously produce a master plan or baseline schedule that is 3-6 months out, and then break that down to 3-4 weeks **look-ahead plan**. The look-ahead plan is about the forward planning of activities, making sure that the right materials, right machines, resources, information are in place. It is about creating (with all members of the supply chain) an evaluation and continuous improvement strategy loop in which executed activities can be juxtaposed against planned activities (the percentage planned and completed analysis). For example, this entails highlighting what was achieved within the week, what was not achieved, and capturing the reasons for not achieving set targets, in order to correct the process next time. The look-ahead plans are further broken down into one-week **production plans** and then **daily huddle plans**. Members of the project team must be present for the daily huddle meetings. This means gathering for 10-15 minutes each morning to discuss "what happened yesterday, what is going to happen today, and what you would like to happen tomorrow." (CDAT23).

6.4.3 Securing Commitment

The Lean manager should trace commitment tracking to ensure that people follow through in their work using PPC, (Percent Plan Complete). The Lean Construction Institute (2018) defines PPC as "a basic measure of how well the planning system is working – calculated as the number of promises/activities completed on the day stated" divided by the "total number of promises/activities made/planned for the week". It measures the percentage of assignments that are 100% complete as planned.

The Lean manager should use different colour postage for every contractor on the job. He should do this by actually putting names on a sticky note and putting it on the visual display board. The sticky note should say the activity the subcontractor has commitment to e.g. a note alongside a contractor's name saying, "I will install the electrical work for 3 days in this area". In doing pull planning and visual management, subcontractors have more influence and seeing the commitment tracking process encourages them to commit. Production planning, PPC tracking, and daily huddles, are very effective in getting commitment from the integrated project team and the supply chain.

6.4.4 Value Stream Mapping

VSM essentially breaks down all the components of the process and accentuates each step so that areas where waste exist are more visible for elimination, and the savings are readily quantifiable when the waste is eliminated. This session can be held during collaborative meetings with the activities identified on a clean board in a time slot, per day, per week, and the teams are asked what activities are necessary to deliver the outcome. From this, they can then map out the principles, which are in line with the master schedule, and then look to optimise that schedule by removing the wasted activities or duplicated activities. It is important to '**make ready**' these activities by outlining the resource requirements of each activity – materials, labour, plants, and equipment. The next stage is to prepare a risk assessment of each activity and 'plan to protect' or mitigate the losses, standardise repetitive work. **Standardisation** ensures that repetitive work or activities on the project are standardised into a particular process, which means increased efficiency by not re-inventing the wheel or rewriting the processes again (knowledge capture). According to CDBB26, project managers tend to disagree on what can be standardised within projects, or across different project with different people. Value stream mapping (VSM) is an effective technique for identifying these repetitive activities.

6.5 Monitoring and Control

The Lean manager, along with the integrated project team, must establish clear targets and performance standards to monitor progress and control results, by means of pull planning.

The agreed-upon targets and performance standards will also form the basis for the evaluation of a performance. Pull planning or production planning is generated from weekly meetings when the integrated project team come together and measure whether those set actions they committed to the previous week have been achieved. This involves measuring, monitoring, controlling, and reviewing team performance based on set objectives. Monitoring and control should start at the concept design stage after the project team has been commissioned through the concept design. At this stage, they have agreed on the contract and committed themselves to completing a task. It also allows the Lean manager to demand accountability when set targets are not being met.

Monitoring and control consists of Lean Visual Management, namely. visual displays boards, stand-up meetings (usually 10 – 15 minutes), and the pursuit of continuous performance improvement on a daily basis. Here, the project team makes use of a variety of Lean tools including, but not limited to, Blitz, DMAICT from Six Sigma, and 5Whys, to direct the project so that efficiency and client satisfaction is achieved. Collaborative Planning (CP) enhances the monitoring, control, and measurement of the actions undertaken on a weekly basis. CP allows for the control and direction of activities that are not meeting set targets. The Percentage Planned Complete is utilised to measure the actual progress. The result shows the project team where they need to improve, or where they need to concentrate more effort. Two important techniques that have proven very effective in this process are stand-up meetings and the use of a visual display board.

6.5.1 Stand-Up Meetings and Visual Display Board

A stand-up meeting should be held around a visual display board (HE, 2018), which has the process maps. Many contractors use the ‘red, amber, and green system’ progression of activities; for example, if schemes are progressing fine and they are due to hit the next milestones (as planned) they are rated as a green. If there are issues associated with the progress to the next milestones they are marked as amber and corrective actions need to be taken. If activities are completely derailed and infringe on the progress of other activities, they are marked as red and require immediate corrective action. This colour system works on the same principle as Toyota’s Andon technique. Andon is the Japanese for 'sign' or 'signal'; this is a visual aid that highlights a problem as it occurs, in order to immediately countermeasure the problem and prevent re-occurrence (Liker, 2004).

If the Lean manager, namely the person with the Project Management (PM) authority, does not have a high level of Lean knowledge, or is not confident in Lean to lead the team and the project, they and the client can appoint a SENSEI to shadow the Lean manager, and help with any issues they may have in the process (a SENSEI is the Japanese word for master or mentor). With regards to Lean, this means a person with great knowledge and experience in Lean implementation; thus, the SENSEI mentors, and the Lean manager learns on the job. At this stage of the Lean implementation, the knowledge of the TPS 14 principles will prove very useful; 5S organises the workplace, Visual Controls are used as communicating tools within the workplace, Kaizen is adopted for continuous improvement, Kanban is a card utilised to signal a prior process to increase production, Andon cord is utilised to signal deviation from norms, Heijunka for facilitating Just-In-Time (JIT) production, Jidoka for autonomation, and so forth (Liker, 2004).

The Lean manager should create an improvement suggestion system where people can easily make some suggestions as to what could be improved in the office or on site. The current effective systems follow the Six Sigma, DMAICT technique. The Lean manager should collect the suggestions and evaluate the benefits or risks it poses to the success of the project. If the suggestion is beneficial, then the team can implement that suggestion at some point. He must make sure that the project team and supply chain pay attention to the Lean initiative on the project, include reminders at collaborative meetings, and emphasise the need for efficiency on the project to achieve commitment and client satisfaction.

6.6 Performance Evaluation

Performance reviews should be conducted monthly (after every four weeks) at Collaborative Planning meetings and run from the concept design to handover. The review should involve looking back at the master schedule or baseline schedule on a monthly basis to 'check' progress, evaluate performance, and reward achievement of milestones (for example, recognition tied to the achievement of programme objectives). The supply chain is evaluated on their performance with regards to goal achievements (as agreed upon in the contract). A variety of tools can be utilised at this stage, including, but not limited to, PPC, DMAICT, HELMA, Root Cause Analysis, and so forth. It is inevitable that some things will not go as planned, and the original plan will have changed slightly; for example, the team has executed more or less activities than expected. Therefore, there is a need to revisit the collaborative master target programme and conduct a value stream mapping session focusing on a certain key milestone, or critical activity. It is then reviewed more critically to showcase the areas that need improvements in order to get back on track. The team should conduct a root cause analysis to understand the kind of problems they face, the reasons why the performance is lagging, and why some problems persist (if any), in order to identify and implement solutions. 5Whys and Fishbone diagram techniques can be utilised effectively at this stage to find the root cause of such problems.

6.7 Reward Performance

This is the point where positive reinforcement aligns with behavioural science. The project team and staff are rewarded for meeting Lean short-term goals and objectives. Financial or non-financial incentives can be administered to encourage positive behaviour. It is important to share real savings as opposed to projected savings. Furthermore, the importance of setting clear key performance indicators (KPIs) from the beginning is imperative for a fair and accurate assessment of a performance. The supply chain is also evaluated on their achievement of these set objectives (KPIs), which have associated rewards, incentives, or compensations. The performance evaluation process must provide appropriate feedback to the supply chain with regards to their own goals as well as the client's goals. When the achievement of Lean targets is rewarded, it sends a clear message to the supply chain in terms of how valuable goal attainment is to the organisation. Furthermore, it shows that the Lean implementation objective is not just an exercise but an integral aspect of a performance appraisal. It also sends a clear message to the beneficiaries of incentives and rewards that their efforts and contributions are valued, and that more Lean efficiency savings and Lean goal attainments will be met with more rewards.

Additionally, the client or their representative must be evaluated, (the process is also known as the "appraisal of appraisers") to give them feedback on how their monitoring and control behaviour has affected relationships and driven the project in positive or negative directions. It involves a regular appraisal of a client or a client's representative by the supply chain to identify areas for improvement in terms of management. Some useful tools are HELMA, and Maturity Assessment. The project team and staff are incentivised or rewarded for meeting Lean short-term goals and objectives as stipulated in the contract in order to enhance motivation and commitment. Financial or non-financial incentives can be administered by sharing real savings as opposed to projected savings. Furthermore, the Lean manager and the integrated project team should refine current working practices for improved efficiency using the DMAICT techniques and repeat the cycle. The quality of work executed, and the productivity analysis will show areas to improve a performance on the next cycle.

6.8 Summary

It has been established in this chapter that the main issue with the infrastructure construction sector is not the absence of Lean implementation frameworks, but the command of high levels of motivation and commitment to the Lean implementation process so that the objectives are achieved equitably to the satisfaction of both the client and the supply chain members. The framework developed from this study brings together the main factors necessary for the effective implementation of Lean in infrastructure construction, which are: equitable contracts, aligning the objectives of the supply chain with that of the client organisation, Collaborative Planning, monitoring and control, performance evaluation, and rewarding the achievement of Lean goals.

Collaborative Planning (CP) has been shown to be the vehicle upon which MBO, including all other Lean tools and techniques, are implemented effectively. Management by objectives has also been shown to be a powerful tool for the alignment of client and supply chain objectives, in such a way that the supply chain is empowered to take responsibility for their performance by participating in the development of the project objectives. Therefore, this encourages the supply chain to have a sense of camaraderie, which increases their commitment, motivation, and loyalty to the Lean implementation process.

7 CHAPTER SEVEN| FRAMEWORK VALIDATION

7.1 Introduction

This chapter presents the proposed Lean implementation framework alongside its pragmatic application to a project. The chapter first discusses the meanings of validity and reliability and how this study meets the criteria. It then discusses the overall evaluation and acceptance of the framework, which is followed by a critique from the respondents' perspectives. The chapter then further discusses respondents' contributions on every single stage of the framework, leading to the final framework that is ready for implementation.

7.2 Validity and Reliability

The validity and reliability of a study depends on the reproducibility of its results and the extent to which the results give new insight to a given field of study (Tongco, 2007). In this chapter, the research will seek to establish the consistency and objectivity of the results. In qualitative research, care has to be taken to objectively interpret the data received from respondents so as not to misconstrue the information given or impose subjective views, which will misrepresent the findings. Achieving reliability requires the reproduction of the results by other researchers, whereas validity is achieved when the results contribute to a greater understanding of given area of study. In other words, it is the usefulness of the results that makes the study valid (Chapman & McNeil, 2005).

7.3 Types of Validation

According to several researchers, there are various validation techniques in qualitative research, which include, but are not limited to, any one or a combination of the following (Creswell, 2003; Jawdeh, 2013; Shenton, 2004):

- Member checking,
- Triangulation,
- Juxtaposing against results from previous studies,
- Peer debriefing,
- Detailed description and an in-depth understanding of the research context,
- Robust sample selection and rich analysis of data collected,
- Testing against opposing information.

These validation techniques are generally accepted in the research community as establishing the reliability, credibility and generalisability of research findings. The research is said to be credible if it withstands rigorous scrutiny from opposing viewpoints; moreover, it is said to be generalisable if the research findings can be extrapolated from a small sample to the general population. Lincoln and Guba (1985) proposed the criteria for evaluating qualitative research, which suggests that if research is found to be credible, dependable, transferable, and conformable, then it is valid. The issue of credibility lies with the ability of the findings to withstand logical scientific scrutiny. A study is said to be dependable when the findings are derived from: (1) reliable sources of information, (2) good record keeping and documentation, (3) transparency, namely all documents, positive and negative findings are presented without bias, and (4) an in-depth description of context. Transferability, on the other hand, refers to the applicability of the findings to a different sample group. Conformability is another term for triangulation in research, where other research methods are used to analyse the same data collected, and if the results are the same, the research is said to be conformable.

In this study, the following were used to examine the validity, credibility, and reliability: member checking, detailed descriptions and an in-depth understanding of the research context, a robust sample selection and a rich analysis of the data collected, tests against opposing information, and the juxtaposition of the results against those from previous studies. Peer debriefing and triangulation were not used for validation as member checking already exposed the researcher to the scrutiny of expert respondents with different viewpoints. Therefore, any implicit bias is easily detected and noted by the validating group. Triangulation, on the other hand, was not possible since only one method of primary data collection was employed in the study, namely interviews.

7.3.1 Member Checking

As the name implies, member checking refers to a validation method where the people (members) from the sample group who provided the data upon which the research findings were drawn, are given the opportunity to confirm whether the findings are accurate. According to Creswell (2003) a unanimous agreement on an accurate representation of the research findings implies that the respondents have confirmed the reliability, validity, and credibility of the findings. Depending on the size of the population and the split, an overwhelming majority agreement confirms the validity and reliability of the research findings. In addition, the robustness of the sample selection, according to Tongco (2007), determines the reliability and credibility of the study.

Since the robustness of a sample determines the validity and reliability of a research study, for the purpose of validation, it is imperative that the research methodology and sample selection are robust, where expert members form the sample group for the study. In this study, senior management experts who are highly experienced and knowledgeable in Lean construction and are currently serving as Lean practitioners and leaders were selected to provide rich information on the current state of Lean implementation in infrastructure construction in the UK. Table 7.1 and Figure 7.1 provide the number, work titles, and the experience of the sample group used for the validation of this study.

