Faculty of Engineering

Department of Architecture

PhD Thesis

A Total Lean Construction Framework

Mohamed Abdussalam Atweijeer
PhD Candidate
Student ID 201956689

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Declaration

PhD Candidate: Mohamed Abdussalam Atweijeer
Signed:
Date:

Abstract

Construction projects are often complex and require robust management strategies to address persistent challenges such as cost overruns, schedule delays, quality shortcomings, and sustainability issues. Despite the availability of various project management frameworks, there remains a critical need for a comprehensive, scalable approach that integrates efficiency with sustainability and stakeholder value across the entire project lifecycle.

This research introduces the novel Total Lean Construction (TLC) Framework, which integrates Lean Construction principles with the Royal Institute of British Architects (RIBA) Plan of Work 2020. The TLC Framework addresses five key objectives: (1) minimising waste, (2) reducing costs, (3) avoiding time overruns, (4) promoting sustainability, and (5) enhancing stakeholder satisfaction through value-adding activities. This dual integration of lean methodologies with a widely adopted architectural project delivery model is the first of its kind and constitutes a significant contribution to the current construction management literature.
Data were collected through a comprehensive literature review, semi-structured interviews with industry professionals, and a case study analysis of the Crossrail project. A combination of inductive and deductive thematic analysis was employed to interpret qualitative data. Findings confirm the TLC Framework's practical relevance in improving time, cost, and sustainability performance while encouraging collaborative working.

By embedding lean strategies into the RIBA Plan of Work 2020 at every stage from strategic definition to post-occupancy the TLC Framework provides a structured, holistic roadmap for enhancing construction project delivery. The study underscores the importance of early stakeholder engagement, continuous improvement, and the elimination of non-value-adding activities. The novelty of this research lies in its practical and theoretical integration of Lean Construction principles into a universally recognised project management structure, offering new insight and practical tools for achieving more sustainable, efficient, and value-driven outcomes.

Keywords: Total Lean Construction (TLC) Framework, Lean Construction, RIBA Plan of Work (PoW) 2020, Project Management, Sustainability, Value-adding Activities.

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Abbreviations

5Cs	Clear Out, Configure, Clean and Check, Conformity, Custom, and Practice
5S	Sort, Straighten, Shine, Standardise, Sustain
ASCE	American Society of Civil Engineers
BIM	Building Information Modelling
BPR	Business process re-engineering
C&D	Construction and Demolition
CBS	Cost Breakdown Structure
CCPM	Critical Chain Project Management
CE	Continuous Engineering
CEBOK	Civil Engineering Body of Knowledge
CIRIA	Construction Industry Research and Information Association
CPM	Critical Path Method
D&B	Design and Build
ERM	Enterprise Risk Management
GDP	Gross Domestic Product
ICE	Institute of Civil Engineers
IGLC	International Group for Lean Construction
IPD	Integrated Project Delivery
JIT	Just-In-Time
LC	Lean construction
LCI	Lean Construction Institute
LPS	Last Planner System
MMC	Modern Methods of Construction
NVA	Non-Value Adding
PERT	Project Assessment Review Technique
PM	Project Management
PMBOK	Project Management Body of Knowledge
PoW	Plan of Work
QC	Quality of Construction
RIBA	Royal Institute of British Architects
RM	Risk Management
TFV	Transformation, Flow, and Value
TLC	Total Lean Construction
TPM	Total Productive Maintenance
TPS	Toyota Production System
VBM	Value-Based Management
VSM	Value Stream Mapping

Glossary

RIBA Stages: According to RIBA (2020), there are eight stages in a building's lifecycle:

- Stage 0: Strategic Definition
- Stage 1: Preparation and Brief
- Stage 2: Concept Design
- Stage 3: Developed Design
- Stage 4: Technical Design
- Stage 5: Construction
- Stage 6: Handover and Closeout
- Stage 7: In Use

In this PhD research, these RIBA stages focus on developing the Total Lean Construction (TLC) Framework.

Total Lean Construction (TLC): As a new concept and approach introduced in this research for the theory and practice of lean construction (LC), TLC refers to the systematic adoption of lean construction strategies and methods across the eight work stages defined by the Royal Institute of British Architects (RIBA, 2020). This concept and approach aim to enhance construction practice by focusing on resource efficiency, quality improvement, and productivity enhancement throughout the entire lifecycle of construction projects.

TLC Framework: This technical framework, developed from this PhD research, facilitates the adoption of LC principles through 8