Table 7.1: Background of the Respondents at the Validation

CODE	TITLE	COMPANY ROLE	EXPERIENCE		
			General Lean	Infrastructure Lean Years & Training	
CDHE01	Lean Technical Manager	Client	11	11	Six Sigma black belt
CDBC03	Programme Controls Manager	Contractor	11	11	Six Sigma black belt
CDAO04	Lean Manager	Consultant	31	13	TPS, Lean greenbelt
CDEM05	Quality Insurance Manager	Contractor	6	6	Lean Practitioner
CDCT09	Performance Manager	Contractor	20	4	TPS and Six sigma
CDAK13	Practice Manager	Consultant	5	5	Lean Practitioner
CDNR14	Black-Belt Candidate	Client	0.3	0.3	Six Sigma black belt
CDCH15	Collaborative Planning Lead	Consultant	7	7	Lean Practitioner
CDCT17	Project Manager	Contractor	7	7	Lean and Six sigma

CDSK18	Process Quality Manager	Contractor	12	1.4	Six Sigma greenbelt
CDCT20	Lean Leader	Contractor	7	7	Lean Practitioner
CDAO21	Performance Manager	Consultant	5	5	Lean and Six sigma
CDCL22	Lean Manager	Contractor	7	7	Lean Practitioner
CDAD23	Solutions Consultant	Consultant	7	7	Lean Training
CDCL24	Business Improvement Manager	Contractor	10	10	Lean Training
CDCL25	Associate Director	Contractor	2	2	Lean Training
CDBB26	Continuous Improvement Director	Contractor	6	6	Lean Training
CDCL27	Operations Manager	Contractor	1.6	1.6	Lean Practitioner
CDSM29	Lean Manager	Client	9	6	Lean Practitioner

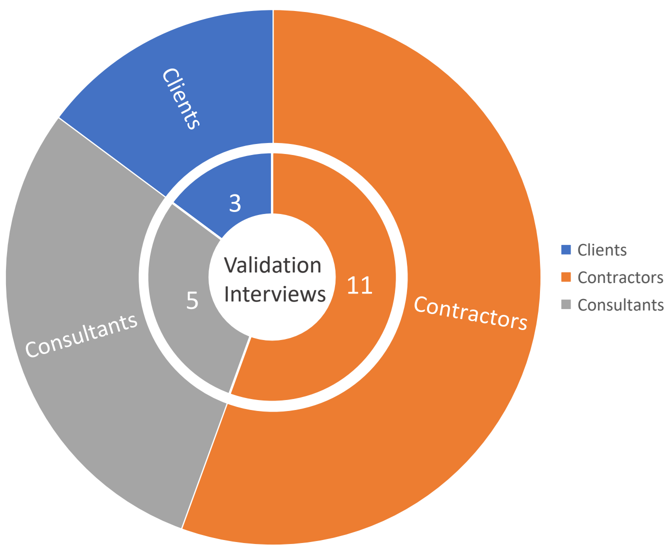


Figure 7.1: Validation Interviews with Lean Practitioners in Infrastructure Construction

These respondents offered in-depth information and a rich description of their personal experiences when implementing Lean in the infrastructure sector. All the respondents within the sample group (27) were contacted for the purpose of eliciting their input on the research findings and framework. The study received a total of 68% responses, or 19 respondents participated in the validation exercise; this comprised 3 clients, 11 contractors, and 5 consultants. The member checking technique was a necessary validation strategy to ensure that any inconsistencies with the framework were identified and corrected, and that the framework presented an accurate representation of how Lean construction in infrastructure ought to be implemented. The study will show, in later sections, that respondents confirmed the validity and reliability of the framework and research findings with useful additions to certain aspects of the framework.

7.3.2 Detailed Description and an In-Depth Understanding of The Research Context

In Chapter 2 and Chapter 3, the research study gives a detailed description of the research context, namely, Lean implementation in infrastructure construction; this provided an in-depth understanding of Lean implementation, which was also addressed within the data analysis and the development of the framework chapters. In addition, credibility was achieved through a detailed representation and description of the respondents' responses and experiences with Lean implementation in infrastructure construction. The respondents' statements have not only been described in the body of the work, but quoted so the reader can comprehend the personal experiences of the respondents in their own words.

7.3.3 Robust Sample Selection and Rich Analysis of Data Collected

Chapter 4 of the study gives detail on the research methodology and the robustness of the sample selection process. A description of other research options was discussed, and it was deemed that qualitative research via interviews was the best approach to answer the research question and satisfy the research objectives. Experienced Lean practitioners formed the sample group, and the interviews were conducted ethically and transcribed; these transcriptions were available for authorised third-party verification. Furthermore, a detailed analysis and presentation of the data collected was provided in Chapters 5, 6, and 7, where additional visual representation of the analysis was used to capture pages of text in a snapshot, for ease of understanding and comprehension by the reader. Since a detailed documentation of the research methodology is achieved, and can be reproduced with similar results, it therefore, establishes the credibility, validity and reliability of the research findings.

7.3.4 Test Against Opposing Information

In qualitative research, validity can be achieved by testing the robustness of the findings against opposing information. For example, if all rebuttals to a viewpoint fail to be true, then it can be said that the viewpoint is valid and reliable. However, if the rebuttals hold true, then the viewpoint cannot be reliable, and so validity is not achieved. Critical analysis requires the presentation of opposing viewpoints, opinions, and perspectives, of respondents, in an objective manner. For example, the differing perspectives of clients and contractors were represented regarding the current state of contracts in infrastructure construction. Here, it was imperative that these opposing viewpoints were discussed to enhance the credibility of the findings and show that they were able to consider and integrate opposing opinions.

7.3.5 Juxtaposing Results Against Previous Studies

The literature review encompasses a discussion of previous research on the subject of Lean implementation in infrastructure as well as in construction as a whole. Juxtaposing the research findings against the literature showed similarities as well as differences, which informed the research study. Hence, this confirmed the observations, and identified the gaps that exist between this research and the existing literature. The ability of this research to fill this gap is what makes this study valid and demonstrates its usefulness to the field of Lean implementation in infrastructure construction.

7.4 Overall Evaluation of The Framework by Respondents

To reiterate, the research findings show that the problems with Lean implementation in the UK infrastructure construction sector is not the absence of Lean implementation frameworks but the absence of a framework that can ensure commitment to the process and motivation to drive the process. In other words, this is a framework where those implementing it are motivated and committed to achieving the optimum Lean efficiencies of time, cost and quality. Therefore, the framework proposed here incorporates incentives and rewards in the contract to increase motivation; it aligns the objectives of both client and contractor to ensure commitment, incorporates Collaborative Planning, monitoring and control, and performance evaluation to ensure optimum efficiency is achieved, and finally, rewards performance for positive reinforcement to further enhance commitment and motivation. The current available frameworks in infrastructure construction do not incorporate these elements.

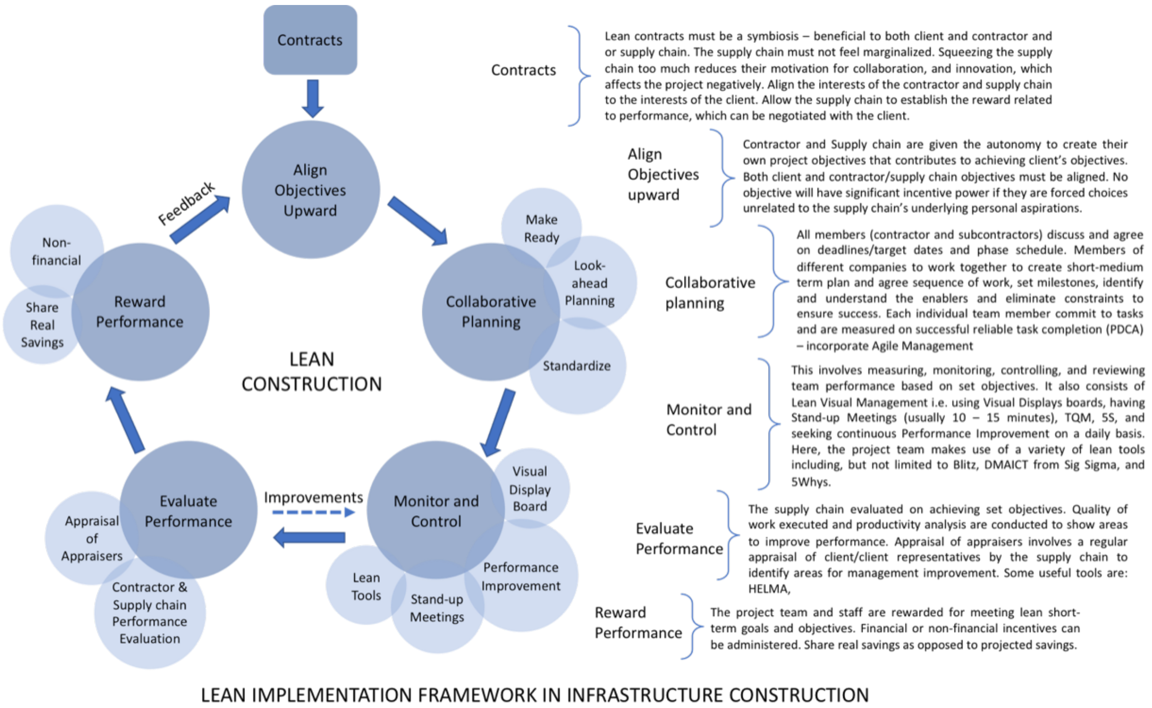


Figure 7.2: The Framework as Validated by Respondents

Figure 7.2 shows the framework sent to the respondents for validation. This section gives a brief discussion of the respondents' reception of the framework; there was a general overall acceptance of the framework amongst respondents. Tables 7.2 and 7.3 illustrate both affirming and sceptical comments from respondents, which further strengthen the validity and reliability of the framework and findings.

Table 7.2: Validation of the Framework

Respondent	Comments
CDHE01	"In the middle where you've got 'Lean construction', that's where 'the client' needs to be. 'Aligning objectives' for me means understanding client's requirements: the client needs to have a say in all of the boxes."
CDAO04	"There is nothing wrong with the framework. Nothing! But the framework won't work, unless leadership really understand what Lean is, are bought into it, and then create a culture for this framework to work in."
CDCL22	"The points on contracts and aligning the objectives are valid"

CDSK18	"… you know, you highlighted some of the interesting aspects in the construction industry."
CDEM05	"You've hit the nail in the head with 'Align objectives upwards … everything you've said here, really just nails how you can get better efficiencies."
CDCT09	"… the framework is pretty spot-on to be honest."
CDAK13	"Looking at the graphic, I think that's good. It spells out how I think it needs to work. I don't think anyone would disagree with this. It's well argued. It all makes perfect sense."
CDCL25	"It's all very well laid out. I don't see anything that I want to change. And you're not biased toward one or the other. You've made it simple and easy to understand." "To me, everything you've got here flows. I think it's really logical, what you've put together. You used the right tools at the right time. Some people, when they do this, they use a lot of jargon. And I don't think you need to do that. I think you should use basic words. Some use Japanese words and it becomes quite difficult. Just keep it simple. I looked at it and I thought maybe we could adopt this in my company."
CDCT20	"… the framework itself, the model itself to be honest, I couldn't comment at all on the actual pictorial part i.e. the framework itself. Because I think it's actually spot on. It is absolutely perfect. It is exactly what we should be doing. It is exactly how we should be doing it as well with the most important aspect of it 'Aligning objective upwards'. It is about creating a platform where there is this symbiosis of mutually beneficial terms of contract, and ways of working that suits everybody across the board where the client, the contractor, the subcontractor, and the suppliers all win. It is possible. And the model which you've analysed there, is a very good example of how it can be done."
CDBB26	"It does capture the Lean process accurately."

Although the majority of respondents affirmed that the framework is fundamentally right, they also pointed out areas of improvement. The most common was the Lean leadership from the people. In the industry, there are barriers that hinder people from implementing Lean construction to its full potential, and only through effective leadership can these barriers be overcome; thus without buy-in from people, no framework or best practice is effective. The comments in Table 7.3 do not encompass the full range of suggestions from respondents; these are only a snapshot of the main focus of respondents. Other inputs will be discussed in later relevant sections.

Table 7.3: Constructive Criticism of the Framework

Respondent	Comments	Address
CDBB26	"I think there's one thing that's missing from your framework, and that is people. Regardless of what's on the framework, without involving the people, none of this will be possible – culture, awareness, training, etc"	Go to section on Leadership
CDAK13	"I think that everything on the framework is spot-on… I think that there's not a lot here that people don't know already. I mean, at work we talk about this all the time."	Go to section on Leadership
CDEM05	"I think somewhere in this model you need to identify that there is a lack of Lean leadership. That is one of the critical things at the moment."	Go to section on Leadership
CDAO04	**"**Focus on the customer and focus on empowering people. Lean is about people"	Go to section on Leadership
CDBT03	"… everything is accurate. I see no issues with it, only that it's designed for UK use and not for other countries because of the terminologies and use of multiple subcontractors."	Go to section on Framework Transferability
CDAK13	"What about the client's point of view. I think there will be a bit more balance if you included the problems the clients are having with the current state of affairs. It gives the impression that the client is winning in the current climate."	Go to section on Contracts

7.5 Improvements to the Framework

7.5.1 Leadership

Although leadership was identified as an important factor to implementation, it was not explicit within the framework sent to respondents; therefore, they were able to point out the absence of leadership. According to Shepherd (2018), leaders play an integral role in fostering a culture of continuous improvement, and without their active participation, Lean improvements cannot be achieved. Respondent CDBB26 points out that, regardless of what the framework may incorporate, it is impossible to implement Lean without involving leadership from the people, namely the buy-in from employees. Culture change starts with the main stakeholders to a project, who are the client, and/or client representative (principal designer who usually has the PM authority and is a Lean practitioner), the contractor, the subcontractors, and the various employees of these stakeholders. After the contract is agreed, various heads can relay the common objectives to their respective employees. The principal contractor can also mirror the contract and pass it down to their supply chain. In that way, the 'alignment of objectives' is built upon or reinforced every time the contract is mirrored and passed down. Leadership is also built and reinforced at every level with common objectives since everyone has the same goals. Therefore, leadership is explicitly shown as the focal point of the new framework as it drives the other stages of the framework.

Respondent CDAK13 opined that everything on the framework is already known by the industry; they state: "I think that everything on the framework is spot-on… I think that there's not a lot here that people don't know already. I mean, at work we talk about this all the time." What appears is the fallacy that having and applying knowledge are the same thing. This thesis does not claim that the industry is ignorant of its problems or solutions; however, it brings together the obvious solutions in a systematic, coherent, and effective manner to achieve Lean continuous improvement, where stakeholders remain motivated and committed to the process. After this was explained, the respondent recognised the fact that the industry is not implementing 'what it knows to be best practice'. Therefore, CDAK13 concludes:

> Looking at the graphic, it spells out how I think it (*Lean*) needs to work. I don't think anyone would disagree with this. It's well argued. It all makes perfect sense. But would people say 'what are you telling me that's new? We know this.' But maybe people don't know it. Or maybe you've made it so simple and comprehensive that it almost sounds like I already know it because now you've pulled it all together in a format. I think I'm probably being too harsh. Maybe you've been very skilful in putting it in a simple format and crystalized into an easy to understand format.

It is important to note that industry professionals are keenly aware of the short-comings of the current available Lean frameworks and, in fact, discuss it regularly. According to CDAK13, many are aware of inefficient behaviours but feel helpless to change the current state of affairs. Through this framework, it is hoped that leaders can drive change; that it will facilitate a change in company culture, which involves looking at the behaviour of people, removing unwanted behaviour, and promote the desired behaviour. Also, having a thorough understanding of why people are behaving in a certain way will help the company to be better prepared to avoid the unwanted consequences of particular behaviour in the future. HELMA is one tool that can be used to assess the behaviour, readiness, and Lean Thinking of an organisation's top leadership.

Additionally, respondent CDAO04, a Lean manager, recommends that the framework focuses on the customer and people. Leadership in Lean is important as it ensures that project objectives are achieved efficiently, which is inherently tied to customer satisfaction and value. The framework focuses on the alignment of objectives and ultimately concerns the best way to ensure the owner's project requirements are met, whilst at the same time, maintaining equity to all parties. There are four main stakeholders on infrastructure projects; the customer, contractor, employees, and supply chain. The customer is looking for better value, higher quality, and quicker delivery; the contractor and the supply chain are looking for profit, whilst a satisfied customer might lead to repeat business, which could increase their market share. The employees are looking for smoother working processes; communication, collaboration, approval, and dealing with concerns quickly; the elimination of inefficient and frustrating processes; better working environments; safety; job security and the certainty of employment, and decent pay. The Lean manager emphasised that there has to be something for everybody when implementing Lean, "Otherwise, it will not work" (CDAO04). Furthermore, "The customer needs to be valued, the contractor needs profit, and the employees need less frustration." (CDAO04).

7.5.2 Contracts

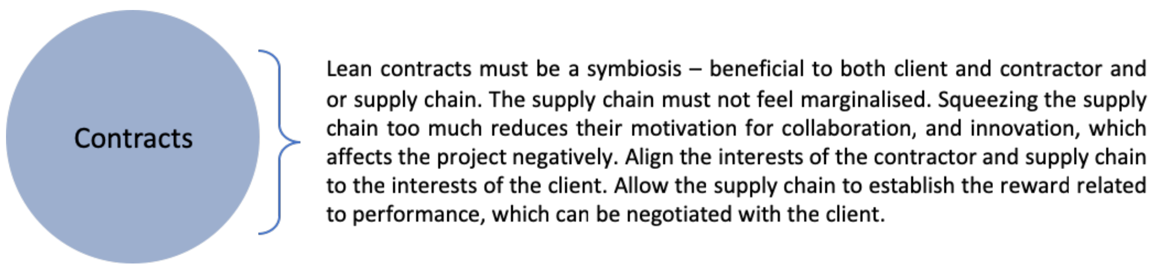


Figure 7.3: Contract Stage of Lean Framework

Table 7.4: Differences Between the Stakeholders' Responses About Contracts

Respondent	Stakeholder	Comments
CDSM29	Client	"It's an easy excuse to blame contracts for lack of innovation and free thinking. I think it's the people, their knowledge and experience that is a barrier."
CDNR14	Contractors	"I completely agree that the current contract structure is a big barrier for Lean adoption."
CDCT20	Contractors	"The framework fundamentally is right. It's absolutely true. In the industry, there are barriers that hinder us from implementing Lean construction to its full potential… The way contracts are made between Tier 2 and Tier 3 contractors, does not give them the opportunity to improve performance. You're absolutely right."
CDAK13	Consultants	"I totally agree that contracts must be a symbiosis/equitable because, otherwise it's not going to work. It's got to be a win-win arrangement. Whereas, at the moment both contractors and consultants feel that it's a bit one-sided. It is a real problem…" "With one the top Tier 1 construction companies, contracts for both contractors and consultants are in the process of being changed because they've realised that the current form of contract is not driving innovation and efficiencies."
CDAD23	Consultants	"From experience, it's really tough to drive the contract and get people to play nicely with each other. I think driving that is easier said than done."
CDNR14	Client	"I completely agree that the current contract structure is a big barrier for Lean adoption.

Prior to validation, it would have been reasonable to envision differences in opinion between clients and contractors with regards to contracts as they are on opposites sides. However, in this case, it is evident that the divide exists (Table 7.4 shows the differences in stakeholders' opinions regarding contracts in infrastructure construction). The previous chapters demonstrate the discontentment of many contractors with the current state of contracts. In fact, contractors reconfirmed their dissatisfaction with the contracts during the validation sessions. However, some clients do not share the same view; for example, CDSM29, who is from a client organisation, believes that contractors are making excuses and blaming the contract and the client for their inability to make Lean savings both within their companies and on the project. CDSM29 states, “It’s an easy excuse to blame contracts for lack of innovation and free thinking. I think it’s the people, their knowledge and experience that is a barrier.”

On the other hand, contractors feel they are being dealt unfavourable terms in contracts; for example, the framework identified contract fees as an issue that needs further deliberation, and respondent CDCL24 affirmed that contractors are being forced to operate at the limit of their margins. CDCL24 stated, “I think that’s absolutely true … It’s actually beyond that. The contractor is almost always under-resourced.” Most contractors believe that they are efficient but respondent CDSM29 disagrees; they believe that, if contractors and or the supply chain were efficient, they would not blame the contract for their low margins, but rather would focus on removing waste from their processes, which could earn them more money than the “2 or 3% margin” they want. Literature attests to the fact that there is a lot of waste in construction processes (Egan, 1994; Latham, 1998). The majority of construction waste is waiting; contractors can identify and reduce waste through value stream mapping and work study, classifying the activities into value adding activities, non-value adding but essential activities, and waste and its elimination. Respondent CDSM29 believes that, by focussing on waste reduction rather than margins, the design and construction organisations can significantly increase their margins.

On the other hand, respondent CDNR14, who is from a client organisation completely agrees that there is a problem with the contracts which stifles buy-in from the supply chain (Table 7.4). However, the consultant’s viewpoint is somewhat moderate in that they agree that the contracts are currently not equitable, but also point out that the framework must also represent the client’s viewpoint. For example, CDNR14 states that, “I completely agree that the current contract structure is a big barrier for Lean adoption.” Meanwhile, CDAK13 notes:

> … I totally agree that contracts must be a symbiosis/equitable because, otherwise, it’s not going to work. It’s got to be a win-win arrangement. Whereas, at the moment both contractors and consultants feel that it’s a bit one-sided.

Lean consultants are caught in the middle where they are trying to get the contractors to commit to Lean and produce efficiencies and the contractors are not complying because of the contractors' fear that the client will cut costs on future projects. Whilst some consultants side with the contractors, others, side with the client; for example, CDAK13, a Lean consultant stated that "the contractors have been squeezed." The contract programme can be agreed but the client can, arbitrarily, "cut 10% off the programme." Lean consultants experience difficulty getting a buy-in from contractors because project managers are asking, 'why do Lean when it will lead to future cuts?' The study identified this as a conflict of interest. It is a problem because the clients have also been promised efficiencies, and so the client will cut fees. According to the respondents, there is currently a lot of confusion about contracts, which leads to friction between the parties; for example, different HE construction project managers interpret contracts differently. According to the Lean consultant, CDAK13:

> No one really knows exactly what the situation is, and so, it creates tensions between suppliers and clients, which is not healthy at all. At the end of the day we are all supposed to be on the same side; everyone making a bit of money while doing what's best for the tax payer. It's definitely not good at the moment.

Furthermore, CDAK13 mentioned that the new contract framework is being changed for consultants in the top Tier 1 construction companies; this is because they have realised that the current form of contract does not drive innovation and efficiencies. According to CDAK13, top Tier 1 contractors are changing contracts, as there are no incentives for consultants to identify and adopt efficiencies. The respondent affirmed that the contract issues raised by the Lean framework proposed this thesis were "completely spot-on."

Lean consultants have also emphasised the clients' point of view as they are employed by the client to aid the contractor to find efficiencies. They assert that clients also have problems with the current state of affairs; thus, discontentment with the contract does not solely lie with the contractor. Respondents CDAK13 and CDHE01 pointed out that the framework may be biased in favour of the contractor. Respondent CDHE01 states:

> … the framework gives the impression that the client is winning in the current climate. Because it's talking about the contractor doing all the work and the client is taking the percentage and so on. It feels as if the framework is speaking very much from the contractor and consultant points of view. It

> comes across as ‘greedy clients!’ They are just squeezing the contractor and pocketing the money. They are having a problem with the contracts as well. The client isn’t always happy.

Respondents CDAK13 and CDHE01 asked about the client’s point of view. They suggested that the framework will be more balanced if the thesis includes the problems the clients are facing with the current state of affairs. Although this was not captured in the framework’s pictorial diagram and synopsis, the chapter outlining the Development of Framework showed that clients, especially Highways England and National Rail, also have problems with contracts. Meanwhile, unreliable contractors who promise and do not deliver similarly frustrate clients. Clients are also under pressure to deliver a quality product as they represent the public and will be held accountable for spending public funds inefficiently. They have also made commitments and so, have targets that they have to meet (rail or road). Clients similarly struggle to meet the efficiencies they have promised because of the contracts. The client is expected to make savings and so will pass that responsibility on to the supply chain, which can increase tension in their relationships. The only way, for example, that Highways England can achieve their targets is by immediately passing their efficiency targets on to the supply chain and expect their supply chain to find the savings and efficiencies. Furthermore, contractors have to find these savings because they have competitors who will take their place if they do not.

Finally, to avoid the generalisation of all contractors as resistant to the adoption of Lean, it is noted that some have sufficient knowledge in Lean construction principles and see Lean as the answer to some of the issues in infrastructure construction. Such contractors can now see that ‘Lean works’. Initially, the client has led Lean, but now some contractors see the benefits of Lean for their projects independent of any client pressure for adoption. In a way, some contractors see Lean as the solution to their budgets being squeezed since they can find savings by being efficient. However, the incentive and motivation to make efficiency savings depends on the contract type.

7.5.2.1 Types of Contracts for Performance Improvement in Construction and Design

According to the Programme controls manager, CDBT03, “the contract mechanism doesn’t really lend itself to a symbiotic relationship.” Similarly, the Solutions consultant, CDAD23, believes that driving the contract is “easier said than done”. CDAD23 states that, in their experience, “it’s really tough to drive the contract and get people to play nicely with each other.” This is evidence of the need for a culture change in infrastructure; indeed, Chapter 5 of this thesis showed the need for the client to drive the adoption of Lean in the infrastructure construction industry. Respondent CDBT03 affirms that, “The client has to drive Lean through the contract mechanism”. It is imperative that the client designs the terms of the contract to match the desired output requirement. For example, a contractor on a cost re-reimbursable contract would not be incentivised by the client to finish early. In contrast, if the contractor has signed to a lump-sum contract, then the client could incentivise them to finish early. According to CDCT17, success comes down to the ‘smart client’ designing the contract to deliver the desired output.

Respondent CDCT20 asserts that the way contracts are currently made, between Tier 2 and Tier 3 contractors, does not give them the opportunity to improve their performance because it is labour based. He stated that, in 2018, the industry is still awarding contracts based on NEC options C, D, and E, although these three are based on actual or target costs. He asserted that, ultimately, options C, D, and E, are a payment per-shift arrangement, where the contractor manages to improve efficiency, that leads to reduced hours and those reduced hours, ultimately results in reduced pay. Consequently, the incentive mechanism for the contractor to minimise costs, and the shared risk strategy are undermined.

According to Designing Buildings Wiki (2018), one of the biggest advantages of lumpsum contracts is that, “… there can, under certain circumstances, be a greater margin for profit for the contractor”, which then provides maximum incentives for contractor efficiencies. Respondent CDCT20 asserts that options A and B, of the NEC 3 contracts are seldom used, but are actually the options that provide a framework for performance improvement. NEC 3 options A and B are essentially lump sum contracts, that are priced and built around the schedule of quantities, where the contractor is awarded a package of works at an agreed price. This means that, internally, if the contractor were to increase their efficiency, and find innovative ways to improve quality, reduce time, and increase savings, they would return more profit. With options C, D, and E, the incentive mechanism for the contractor to minimise costs, is weak. Lean leader, CDCT20, shares their frustration with the current choices of contracts:

> The shocking thing is, despite the fact that we know that NEC options A and NEC option B, promote a performance improvement environment, we still

> award contracts based on NEC options C, and D, and, option E occasionally, which is labour based.

Driving quality and being certain about the duration of the project through the specifications in lump sum contracts is the responsibility of the client. However, some respondents argue that the same efficiency savings achievable using lump sum contracts are not conceivable with design contracts. For example, with a designer, a client can either put them on a lump sum or cost reimbursable contract for the design. If a lump sum contract is chosen as the method of procurement, then the designer produces the design once and sends it out to the site. However, if they are on cost-reimbursable, they will complete the design and be willing to revise, upgrade and refine the design. Although this means that the design may cost more to the client, in the long-term, a better, more refined design will be produced, and therefore, this will work out to be cheaper as it would cost less to build on site. However, NEC 3 options C, D, and E may not the best contracts to drive performance improvements on construction contracts, they are appropriate for design contracts.

7.5.2.2 Pay Per Shift

The fair pay charter protects the pay for ground workers on a pay per shift/hour rate, where even if they finish work early, they are still paid the same amount of money. This encourages collaboration on the job. However, the fear of such contractors is that, by being more efficient on the current job, the duration of future jobs will be cut, which will ultimately affect their overall profit. Therefore, the industry has to work out a way that certain standardised jobs will have set durations that do not change with efficiencies unless such efficiencies are of such a magnitude that they cannot justify maintaining the agreed the duration.

According to respondent CDSM28, "on a payment per shift setup, ultimately, the people that lose are the people that do the work." For example, if a contractor is incentivised under NEC options C, D, and E to work faster, they may make more money because of the financial incentive; however, the people that work for them would have less money because they will have less time employed. Respondent CDCL24 agrees that pay per shift contracts do not provide the incentive for people to work efficiently, stating that, "I see the point about, if you're being paid per shift/per crew, then you shoot yourself in the foot by declaring your efficiencies."

On the contrary, Consultant CDAD23 does not believe that contractors and subcontractors will work slower to make the job go longer on purpose because a mature client will notice that they are not being efficient and will not hire them next time. CDAD23 asserts that:

> I do not think contractors do not want to be efficient and save time, because that will result in less work in the future. But if that's the case, then an incentive should be introduced. For example, the contractor can say to the subcontractor, "so this job is going to take 1000 hours, but if we're really efficient, it should take us 900 hours, that's 100 hours of less time that I get to bill my guys. So there needs to be an incentive to those contractors.

The researcher clarified that the study did not intend assume all contractors adopt the same assumptions and behaviours. It is certainly true that some contractors and subcontractors will be efficient regardless of the contract. However, the research findings showed that the majority of contractors have an issue with working efficiently to their own detriment. For example, respondent CDCL24 states that, "it is like shooting yourself in the foot." A conflict of interest exists, and the industry cannot ignore it if it intends to replace the current adversarial contractual climate with a continuous improvement Lean culture. After this discussion, the respondent reflected and commented that they still did not believe that contractors would work slower just to keep themselves busy but accepts that they have a lot of incentives to finish earlier, or to be efficient. CDCL24 affirmed at the close of the interview that, "I kind of see that conundrum".

7.5.2.3 Reward and Incentives in the Contract

Respondent CDCT17 and CDCL24 argued that simply saying, a payment per shift setup demotivates people is inaccurate because "motivation is driven by many factors." This is correct, as the job of a Lean practitioner/lead is to identify those motivations. Money is not the only thing that motivates people; for example, people can be motivated to finish work faster for an opportunity to take on more work, which would result in a higher turnover by the end of the year. Reputation and recognition can also be motivating factors for contractors. Furthermore, incentivisation should happen in-house as well as with the client. Contractors need to incentivise their own staff to be more efficient, to do collaborative planning, challenge them to look for innovations, and look for different ways of working.

In order for collaboration to thrive, project stakeholders (client, contractor, subcontractors, and suppliers) have to establish some common ground, such as delivering the project on time, getting it right first time (without any rework or issues), and ensuring the right quality. Exploring the motivation factors are avenues for common ground, such as sharing benefits with the supply chain as a result of all parties driving efficiencies on the project. Respondent CDSK18 emphasised the sharing of benefits "there should be something in it for the supply chain … otherwise, we can talk about innovations, we can talk about all the other efficiencies, if there are no common grounds, nobody is going to do it."

Respondent CDSK18 recommends a further exploration of the elements of motivation within the infrastructure industry. The overarching aim of this study is to design a framework that incorporates incentives and rewards to drive motivation and commitment so that Lean innovations and efficiencies are achieved effectively. People need something in return for their efforts. If their needs are not secured, it will be challenging to implement any Lean initiatives or any other improvement activity.

7.5.2.4 Pain and gain

According to respondent CDCT09, some infrastructure companies are trying to introduce shared contracts with incentives, where the contracts reflect the same goals for everybody, and pains and gains are shared equitably. However, it appears that this is not the case for many organisations. The contractor shares more of the pain in the short-term, and in fact, it gets worse in the long-term because he is asked to accept less money for future contracts. Respondent CDEM05, from a contractor organisation, describes the current pain-gain dynamics in infrastructure contracts, and states:

> At the contract level, the pain-gain arrangement can be heavily biased towards the client. The tendency is that when a contractor identifies a gain, say 10% of the cost, then the client expects, when the contractor is awarded a similar project or scheme next time, that he knocks off 10% of that cost.

Respondent CDHE01, who is from a client organisation, confirmed that the pain-gain share is heavily skewed in favour of the client, and notes:

> Yes, we do share gain. But with regards to the sharing of pain, they're going to take more of it. The reason they do share more of the pain is to incentivise

> them not to go there. I mean, some of them play games with that and almost let projects run on.

There is a level of distrust between the clients and contractors, which undermines the collaborative objective of Lean construction. To provide a way to bridge this mistrust, Highways England Collaborative Delivery Framework Contract has an arrangement called Programme Level Incentive Fund, and Package Contract Performance Fund. Under Clause Z22, and Clause Z54 – Z59, it states that, if a contractor can demonstrate a level of savings, then the savings will be shared 50-50 between the client and the contractor/consultant. It is imperative that this incentive remains throughout the contract term or to find some other non-financial angle of motivation so as to sustain the motivation of contractors and supply chain to keep finding savings. If these incentives are not noted, contractors may be reluctant to keep finding savings, which would mean working against their own interest, namely reducing potential turnover with every savings declared. According to the respondent, CDHE01, contracts have to be very clear at the start about the pain-gain-shared savings. They state that the client should expect some of the money from the savings but also that the contractor, who has worked hard to identify these savings, should be rewarded with some bonus or financial benefit for the remainder of the contract.

7.5.2.5 Length of Contract, Continuity, and Job Security

According to respondent, CDSM28, both Tier 1 and Tier 2 contractors want continuity of work but the length of the contracts in infrastructure construction does not lend itself to the facilitation of Lean and continuous improvement. A lot of the contracts awarded tend to last for five years. However, the respondent classes them "short term contracts" due to the sheer size of the projects to be delivered within five years; they explain,

> Five years doesn't sound like a short-term contract, but when you consider, for the first 12 months of the contract, you're getting mobilised, you're getting staff in to deliver the contract, you're finishing off things with your previous contractor. Second year, you've started building, setting up processes and functionalities of Lean continuous improvement within the business. Year three, the project starts to deliver, and then come the end of year four, you've started to think about the end of the contract and demobilising.

CDSM28 asserts that the Tier 1 contract delivery depends on a buy-in from the Tier 2 contractors. Moreover, the Tier 2 contractors want continuity of work before they can buy into Lean. However, the Tier 1 contractor cannot promise continuity because they do not have the continuity of work due to the length of a Tier 1 contract. Job security is paramount in the construction industry. It serves as an incentive, which, in itself, motivates employees to be more collaborative. According to respondent CDSK18, the impact of job security for contractors on projects is significant and cannot be ignored. He stated that based on his experience in driving Lean efficiencies on projects, job security is the key motivation for a lot of contractors, stating that:

> … these people have a fear of finishing work early. They have a fear of getting the next job (if there is any), and similarly, the managers have a fear of moving from one job to the next job. If they cannot see the next job, their next project, then obviously their morale will go down. So, it's a big motivation factor.

Construction is unlike manufacturing, where suppliers are awarded rolling contracts; for example, this could mean a rolling three-year contract that lasts for up to twelve years. Such long-term contracts enable the supplier to invest in resources; furthermore, it facilitates a team/family spirit that promotes innovation and collaboration that short-term five-year contracts struggle to attain. In addition, long-term contracts allow the supplier to build their capacity by investing in training staff, equipment, quality control, Lean delivery, and so forth. Such a mutually beneficial relationship is what the infrastructure construction industry should emulate. Conversely, in infrastructure construction, for example by the end of HE's five-year contract, there is no review and continuity; instead, it is retendered for new bids. Needless to say, the level of investment, motivation and commitment, collaboration and innovation that can be potentially achieved on a five-year contract cannot be compared with that of a 15-year contract. Similarly, the office of Rail and Road at Atkins found that, "a lack of committed work for the Supply Chain is a barrier to building capability and capacity" (Atkins, 2017).

7.5.3 Aligning objectives

> The framework itself… is exactly what we should be doing. It is exactly how we should be doing it as well. With the most important aspect of it 'Aligning objective upwards'. It is about creating a platform where there is this symbiosis of mutually beneficial terms of contract, and ways of working that suits everybody across the board where the client, the contractor, the subcontractor, and the suppliers all win. It is possible. And the model, which

you've analysed there, is a very good example of how it can be done. (Lean Lead, CDCT20)

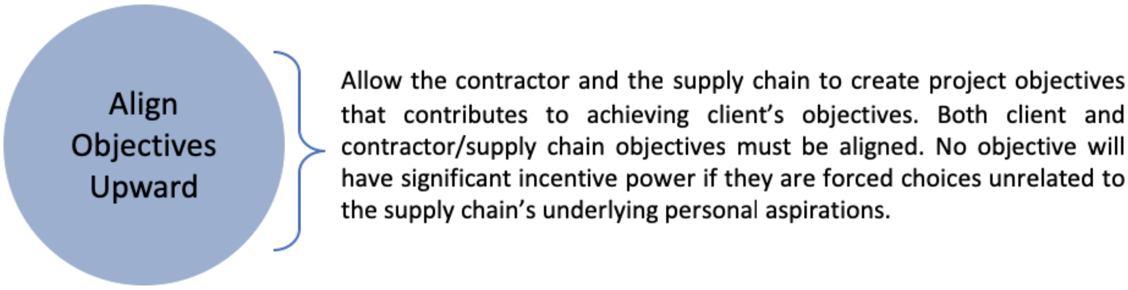


Figure 7.4: Align Objectives at the Upward Stage of Lean Framework

The alignment of objectives is the backbone of any Lean implementation. When objectives are well aligned, they form a solid base for collaborative planning, monitoring and controlling the direction of the project, and evaluating and rewarding performance based on the aligned objectives. Respondent CDCT17 believes it can be hard to align objectives at the beginning of a project because people are afraid of upsetting the standard contract forms. They state:

> Your top circle is 'aligning objectives'. That's like the ultimate. If you can get that bit done, it means when you're doing collaborative planning, you've got a lot more buy-in to monitor and control, and evaluate performance, and rewards administered contractually. So, that's the key but it's also the hardest because that's the bit that most people are afraid of, because we are used to standard terms and conditions.

Some respondents believe that the alignment of the objectives can be difficult to implement because of the lack of readiness and willingness of people in both the client and contractor organisation to listen to each other's problems and collaborate. For example, respondent CDNR14 believes that some of these contractors are over dramatic. He emphasised that none of the contractors were forced to work for them, "and so the choice is theirs." CDNR14 asserted that they, as a client organisation, are unapologetic about their philosophy of continuous improvement and are certainly going to continue driving efficiencies at all times. Conversely, if the current contracting community cannot meet the efficiency drive, there are others who will due to increasing competition in the industry; "It is about getting the existing contractors to think in a new, more efficient way" (CDNR14). During the validation session, the respondent confessed that some contractor's margins are "dreadful and abysmal, and not worth getting out in the morning for"; however, they asserted that the solution is with contractors, and recommends Lean continuous improvement to increase their margins.

Similarly, HE has produced a document called *Executive Resistance to Lean*, in order to understand its people and ensure their objectives are aligned to those of the organisation. The document showed that there is a conflict in the way the executives run the business and the way Lean is supposed to be implemented. However, respondent CDSK18 disagrees that the squeezing of contractors is an issue, and believes that if, as a client, they do not 'squeeze the contractor' for efficiencies, the contractor will not do the same to his supply chain. CDSK18 states that his organisation squeezes the supply chain only because they are not meeting their primary obligations, which are to deliver projects on time and right first time, at the right quality, with zero defects and zero accidents.

There is a clear divide in understanding, and mistrust between the client and contractor organisations, which is responsible for the current friction and adversarial relationship in infrastructure construction. Furthermore, respondent CDEM05 stated that the alignment of objectives tends to be difficult because of varying skill levels in both the client and contractor organisations. For example, even though HE is an intelligent client, they have many new staff and as a result, these newcomers are unaware of the existing systems capturing Lean efficiencies and how to secure efficiencies from the supply chain. In addition, they do not really understand how efficiencies work; moreover, there is a skills gap, which makes the aligning of objectives very difficult. Leadership skills are required to get all stakeholders to align their objectives with those of the client objectives.

Other respondents, for example CDAD23, affirmed that 'aligning the objectives upwards' is critical to the success of Lean implementation. CDAD23 states that:

> Aligning objectives at the beginning is like super important. I think that's really key. That comes from the contract. If you don't have the right contract, you can't do any of this stuff. I think that's a huge factor that needs to be identified. If you don't have the right framework, laid out and agreed to it, before going out to do lean, it will fail.

Furthermore, respondent CDCL25 agrees that aligning objectives is pivotal to driving the right kind of attitude, motivation and commitment to the project.

> If our needs are not aligned to each other, if the benefits are not mutually equitable, then people will not give their all. When their basic needs are threatened, then they lose hope, they lose concentration, and they are not where you want them to be.

Respondent CDCT17, CDCT09 and CDCL24 also state, respectively;

> Aligning the interest of the contractor and the supply chain to the interest of the client, I think that really is a good point. And I think it's one of the critical things.

> Aligning objectives. It is happening. I think also the commercial, legal, and contractual people are actively looking at the way contracts are set up to align those interest from all parties.

> Early on on the project, we do have Lean workshops to address culture. We also try to align with the overall client's objectives at the workshop. The reason we know that it aligns overall to the company's objective is that during the workshop we usually have the company's vision and mission statement up on the wall so that we constantly go back to it and keep challenging them (subcontractors), 'does your strategies align with the client's strategies?' So, we do that crosscheck. So, they don't go out of alignment, where people start heading off in different directions.

The findings showed that, without aligning objectives, there are no incentives for all parties to share gains or pain, whether financial or otherwise. Hence, if the contract is not laid out properly from the beginning, nothing else on the framework will be achieved. Emphasis on the contract, and clarity around it is key to the success of the Lean implementation. Furthermore, respondent CDSK18 does not believe the desired innovation and efficiencies can be achieved without finding a common ground between the contractor and supply chain. He states that sustaining the morale of people is critical to the success of a project and that, unless the basic needs of the supply chain, such as the continuity of work are met, there will be a struggle to drive efficiencies. CDSK18 states that:

> Low morale! Especially when the projects are halfway, or 70% finished can be a drawback to Lean implementation; people lose focus. They know that they need to find another job. For example, some of the project managers, or construction managers or even engineers would be asked to move when the project is 80% finished. With low morale, driving Lean becomes the least of their priorities. Their needs are not aligned to your needs and expectations.

The respondent's comment touches on the significance of the aforementioned 'Length of Contract, Continuity, and Job Security'. The impact on a project is currently underestimated; however, to align objectives, the client and the Tier 1 contractor agree their aligned interests through the NEC contract, which is passed down to the supply chain. Respondent CDCL24 called this type of contract a "back-to-back" contract, which means that the contract agreed with the client is the same as that used with subcontractors. Therefore, the terms and conditions are the same, and the objectives remain the same for everybody. It not only aligns objectives but also means that difficulties become common to everybody.

7.5.4 Collaborative Planning

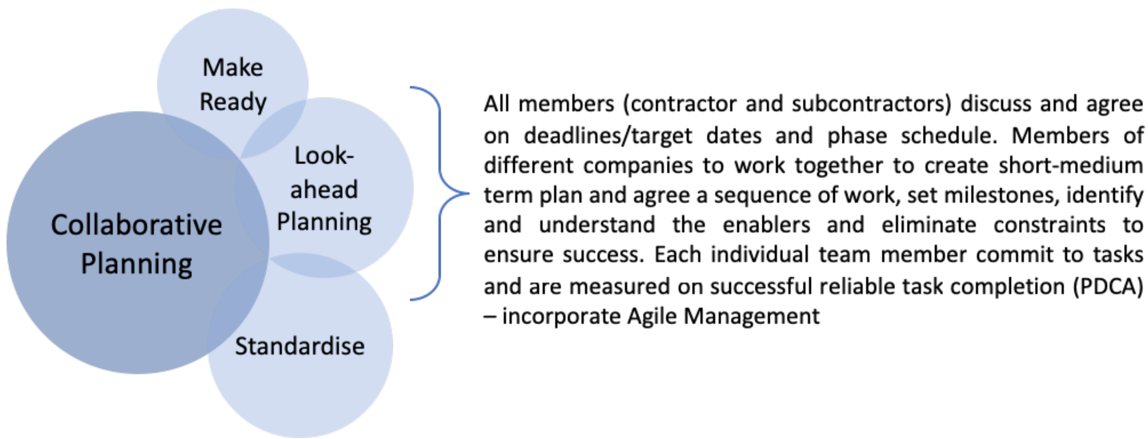


Figure 7.5: Collaborative Planning Stage of The Framework

Collaborative planning and programming are pivotal to a Lean efficiency delivery. The importance of getting all the parties (necessary for the project) involved at the very beginning of the design phase cannot be overemphasised. Early contract involvement (ECI) is important for the success of a project. It is imperative that everybody involved in the construction phase is involved early in the design phase to avoid rework, delays, changes in variation, and claims. The advantages of an integrated project team include: improved communication, early problem solving and root cause analysis, and productive Collaborative Planning. Examples of respondent comments confirming the importance of Collaborative Planning in the proposed framework are detailed below.

> … the concept of integrated teams is important - this encourages collaboration. (CDSK18)

> We have an integrated design function. We start the Collaborative Planning process as soon as the design starts. So, right at the start of the design process, we have the client, Tier 1, Tier 2, and Tier 3 contractors in collaborative planning meetings to talk about the design and will be giving their continuous input until the design is completed. So that, at construction phase, little to no changes would be necessary. Problems arise when designers have been left to go ahead and not involve people from the beginning. Collaborative Planning is a real key part of a successful project. (CDEM05)

In traditional procurement methods, the client separately engages his designers without involving other people critical to the success of the project. The designers complete the designs, send them to site, and then have to change the designs to accommodate site conditions or the input of other project members. This could include the inputs of facilities managers, for example, which are important post-completion and handover. In these situations, the designs have to be changed because the key people have not been involved from the beginning of the project. There are cost and time implications to these changes, which the client has to bear.

According to the respondents, the major problem with the infrastructure industry is that the client and the Tier 1 and 2 contractors do not consider the Tier 3 and supply chain skills and expertise; therefore, they are not invited to participate in the Collaborative Planning process. For example, respondents CDCT20 and CDEM05 stated that the supply chain is not sufficiently consulted.

> We don't use our supply chain as much as we should in collaborative planning. The fact of the matter is the person on the ground doing the work is probably the person with the right amount of knowledge on how it actually could be improved. (CDCT20 and CDEM05).

According to respondent CDEM05, "the majority of the spend, is in Tier 3." By implication, the opportunity for savings lies within Tier 3, who should therefore be included in Collaborative Planning meetings. One of the biggest issues with the lack of collaboration in infrastructure construction is the nature of contracting itself. Tier 1 and 2 contractors feel their jobs will be undermined if they involve Tier 3 contractors, because Tier 3 undertake most of the work. Therefore, Tier 1 and 2 contractors fear they will not be needed if they allow Tier 3 contractors into the collaborative working environment where they may appear more valuable to the client. However, the presence of the Tier 3 contractor in Collaborative Planning makes the work of the Tier 1 and 2 contractors easier; they would still have a valuable role as the managers of Tier 3 and create a more effective culture in the work place.

A fully integrated project team is where the divisive lines of contracts are blurred, and the project objectives are enhanced. According to respondent CDEM05, the team is fully integrated when there are no client and/or contractor teams on the project, but just the 'Team' where the client and contractor all work in the same offices, sitting next to each other, with contractor managers managing client staff and client managers managing contractor staff. In such situations, they have agreed on joint objectives for delivering the contract, and agreed on a joint collaborative performance framework. The respondent affirms the key findings of this research concerning the importance of aligning objectives and facilitating this through Collaborative Planning with an integrated project team where the focus is not on measuring the performance of the contract but rather on measuring the performance of the integrated project team. Therefore, everybody is measured on their performance, and not just the contractor. A collaborative culture is important to realise the full potential of the integrated project team. Collaborative working is more than Collaborative Planning; it involves working together from the beginning of the project to handover. This means sharing information, offering help or support where a party is lacking, having a 'familial mindset' without either expecting anything in return or 'keeping score'. It is fundamentally about the project and delivering the best quality product together (meaning client, contractor, consultants, subcontractors, and suppliers).

7.5.5 Monitor and Control

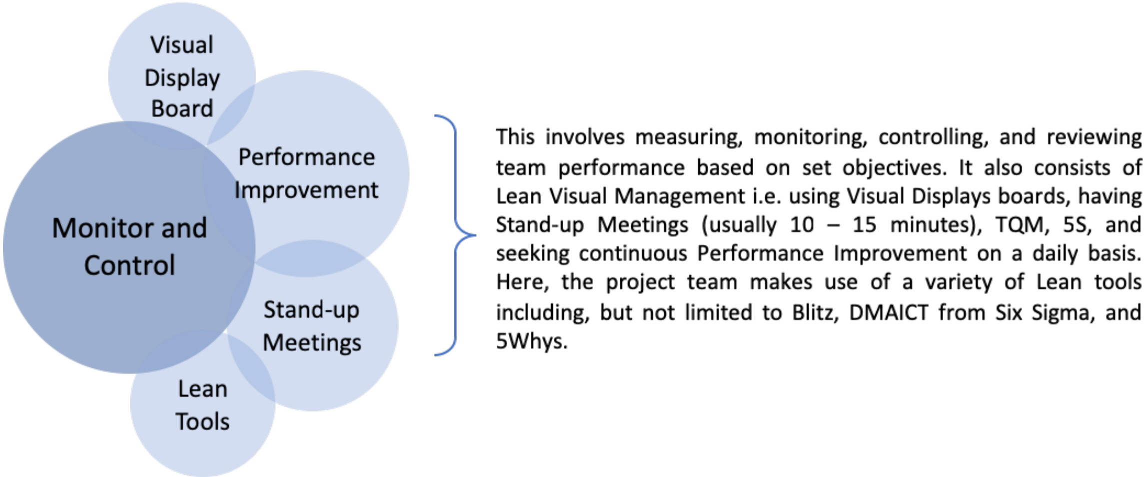


Figure 7.6: Monitoring and Control Stage of The Framework

In terms of performance, the client (government) wants the supply chain to identify some performance measures. This would be appropriate for standardisation since elements can be measured in a more consistent way. According to respondent CDNR14, there are projects that do not use visual boards or conduct stand-up meetings because they do not know what they are or how to use them. This raises an issue about the creation of awareness in the industry and the training of staff in Lean competency, even before a project is awarded. Respondents also raised the issue of using different formats in reporting; for example, one organisation wants reports in a particular format, and the same information has to be rewritten in a different format for another partner organisation. This can lead to time wastage and over-reporting. It is imperative that standard project reporting formats are introduced from the beginning of a project, unless in the exception of multinational companies working together where the problem cannot be avoided.

7.5.6 Evaluation of Performance and Reward

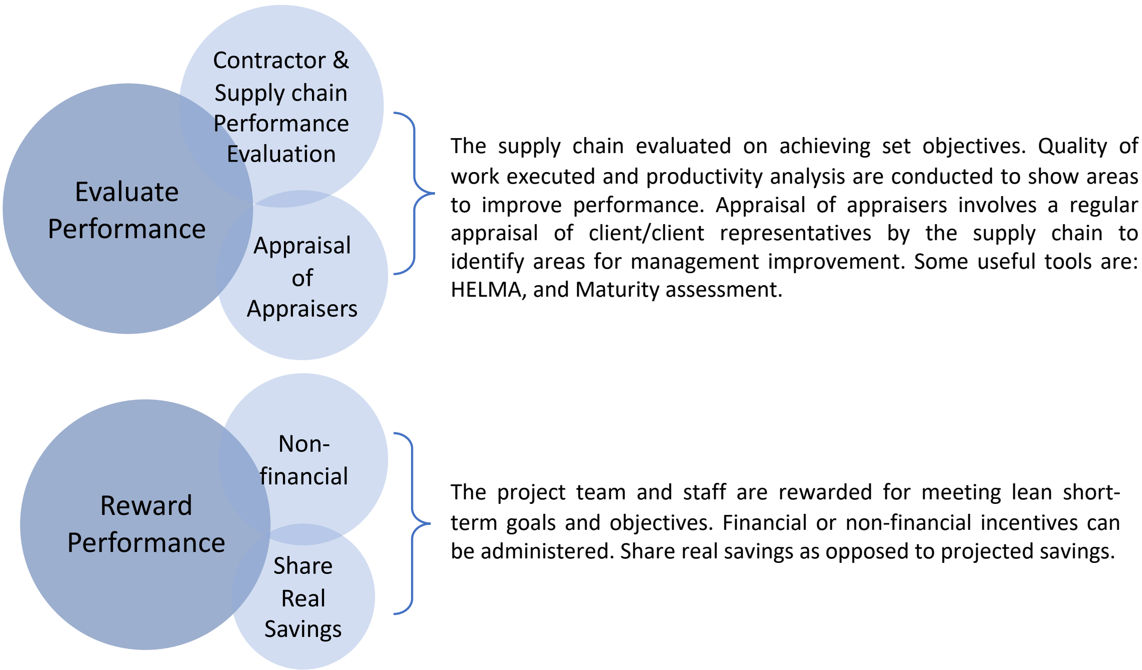


Figure 7.7: Evaluation and Rewarding of Performance Stage of Framework

Respondents were quick to point out the Lean manager has the responsibility of driving performance evaluation. This is due to the tendency of workers to contribute less effort on tasks that are not directly related to production. In the pictorial representation of the framework (Figure 7.7), there is a dotted arrow that represents 'improvements' that links 'Evaluate Performance' with 'Monitoring and Control'. Respondents CDBB26 and CDCT17 confirmed the importance of sending small improvements back to the monitoring and control stage for immediate implementation. These are usually improvements that do not require approval from top management. According to respondent CDBB26:

> Evaluate performance should definitely be a two-way arrow with the dotted line going backwards, because you're evaluating performance, and it will happen at different frequencies, daily, weekly, monthly. If it's daily, it's probably not going to make it back into Collaborative Planning, but it will go into monitoring and control. If it is happening weekly, it will go back into Collaborative Planning; and if it's happening monthly, it will probably go into aligning objectives. Performance evaluation takes place during monitoring and control and also during Collaborative Planning.

CDBB26 is correct as that is what the framework is seeking to represent; the impact of small improvements can be seen immediately, while big improvements require more collaborative deliberations before being approved for implementation. Furthermore, those improvements will follow the big arrows from the Collaborative Planning stage. Similarly, respondent CDCT17 resolved:

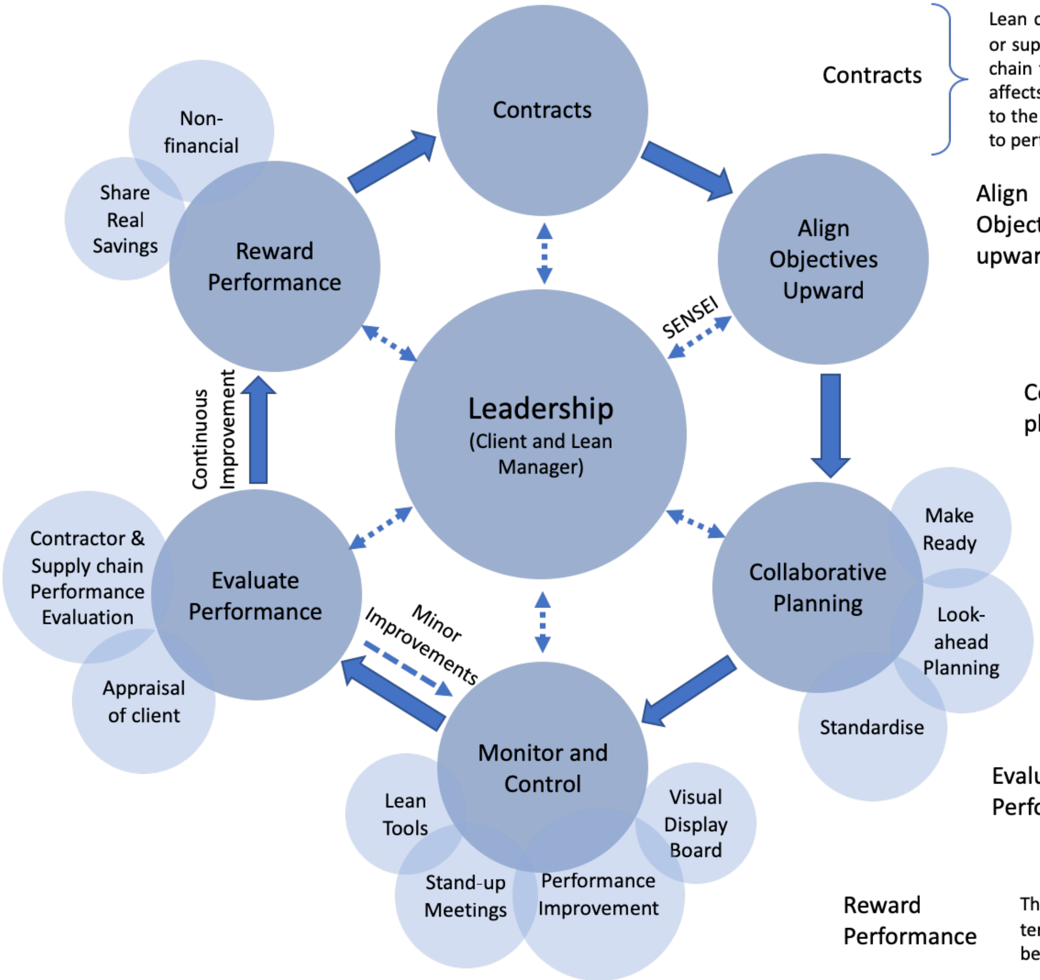
> I like how you sent the improvements back to monitoring and control. That's kind of the PDCA technique. They are one-step improvements like innovation. Kaizen is a small step improvement that happens every day on the project.

Rewarding performance can take two different forms; financial and non-financial. Some companies offer additional leave or holidays to the team that works well on the job. Positive reinforcement helps to motivate people too as such incentivisation drives behaviour. Respondent CDCT17 stated, "Rewarding performance is brilliant. I think you can only do that successfully if you've done your 'aligning objectives' properly."

In order to effectively reward performance, the key performance indicators (KPIs) based on project objectives have to be written in the terms and conditions of the contract which allows for the equitable sharing of rewards. The current NEC 3 and 4 contract forms are increasingly adopted within infrastructure construction because they are a more collaborative form of contract. However, this is not the full risk/reward sharing that the study recommends when aligning objectives; therefore, this needs to change. Furthermore, good HELMA scores need to be celebrated and rewarded. According to respondent, CDCT17, at the moment there is no reward for a positive scoring on a HELMA assessment. The purpose of the HELMA assessment is to measure the Lean maturity of the supply chain. Rewarding impressive HELMA scores serves as positive reinforcement of good behaviour and will drive Lean leadership, motivation, commitment, and participation in the Lean implementation process.

7.6 Final Framework Incorporating Modifications

The majority of respondents affirmed the framework, but also pointed out areas of improvement; thus, leadership from the people was the main addition to the framework. A comment by CDHE01 was significant, stating that the framework needed to make the voice of the client explicit. From the perspective of this study, the quality of leadership exhibited by the people in the process drives and hears the voice of the client. If the leadership is ineffective, the Lean objectives of the client will not be achieved; conversely, if the Lean leadership is effective, then the Lean objectives of the client are achieved. Through leadership, the voice of the client can be heard at all stages. Hence, leadership needs to be at the centre of the framework, and the final version can be seen in Figure 7.8.



Contracts

Lean contracts must be a symbiosis – beneficial to both client and contractor and or supply chain. The supply chain must not feel marginalised. Squeezing the supply chain too much reduces their motivation for collaboration, and innovation, which affects the project negatively. Align the interests of the contractor and supply chain to the interests of the client. Allow the supply chain to establish the reward related to performance, which can be negotiated with the client.

Align Objectives upward

The contractor and supply chain are given the autonomy to create their own project objectives that contributes to achieving client's objectives. Both client and contractor/supply chain objectives must be aligned. No objective will have significant incentive power if they are forced choices unrelated to the supply chain's underlying personal aspirations.

Collaborative planning

All members (contractor and subcontractors) discuss and agree on deadlines/target dates and phase schedule. Members of different companies to work together to create short-medium term plan and agree a sequence of work, set milestones, identify and understand the enablers and eliminate constraints to ensure success. Each individual team member commit to tasks and are measured on successful reliable task completion (PDCA) – incorporate Agile Management

Monitor and Control

This involves measuring, monitoring, controlling, and reviewing team performance based on set objectives. It also consists of Lean Visual Management i.e. using Visual Displays Boards, having Stand-up Meetings (usually 10 – 15 minutes), TQM, 5S, and seeking continuous Performance Improvement on a daily basis. Here, the project team makes use of a variety of Lean tools including, but not limited to Blitz, DMAICT from Six Sigma, and 5Whys.

Evaluate Performance

The supply chain evaluated on achieving set objectives. Quality of work executed and productivity analysis are conducted to show areas to improve performance. Appraisal of appraisers involves a regular appraisal of client/client representatives by the supply chain to identify areas for management improvement. Some useful tools are: HELMA, and Maturity assessment.

Reward Performance

The project team and staff are rewarded for meeting lean short-term goals and objectives. Financial or non-financial incentives can be administered. Share real savings as opposed to projected savings.

Figure 7.8: Lean Implementation Framework in Infrastructure Construction

7.7 The Lean Framework Simplified

Table 7.5 gives the simple steps that summarises the framework developed throughout this study.

Table 7.5: Infrastructure Lean Framework Simplified

STEPS	ACTIONS
STEP 1	– Work place organisation. Get control of the work place. Apply 5S to the work area (everything in its place, a place for everything).
STEP 2	– Ensure you and your team are clear on your objectives. Find out what the customer wants and be clear on the nature of the client and the project objectives.
STEP 3	– Be clear on your purpose and align, not only your objectives around delivering that purpose, but also your processes.
STEP 4	– Collaboratively plan how to achieve that purpose and start delivering the project
STEP 5	– Measure your performance through the customer's eyes; monitor and control the project to meet the client's objectives.
STEP 6	– Display the results of the measured performance in the team area (visual display board) and discuss how to improve performance with the team.
STEP 7	– Conduct an analysis of the outcomes and develop solutions for continuous improvement
STEP 8	– Reward performance and good Lean behaviour
STEP 9	– Redo steps and that leads to continuous improvement.

7.8 Summary

This chapter discusses the proposed Lean implementation framework that was presented to the research sample. 'Member checking' was the chosen validation strategy, and interviews were held with top management experts who were highly experienced and knowledgeable in Lean construction and currently serving as Lean practitioners and leaders within their companies. The interviews confirmed the validity and reliability of the research findings.

There was a general overall acceptance of the framework amongst respondents, and the majority affirmed that, fundamentally, the framework is correct and appropriate. They also gave additional information regarding the stages of the framework and pointed out areas of improvement, which have been revised. The major areas of discussion during the validation were: Lean leadership, existing contracts, and aligning the objectives upwards. Collaborative Planning, monitoring and control, evaluating performance, and reward performance were also discussed but, to a greater degree, many respondents believed that, with the right leadership and the right contract (which is based on the aligned objectives and comprises a win-win for the client, contractor, and supply chain), all other stages will be easier to follow and execute. In summary, there were changes to the framework, but the overall themes and structure of the framework remained the same.

8 CHAPTER EIGHT| CONCLUSION AND RECOMMENDATIONS

8.1 Conclusion

In conclusion, the main finding of this research is that the nature of contracts determines the level of motivation and commitment given to any Lean initiative. Having the right contract that is equitable to all parties provides the maximum incentive for the contractor and supply chain efficiency in infrastructure construction. Leadership and aligning objectives upwards, collaborative planning and working, monitoring and control, evaluating performance, and rewarding good performance are other chief findings identified as necessary for achieving success in Lean implementation on infrastructure projects.

This thesis set out to develop a Lean implementation framework that drives the right kind of motivation and commitment to achieve Lean goals on infrastructure projects. A thorough literature review of Lean principles and construction revealed that the current, available Lean implementation frameworks in the industry have failed to drive and sustain the commitment needed to achieve Lean efficiencies on infrastructure projects. It was found that certain barriers and challenges exist in the construction industry that prevents the adoption of Lean. Similarly, Aziz et al. (2016) showed that there was a lack of motivation and commitment to the Lean implementation process amongst HE's supply chain. Hence, a qualitative research method was conducted amongst infrastructure companies, using open-ended question interviews as the chosen instrument for the data collection. This aimed to ascertain, both the barriers and challenges impeding the adoption of Lean construction, and Lean implementation best practice in the industry.

The respondents were chosen through the use of a purposive sampling technique; this helped to select members with sufficient knowledge and expertise in the area of study. The data collected were coded using content analysis, and a number of themes were revealed. The themes were then categorised under: The Lean philosophy of infrastructure companies, barriers to Lean adoption in the infrastructure sector, the benefits, drivers, and challenges of Lean in infrastructure construction, and the Lean tools currently employed in infrastructure construction today. The study revealed that many of the respondents were highly knowledgeable in Lean and had a common philosophy, which was: (1) everything can be improved, (2) there is waste everywhere, and (3) people are not the problem, but rather the process. It was found that the respondents were mature in their 'Lean thinking' and approached problems positively through leadership and attitude. They understood Lean as not only eliminating waste in the production process, but also helping to develop creative, smarter, and sustainable solutions, of which Koskela (2000), and Hines et al. (2004) were proponents. Given that Lean leadership is of great importance to the successful implementation and achievement of Lean efficiencies, respondents from both client and contractor organisations convincingly displayed an excellent knowledge of Lean leadership and continuous improvement capabilities as they are constantly trying to engage their people to become even better problem solvers to deliver targeted improvements. However, there was a lack of top management that impeded successful implementation and adoption in the industry. This requires a culture shift in the industry where top management recognises the importance of Lean and that the benefit outweighs the cost.

The study revealed that the main barriers to Lean adoption in infrastructure construction are: conflict of interests, competing improvement models with the supply chain, that construction is not manufacturing, contracts, a lack of forward thinking from the supply chain, the cost of implementation, language barriers, project members' limited knowledge of Lean, resistance to change, unwanted pressure due to transparency, lack of top management commitment, and the lack of knowledge transfer. The study found that clients put emphasis on barriers, such as: resistance to change, a lack of forward thinking, and the difference between construction and manufacturing; while contractors emphasised barriers, such as: problems with the way contracts are designed, the cost of implementation, and resistance to change. Consultants, on the other hand, were particular about the industry's resistance to change, the cost of implementation, and project members' limited knowledge of Lean.

The study revealed that the main reason for the resistance to Lean in infrastructure construction is the associated conflict of interest. Unless the contracts are designed to eliminate conflict of interest, the potential efficiency of Lean could never be realised in infrastructure construction. Lean thinking encourages the contractor to find efficient ways of finishing the project in half the time and at half the cost. A conflict of interest arises for contractors when finishing the job early, which leads to either a percentage cut in fees, a cut in future budget, or reduced hours on future jobs. Therefore, there is no incentive for the contractor to be efficient. The annual tightening of contracts dis-incentivises contractors from fully committing to the process. Therefore, to encourage positive behaviour, and drive motivation and commitment in the Lean process, it is imperative that the contractor's interests are aligned with those of the client's, and further reinforced through incentives and the reward of positive Lean behaviour. Hearn (2017) asserts that, when contractors can see that their interests are secured, they are more engaged and motivated to meet the goal of the client.

Furthermore, the study revealed that the general area of concern for all respondents was the current nature of contracts in infrastructure construction. This entailed; fees (pay per hour/shift/crew), continuity and job security, the pain and gain mechanisms of the contract, and incentives and rewards. There was a clear divide in opinion between clients, contractors and consultants with regards to the contract. Some clients believe that contractors use the contract as an excuse to cover-up inefficiencies. Other clients, along with consultants, acknowledge that there is a problem with the contract and the margins that contractors receive, but believe that contractors could also improve their margins by being more efficient. On the other hand, the contractors assert that the contracts deal unfavourable terms with little to no margins, inequitable terms where the contractor bears more of the pain while the client enjoys more of the gains, little to no incentives and rewards, and the pressure of driving efficiencies that benefits only the client organisation. There is also the issue of low morale, motivation and commitment due to the lack of continuity and job security.

The findings showed that clients also have problems with the contracts because of unreliable contractors who promise and do not deliver. Clients represent the public and are accountable for their spending. They also promise efficiencies and, consequently, are under pressure to deliver these targets; moreover, having inefficient and uncooperative contractors can be frustrating. It was also revealed that the client has to drive Lean through the contract mechanism. In infrastructure, the government is the main client, and therefore has the power to push for efficiencies by adding Lean competency requirements into contracts. For example, Highways England has instructed its supply chain to demonstrate Lean efficiency in their processes if they want to continue working for HE. However, it is imperative that the smart client designs the terms of the contract to match the desired output requirement.

The lump sum contract was shown to provide better incentives for contractor efficiency than the cost re-reimbursable contract. It was shown that the way contracts are compiled, does not give Tier 2 and Tier 3 contractors the opportunity to improve performance because the contract is labour based. The industry still awards contracts based on NEC 3 options C, D, and E, although these options are based on actual or target costs, which undermines the incentive mechanisms. On the other hand, options A and B of the NEC 3 contracts are classified as lump sum and provide a framework for performance improvement because they incentivise contractors to work more efficiently. This means eliminating or reducing waste, improving quality, reducing time, and increasing savings, thereby returning more profit. However, a cost-reimbursable, actual cost or target cost contract would be preferred when dealing with design contracts. In essence, NEC 3 options C, D, and E may not be the best contracts to drive performance improvements in construction, but they are appropriate for design contracts.

The findings also showed that there are a plethora of tools and techniques to facilitate Lean implementation. However, the majority of respondents emphasised 'Collaborative Planning' as the most useful technique for the implementation of Lean thinking in infrastructure construction, as it facilitates the implementation of other Lean tools. In other words, it is the framework upon which Lean construction principles and efficiencies are actualised. Collaborative Planning and programming are pivotal to the delivery of Lean efficiency as it involves all the people necessary for success from the very beginning of the project. Early contract involvement is important to the success of the project. Collaborative Planning must include Tier 3 contractors since the majority of the spend is in Tier 3, as they do most of the work on site.

The best practice for the implementation of Lean in infrastructure construction starts with leadership and was found to incorporate: the leader's ability to make Lean simple for their employees; the removal of fear in stand-up and Collaborative Planning meetings; the training and development of employees to increase their Lean competence; the assurance that Lean complements existing good practice; the capture of knowledge for future dissemination; the creation of Lean awareness; the driving of commitment and motivation, and the management of expectations amongst the client, staff and supply chain. This leadership strategy requires: self-education, the education of others, the driving of continuous improvement, and vision.

The study revealed that the problem in infrastructure construction today is not the absence of Lean implementation frameworks but the absence of one that ensures people give their full commitment and remain motivated throughout the process. The study's proposed framework achieves this goal. It starts with leadership, which is placed at the centre and ensures that the voice of the client is heard at every stage of the framework. 'Contracts' denotes the beginning of the project, where the Lean leader, client, and the contractor agree on the terms and conditions of contract. Lean contracts must be equitable and fair to all parties in order to drive the kind of motivation and commitment necessary to achieve optimum efficiency. The next stage is the alignment of objectives, which means harmonising the interests of the contractor and supply chain to those of the client; without this, no objective will function as a sufficient incentive if they are forced choices and unrelated to the supply chain's underlying personal aspirations. The next stage is Collaborative Planning, which allows the integrated project team (including the client, contractor, designers, M&E engineers, facilities manager, and sub-contractors) to work together, using several Lean tools, to improve productivity, reduce time and cost, and ultimately improve the reliability of project completion. Monitoring and control involve measuring, monitoring, controlling, and reviewing team performances based on set objectives. Lastly, performance evaluation and reward look back at the master schedule or baseline schedule on a monthly basis to 'check' progress, evaluate individual and group performances, and then reward people and/or teams for their achievement of milestones. The contractor and supply chain should also be rewarded (financial or otherwise) with the incentives agreed upon in the contract documents to reinforce trust and future cooperation.

8.2 Contribution to Knowledge

The study will contribute to the body of knowledge, both academic and practical, in the area of Lean implementation in infrastructure construction in the UK. Numerous researchers proposing Lean implementation frameworks (Al-Aomar, 2012; AlManei et al., 2017; Ballard & Howell, 2003; Kasiramkumar & Indhu, 2016), do not ensure commitment or drive the motivation of the stakeholders involved (client, contractor, subcontractors, suppliers, and employees). This research seeks to better understand the drivers and/or barriers that are responsible for the lack of commitment to invest in Lean in infrastructure construction. Based on the absence of frameworks in literature that drive the motivation and commitment to implement Lean in infrastructure construction, there is a need to develop a framework with the potential to remove the barriers and attract more buy-in from management and the supply chain so that the promised benefits of Lean implementation in infrastructure construction can be realised. The framework will allow for every project member's desires and aspirations to be addressed at an early stage, so there is complete motivation, focus, and commitment to effective and efficient processes from the inception to the completion of the project, where the culture of continuous improvement and collaboration becomes an innate trait. The findings of the research study will ensure that, not only is Lean implementation easier on infrastructure projects, but also that all project participants (client, contractor, the supply chain, employees etc.) are fully committed and motivated to the realisation of Lean benefits. Furthermore, the framework will facilitate the uptake of Lean amongst the supply chain and seek to improve the project performance by incorporating the current most effective Lean tools and techniques in the construction practices. The research will also make recommendations on best implementation practices that enable integration between client organisations and the supply chain and enable the application of sustainable Lean tools that increase the productivity and performance of the project team in infrastructure construction.

8.3 Recommendations

- **The Contract has to be Mutually Beneficial to All Parties:** The problem with the current contracts is that every year, contract rates drop. Contractors see their rates dropped by 5% every year to deliver the same level of work. Furthermore, the client expects greater efficiency from the contractor and supply chain. The contract has to be beneficial for both the client and the contractor. It is counter-productive to squeeze a supplier to the point that they leave and refuse future jobs because they are not making enough profit.

- **Lean Requirements Should be Written into the Contracts:** Highways England, for example, has incorporated Lean into their contracts. They expect their supply chain to show Lean competency and to participate in their development through Lean training programmes.

- **Clarity in Contracts on Performance Incentives:** Some contractors have pointed out that industry contracts on incentives and reward are grey and open to interpretation. Contractors and the supply chain have stated that, while HE has Clauses Z22 and Z54 in the contract, the client's interpretations of the Clauses are totally different from those of the contractors. Hence there needs to be clarity on the incentives and rewards in the contract.

- **Equitable Pain and Gain share:** At the contract level, the pain-gain arrangement can be heavily biased towards the client. However, this is changing as Highways England's Collaborative Delivery Framework Contract has an arrangement called Programme Level Incentive Fund, and Package Contract Performance Fund, under Clause Z22, and Clause Z54 – Z59. These state that, if a contractor can demonstrate a level of savings, then the savings will be shared 50-50 between the client and the contractor/consultant. It is therefore important for clarity to specify the sharing of real rather than projected savings.

- **NEC 3 Options A and B Contracts to be Used More:** These options give contractors the incentive to improve their performance. In contrast, NEC 3 options C, D, and E, which are based on actual costs, reduce the contractor's incentive for efficiency savings, as that leads to reduced hours and pay.

- **Encourage back-to-back Contracts:** This means the contracts agreed with the client are the same as those used with subcontractors. Therefore, the terms and conditions are the same, and the objectives remain the same for everybody.

- **Length of Contract, Continuity, and Job security:** Job security for contractors and the supply chain is paramount in the construction industry. Sustaining the morale of the people on a project is crucial because it allows the contractors and supply chain to invest in the Lean adoption process in the longer term. Moreover, it drives motivation, innovation and commitment to make efficiency savings. The findings showed that half of the problems faced on infrastructure projects could be reduced by 80% if the lengths of the contract are increased to 10, 15, or 20 years, for example. The problems stem from the length of the contract because efficiencies emerge over time rather than immediately. It recommended that the infrastructure sector learn from manufacturing, where suppliers are awarded long-term rolling contracts, which permits them to invest in resources and facilitates a team/family spirit that promotes unprecedented innovation and collaboration; however, short-term, five-year contracts cannot attain this.

- **Standardisation:** Standardise processes where job durations are set on future jobs, so that efficiencies that lead to an early finish do not lead to a reduced job duration on the next job. Furthermore, the pay of certain standardised jobs does not change with efficiencies unless such efficiencies are of such magnitude that they cannot be justified.

- **Good HELMA Scores Need to Be Celebrated and Rewarded:** Currently, there is no reward for a positive score on a HELMA assessment. The purpose of the HELMA assessment is to measure the Lean maturity of the supply chain. Rewarding impressive HELMA scores serves as positive reinforcement of good behaviour and can drive Lean leadership, motivation, commitment, and the participation of people within the implementation process. Performance evaluation should include lessons learnt and the sharing of best practice across the industry. However, there is a reluctance to share best practice with other contractors in the industry due to competition. This makes it difficult for Lean best practice to be pervade the industry. This change, however, has to come from the client where they share best practice with the contractor with whom they are working.

- **Clients Should Provide Training Support with Lean Improvement Strategies:** The client should not be quick to dismiss a supplier failing to meet their Lean efficiency targets; instead, the client should work with the supplier to improve product quality, processes, and culture to support the supplier to meet the standard required.

8.4 Limitations of the study

The research was limited in the sense that it could not reach everyone that was invited to participate in the study; as such, their knowledge and contributions is lost. Furthermore, limited time was a limitation as the research expected to follow a strict timeline and the data collection had to be completed and analysed within that stipulated time.

8.5 Further study

Further areas of study for this research should focus on motivation factors in the infrastructure industry. Such research questions could include: (1) what are the sources and solutions for the fear of job security that the supply chain exhibits on projects; and (2) what are the motivation factors that can be used to increase and maintain morale on projects in infrastructure industry? These questions could also explore, for example, the motivations of the supply chain, regardless of whether they have their next jobs. Finally, the impact of the 'Length of Contract, Continuity, and Job security' on a project, could also be measured, particularly towards the end of the project when the project is 70-80% finished.

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10 APPENDICES

10.1 Appendix 1

NEC3 Main Options

Option A: Lump Sum priced contract with activity schedule

The Contractor offers to provide the works described in the contract for a sum of money. The contract provides for certain risks to be carried by the Employer which will result in the lump sum being adjusted if the compensation events occur.

The activity schedule is normally written by the Contractor since he is the one who knows what activities will be carried out. Each activity is priced as a lump sum by the Contractor which is the amount paid when he has completed the activity. In pricing an activity, the Contractor takes responsibility for estimating quantities and resources, and assessing and pricing risks that are his.

Option B: Remeasurement priced contract with bill of quantities

The Employer provides a bill of quantities which is priced by the Contractor. The contract price is the sum of prices for all items in the bill which may include lump sums for certain items. When the work is done, if it is found by remeasurement that the estimated quantity is not correct, it is corrected, and payment is made to the Contractor to reflect the actual work carried out. Under this option, unlike Option A, the Employer takes the risk of the correctness of the quantities.

Option B would normally be used where the risk of change in quantities is relatively high. It is not appropriate for design and build contracts since the Contractor is responsible who designs and prepares the detailed design and plans.

Option C: Target Cost contract with activity schedule

In this option the Contractor tenders (or negotiates) a target price using an activity schedule. Each activity is priced as a lump sum and a Fee is also tendered as a percentage for subcontract work and for the Contractor’s own direct work. The initial target price is the sum of the activity prices and the fee. During the course of the contract, the target price is adjusted to cater for compensation events that are set out in the contract.

Payment is made on the basis of actual costs with an incentive mechanism for the Contractor to minimise costs. Savings and over-runs are shared between the parties. The sharing of risk in the target cost approach is likely to reduce the occurrence of disputes.

Option D: Target Cost contract with bill of quantities

This is similar to Option C except that the target price is established by means of a bill of quantities rather than an activity schedule. During the course of the contract, the target price is adjusted to allow for changes of quantities as well as for compensation events. Thus, the Employer carries a rather greater risk than is the case with Option C.

Option E: Cost Reimbursable contract

Under this option the Contractor takes a very small risk since he is paid his actual cost plus the Fee with only a small number of constraints to protect the Employer from inefficient working or incompetence by the Contractor. It is used when the work to be carried out cannot be defined at the outset and the risks are high. It may also be used for emergency work.

Option F: Management Contract

This option is suitable for management contracts in which all or most of the work is done by subcontractors, and the Contractor manages the procurement and the work undertaken by the sub-contractors. Payment is made to the Contractor for the cost of the sub-contracts plus a management fee. The Employer carries most of the risk.

10.2 Appendix 2

SEMI STRUCTURED INTERVIEW QUESTIONS

BACKGROUND INFORMATION

Section A: General Information

1. Which title best describes your position in your organisation?
2. How long have you worked with lean thinking in the UK construction industry?
3. How long have you worked in your current organisation?

Section B

Research Objectives	Questions
To analyse current best practice in the UK construction industry.	a. What is the best-practice implementation framework for lean thinking principles for your organisation in the UK context?
To evaluate and synthesise a range of lean implementation frameworks that can be applied to processes of the UK infrastructure construction industry.	a. What methods are currently employed by you for the implementation of lean thinking? b. Why are these practices applied by you to UK construction projects?
To evaluate the barriers and challenges, benefits and drivers, and current industry best practice for lean implementing in the UK infrastructure construction industry.	a. What are the obstacles affecting the application of lean thinking practices in your organisation? b. How do these barriers affect the lean thinking implementation in the UK construction industry? c. Why do these barriers affect the lean thinking implementation in the UK construction industry? d. What are the drivers influencing the application of lean thinking practices in the UK construction industry? e. How do these drivers influence the lean thinking implementation in your company in the UK construction industry? f. Why do these drivers influence the lean thinking implementation of your company in the UK construction industry?

	g. What are the current LT implementation practices for the UK infrastructure construction industry?
To develop a framework for the implementation of lean in the infrastructure construction industry.	a. What are the current and potential benefits of the lean thinking implementation for your organisation? b. Do you deploy Lean from inception to completion of the projects? c. How do you start deploying Lean within your organisation, how do you convince people? d. What is the profit, savings you have made by deploying lean?
To validate the framework.	a. Does this framework represent best strategy for lean implementation on infrastructure projects?

10.3 Appendix 3

PARTICIPANT CONSENT FORM

Title of Project: The Evaluation of Lean Thinking Implementation Factors in the UK Construction Industry

Name of Researcher:
Contact of Researcher: School of the Built Environment
The University of Salford
Manchester
M5 4WT

Statements	Please tick where appropriate		
I have read and understood the participant information sheet for the above research and my participation in the research	No	Yes	N/A
I have been given the opportunity to ask relevant questions about the research			
I agree to take part in the research interview			
I understand that taking part in the research interview include tape recording which I agree to			
I understand that information provided by me during the interview will only be kept for the period of this research			
I understand that information provided by me during the interview will be confidential and will not be disclosed to people outside this research			
I understand that my participation in this research is voluntary, I can withdraw from this research at any time and I do not have to give any reason(s), for why I no longer want to take part in this research and any information I have provided shall accordingly be destroyed immediately			
I hereby agree to take part in this research			

Name of Participant:……………Date……………Signature:…………………………

Name of Researcher:……………Date……………Signature:……………………….

<u>Research Supervisor</u>
School of the Built Environment
The University of Salford
Manchester
M5 4WT

10.4 Appendix 4

PARTICIPANT INFORMATION SHEET

Dear Participant,

I am a PhD researcher at the University of Salford, Greater Manchester, UK, in the field of Construction Management. I would like to invite you to participate in this research.

The target of this research is to take your opinion on lean thinking implementation factors in the UK construction industry.

I would like to invite you to participate in the data collection of a face to face interview. It would last approximately sixty minutes.

If you decide to participate in this research there are no known risks for you, nor are there are any costs for taking part.

Please be assured that your anonymity is guaranteed, and no identifying data is stored on file at the completion of the study. Email addresses and identities are optional and are gathered so that you can be contacted and at the completion of the research, the information will not be identified, that is any identifying data will be permanently erased. The information will be kept digitally with a protected password, and any hard copy will be stored in a locked storage cabinet in my office.

Participation in this research is entirely discretionary and you may withdraw your participation at any stage of the research. If you decide to withdraw your data will be immediately deleted.

10.5 Appendix 5

Sample Transcription of Interviews

Section 1

Q1: Which title best describes your position in your organisation?

X: My official title is Operations Manager. What that mean to me is I am a lean practitioner full time on a road construction project and I manage the implementation and drivers, lean continuous improvement and innovation initiatives.

Q2: How long have you worked with the lean thinking in the UK construction industry?

ST: I have been employed by xxxxx on a temporary basis for around 3 months and I have been employed 12 months full time. I have only worked with xxxxx in Lean and I have been doing that for around 18 months.

Q3: How long have you worked in your current organisation?

X: 18 months.

Section 2

Q1: What is the best practice implementation framework for LT for your organisation in the UK context?

X: We have two main approaches, we have a bottom up approach based on educating people in Lean and Lean Thinking and how they can apply to their daily work. And we also have a top down approach which is having lean champions, having lean steering groups, leading and driving lean within their elements of the business. You need both. I think you need that investment from individuals' sort of a ground level. So, you also need it to be driven from higher up as well, it has to come right from the leader of organisation downwards.

Q2: What methods are currently employed by you for the implementation of Lean Thinking?

X: We have a fix main method used. The dominant ones are Collaborative Planning. Collaborative Planning is a method we use for developing and refining short term plans so 6 weeks normally plans for construction projects. What it uses a large visual management tool which is a gridded square it goes along walls and posted notes to pick the activities and day cards. And how we run those meetings is we get everybody who would be involved in those works into the room and the meetings are facilitated by myself or another lean practitioner and we work through the processes developing a plan in the coming weeks, so we have a 4- step procedure that we follow every meeting. What that is discussing last week activities assigning reason codes any incomplete activities and things like that, discussing why things did not get done and what did not get done. Secondly, we run through our plans for the next week so that you're immediately becoming in detail. And then we discuss any future key dates that is coming up in the next 6 weeks and then we plan backwards from then to develop a plan to make sure that we do hit those deadlines. And then finally we discuss concerns, blockers and opportunities. So, anything that has come up in the meeting that we think we can do to improve productivity or something that might be a risk that is coming up and how we can address that. So, in the meeting it is quite important that we have everyone involved. So, on my project we have 3 meetings, 3 collaborative planning meetings a week with the 3 different work sections. So, we have North section, who manage a third of the job, the Central section who manage the middle third of the job and South section who manage the final third of the job. And within those meetings we have everybody from the sectional head right down to the floor-men in the room. That includes the engineers, senior engineers and any subcontractors working in the area we make sure we get those in especially things like blacktop and signs, comms, and things like that. Also works managers per section. Another tool we use is workplace organisation, 6S. So, we follow the standard 6S procedure, sort standardize, sustain…approach. So, in addition to the 5S, the 6th S is safety. So, within every step of the procedure we consider the safety implications in what we are doing and how we can maximize safety. There is something that obviously xxxx being very safety driven and us being a very safety driven project on xxxx. It is very important that we do consider that safety element of everything. So, 6S projects that I've run are on the site storage yards. So, our storage warehouse we ran a 6S project and our site storage yards, both the one, we have two, one at one end of the job and one at the other. So, we've run two 6S projects, one in one end of the project, and one the other. Just to refine our storage yards and implement visual management systems and make sure we sustain any improvements we are going to make. Another lean tool is running lean projects. It is one the main elements of my job are leading lean projects. So, getting a small team together to look at how we can develop and refine their current working practices in order to improve efficiency. And to do that we follow the DMAIC process so that recognise Define, Measure, Analyse, Improve and Transfer. That has worked very well on the project so far, we have got a number of successful projects. How we deploy DMAIC is, we have a facilitator who is leading it which would be me on my project. And they facilitate the process of an improvement project and then the people who actually carry out the improvement project, there are other people who work on these activities. So, say we are looking at concrete step barriers, we would take the team in our side who produce concrete step barriers and I would work them processes improving as a lean improvement project, maybe they develop their own improvements to develop the way they work. Lean Visual Management is also very important on the project using visual management boards, using posters, using presentations anything like that we can use to improve understanding to increase leadership by having a stimulant there to talk around. So, we have that implemented quite widely across the project. We have used process mapping depending on what our lean project calls for, then we will use relevant tools. I can't think of any more that we implement very widely. We deploy our lean training as well is very important. We try to get everyone to go through lean training which is a 2-hour interactive workshop that we have developed where we teach them the principles of lean. And then we also take it through the procedure of improving a production process. So we have some things called Stickle bricks, which are sort of like Lego, and we begin with a broke process and that does not produce very good quality things very fast and then we run a lean project on it doing the space of the workshop and we improve it and then we discuss how we can transfer those skills and that knowledge into our everyday work. So, everyone can make their own little improvements. We use Last Planner System; our last planner system is integrated into our collaborative planning. So, at the beginning of every meeting we discuss what has got done, why did not they get done, and things like that and we create all relevant charts and data management, things from that information. As far as value stream mapping and things like that it depends on, we will use within lean projects if it appropriate. It is something that we have been trying to increase the use of recently. But it has not proven to be as useful as we thought it would. We use 6 Sigma approach depending on the lean project. It depends on how deep we need to delve into the current process and things like that. But we always use things like, you grid of defining it, things like that. We use any lean tools that are appropriate for use at the time. But our main is using lean training, using 6S in workplace in organisation, using strong visual management, collaborative planning and into that last planner system. And where appropriate we use Value Stream Mapping and Process Mapping.

Q3: Why are these practices applied by you to UK Construction Projects?

X: Especially things like collaborative planning we have seen real benefit sort of immediately after implementing it. And now that we have had quite a few successful lean projects and things like that, people really understand the benefit of doing it. So, I think it is the efficiency savings being made, and also making people jobs easier, things like that. They will be the two main reasons. I think it is all speak to itself. Once you become involved in and improved the project, you see how much time and effort you saved through it.

Q4: What are the obstacles affecting the implementation of Lean Thinking methods and practices in the UKCI?

X: The main obstacle is that some people view lean as a process purely from manufacturing. And they struggle to see how it applies into construction industry. And as a result of that they do not become engaged to the process, they do not give it a chance. In reality we do have processes we repeat and that we can standardise, we do have set of procedures that we can reduce, we do have workplaces that can be organised, things like that and it is just getting people to realise that it is transferrable, and it is adoptable into the system.

Now that we have developed our own training, the training is so much… In terms of training we have our own training system and the demand on that is quite high. We cannot carry all the training that people want us to do at the moment. So, we trying to up our efforts to provide training across the business, things like that. In terms of change people are very reluctant to change, it is quite an old industry. People are reluctant to innovate and adopt new ideas, new practices. It is just educating people, it is going to be the biggest barrier I think. Once people get to realise, see the benefits, see how it applies in terms of they work, it will become less of an issue.

Fragmentation in the industry, within the industry it is very hard to share best practice. xxxx`s forum for sharing and improving ideas, working together things like that is not as good as it could be. I think that is a slight barrier. It is very difficult to get together and work together and develop a new way of working, things like that when you are competing with people.

I think it is all covered in people`s attitudes or approaches towards it. I think it is an issue of educating people.

Q5: How do these barriers affect the implementation of Lean Thinking in the UKCI?
X: If you have any individual within a group that does not want to engage in an improvement process or something like that then they become a bit of a terrorist towards it and they can really affect how projects work and how collaborative planning work.

Q6: Why do these barriers affect the implementation of Lean Thinking in the UKCI?
X: When we first implemented Collaborative Planning there was 2 individuals in particular that did not see the benefit and did not want to be engaged in the process because they did not feel like they gained any benefit out of it, they felt like they were educating others in what the plans should be and things like that. And I explained to these individuals why it was important that we worked together, things like that. It was a struggle at the beginning but both of them have really come around to it now and they are quite engaged in the process. We've had similar people with lean improvement projects, as people not wanting to become engaged in improving the way they work. They thought that we were just there to tell them to how they do their jobs and things like that. And after explaining to them that we are actually there to try help them deliver new ways of working and help them make their jobs easier, things like that then they tend to come along.

I think if people are refusing to adopt something then they all see it effects how well it is implemented. If people are straight up refusing to entertain the idea of changing the way, they work then it is obviously very difficult to change the way they work.

Q7: Is senior management buy in a barrier?
X: We have a good senior management buy in throughout the company really. It is more…we don't have much resistance across really. So, we have a really good senior management buy in. And we have in general very good buy in from the workforce and managers and supervisors and subcontractors as well. It is just the occasional individual that affect something. There is an occasional resistance to change from especially the individuals who people like supervisors and stuff like that that would be helping to implement an improvement.

Q8: What are the drivers influencing application of lean thinking practices in the UKCI?
X: The biggest driver is the improvement you see, the tangible benefits of reducing time wasted, reducing set up times, improving safety and also the cost benefits as well. And from that you become better, more profitable. And also, because xxxx has such a strong drive for making a continuous improvement and things like that, it also helps us in bidding work and stuff like that, to prove that we are doing these initiatives and we are seeing benefits. That is the biggest driver from within a company. Another driver I would say is improving collaboration, so working with subcontractors, working with people who work on site, working with the senior management team to develop new ways of working, to innovate and improve. It has been very beneficial for us. So just improving engagement and things like that and proving and showing people that we understand, and we care about how hard the job is and things like that and we want to try help and improve that.

The biggest drivers are profit, time savings, improving general wellbeing of people by making their jobs easier.

Client is the driver, we need to make efficiency savings, they want us to make efficiency savings and we're measuring against those. Obviously the better we do that the better we are looked in the client`s eyes and the more profit we make and the better we are at work winning.
It is a mistake to do lean just because client want it. Because it is a good structured approach towards continuous improvement. And if you want to continuously grow and develop as a company then you need to make these marginal gains. You need to be constantly developing and improving the way you work in order to improve efficiency and make profit. Otherwise you will be out-competed.

Q9: How do these drivers influence the lean thinking implementation in your company in the UKCI?
X: Beginning with the because the client wants it as a driver, I would say that one of the biggest impacts that has had is the transferability and making sure that we share best practice across the industry and things like that. I think if the client did not want us to implement lean and to share best practice and help other schemes and from within HE supply chain, DMAIC efficiency savings then we would be very reluctant to share the improvements we made. But because the client has such a strong drive towards sharing

information and working together within the industry to improve industry practices, I think that has really been a big driver for transferring knowledge and information and new ways of doing things. In terms of examples from our own project, we currently have 15 lean knowledge transfer packs just from xxxx on the HE`s lean tracker. We have done that purely to help other companies and other projects to learn best practice and learn from what we have done and hopefully implement some improvements and develop some efficiency savings across the highways industry.

In terms of improving profit, how it influences is. We constantly looking to make efficiency savings and lean provides a structured approach to that. So how it drives, and influence is by providing a structured approach.

Q10: Why do these drivers influence the lean thinking implementation in your company in the UKCI?
X: And expanding to your why. You do not need to have a strong knowledge of a particular construction process to be able to follow a lean improvement system. So, one example of that from our company would be myself. So, my background is not in construction, it is in psychology but because I am good at facilitating groups, I am good at data management, things like that then I can follow a lean improvement process like facilitate a group through that process and develop efficiencies. In terms of making people`s jobs easier that is another driver we discussed, keeping our workforce happy and healthy quite important within the company. We are making sure that we improve the way people work and make their job easier and reduce that stress and frustration that people feel when they are working within a broken process. So, an example of that from our own projects would be the use of BIM and things like that to improve understanding. Then all visual management tools and things like that then they can really make a process clear and make people understand what they are supposed to do when, why, how, and how we do that safely that is quite important to us.

In terms of making time savings on the project and within the company, it is very similar to profit and the time is money and that the less time we can spend on site it is safer, the less time we can spend working on a process the more profit we have, the faster the job is finished, fast people go home and see their family, things like that. It is quite important to us if we improve that, we shorten the time that we work.

The why is because there is benefit there. So, if we did not see the real benefit in terms of time savings, in terms of cost savings, in terms of our feedback from our client, things like that, that is why we do it, we see those benefits.

Q11: What are the current and potential benefits of lean thinking implementation for your organisation in the UKCI?
X: That is quite an easy one really. I think the immediate benefits are the same you make those time and cost and things like and saving. And the future benefits are, because you standardize the process, you continue to make those benefits, you continue to improve on them. So, it is not only seeing the short term benefit, it is making the long term change in a way you work. If we are doing that I think you develop efficiencies as you go along. And another thing in terms of long term benefits, once you have adopted and accepted lean as beneficial and as a good improvement process within your company of project then you change the mindset of people, they begin to constantly work to improve their own ways of working and to develop their own better ways of doing things, to begin to question their current processes and things like that. So, developing a mindset and a new approach into how we tackle issues is also very beneficial.

All the things we previously covered in terms of time, cost, safety, public representation, representation in front of the client, HE, better workplace organisation, better planning, more reliable planning, less uncertainty in what we are doing, better coordination with subcontractors, better coordination with the client, better coordination with other companies, and other projects because we are constantly working to share best practice with them. I think they are the main current benefits.

In terms of future benefits again, I do not have the figures in front of me, but I think it grows year on year because not only you are making the efficiency savings that you have already implemented, you are then developing further savings, you are improving more things and you are standardizing those approaches. So that you have a new improved system, and you can look at that system and improve that and continuously develop as new technologies can be implemented and things like that. Again, to make more and more efficiency savings.

Q12: What are the current lean thinking implementation practices for the UKCI?

X: I think the biggest one is Collaborative Planning. It was a tool that was developed within the construction industry and because of that it works very well for the construction industry. Visual Management is also very important. Using posters, using graphs, using charts, using technology, using presentations to facilitate leadership to improve understanding, improve safety. I think that is very important across the construction industry. Value Stream Mapping and process mapping as well. Using things like 6S and 5S to improve your storage areas to improve your office environment, to improve your onsite work places, any warehouses and things like that, it is quite important. Even your filing systems, your computer systems. Another would be things like SIPOC, it is considered quite like an old school approach, it can be very useful if you're struggling to understand a standard process in depth, understanding who your supply chain is, who your customers are and things like that for each process has been very beneficial. Last Planner as we discussed before, we have, within xxxx, we work very hard to integrate that into the collaborative planning system. That is a now an everyday practice to use that in our system and design our work around that and use that data to improve the way we approach things in future. We use Fishbone analysis or Cause and Affect things like that. My experience of using a Fishbone analysis has been very…. used beginning of the lean improvement project quite a lot to work with the improvement team to discuss how and what factors could be affecting production and things like that. So that we understand what we need to explore in order to improve efficiencies. So, the process of how we generate them, so we tend to have different headings, such as people, materials, method depending on what the things we are trying to improve depends on the headings used, but, they are the common ones. And then we work with team to come up with headings of things that could affect productivity. We also use the 3C system that is concern, cause and countermeasure. We use that within our collaborative planning system within xxxx so at the end of every meeting we discuss opportunities for what we can do to improve productivity. And we also discuss any concerns that we think will affect productivity. And by using the 3C system we look into why the cause of an issue. And by doing that you develop a better countermeasure. Things like 5 Whys, we use that in the lean improvement projects. I think 5 Whys help you develop the root cause of a problem. So, if you have an issue and you ask why that issue is and you ask why, where root cause that issue has happened and you ask why that has happened. It helps you develop a root cause and understand the root cause of the problem. And therefore, you can develop an improvement that addresses the core issue not just a symptom. We tend to avoid within the construction industry using Japanese terms and things like that so there will be plenty of things that we do we call something else.

Q13: Do you apply Lean from inception to completion of the projects?
X: We try to and that's something we're driving to do more and more. So, I think xxxx has just started a project in xxxx, the xxxx. I think that is the one of the perfect examples of what we are trying to do, our approach. They already have three or four lean people driving lean on the project and the project has not even started construction yet. So that they are working hard to get collaborative planning implemented right from the beginning. They are working hard to get the last planner system implemented. It is part of that they are also working on 3Cs, things like that. They are working to organise their storage areas before, so running 6S on a storage area as you create it rather than trying to improve something that is broken. So, you're correctly using lean from the beginning. As xxxx go forward, we are doing that more and more. Obviously the earlier you implement and improve the process, the more benefit you see. And in terms of running through right till the end of the project on xxxx we have run lean throughout the entire the project then we are currently working on a lean project looking at the handover process and settling the final accounts and things like that. So, we are running lean right from the beginning right up until the very end, right until the official handover of the scheme. And then continuing from that we also take all the lessons learnt from the project. We are taking that transferable information and applying that to future projects.

Q14: How do you start applying Lean?
X: Lean training has been very useful for that. So, taking people into a room for two hours and running through a small and interactive workshop that explains what lean is and how it works and how that can apply that has been quite useful. Getting people engaged in lean improvement projects. So, explaining why we need to do it, how it is to be beneficial, that it's going to improve the way they work and make their job easier. Getting people involved in lean improvement projects so getting them to understand that it is going to improve the way they work and make their jobs easier and things like that. That has also been quite beneficial getting them involved in the process. And showing people what other projects, things like that have done and how the knowledge gained from what other people have done can be transferred into their day job. That has been quite beneficial as well. The main thing is it is just educating people and how it can benefit them as individuals but also

showing them how it benefits the company and driving efficiency savings and things like that. We have good, strong team that is applying from across the company. That turns out that we develop the implementation strategies that is highways wide and that is on individual projects. Every individual project has their lean strategy, how they are going to implement lean across the project and what benefits they plan to gain and things like that what tools they plan to use in order to do that. And as part of that we have time skills as well, so we say that we want to have 75% of people trained within the first two years on a project. In lean training we want to have last planner and collaborative planning implemented across the project as soon as possible things like that. Setting ourselves up to really (24.10min) benefit us in terms of individual projects.

Q15: What is the profit?
X: In terms of companywide I am not sure. I know that currently everyone else on the improvement project has around £3.5million of confirmed savings on their lean tracker but as far as xxxx wide I am not sure. Especially when we have construction, we have buildings and roads and maintenance and things like that and rail as well. So, taking it all in, I have no idea what the figure is.

Q16: Do you think BIM is a lean tool?
X: It can be used as a lean tool. I think it can be used as a visual management system. It can be used as a facilitate planning. In terms of things like that I think it is very useful considering the long-term impacts of a decision you make can be very useful. I would say that it is not officially a lean tool, but I would say there is a number of ways in which you can apply BIM that it can be useful in lean.

Q17: How do you integrate BIM and Lean?
X: It depends on who you are trying to get adopting. People are also very reluctant to accept BIM as a technique. I think it is the same as lean where you have to show them how that is going to benefit them as individuals. I think it is almost useless showing a supervisor all the amazing things we can do when you get to planning out meetings and things like that. Because that is never going to affect their day job. I think showing them how it can be used to schedule works, how it can be used as a 3D map to increase understanding to show subcontractor what works need to be done in an area. I think that is how you get individuals by in. And similarly, if you are talking to someone who works in finance, then they are not

going to care about all these things you can do in terms of using as a 3D map. They are going to care about how you can calculate life time cost savings and things like that. So, it depends on who you are trying to convince basically.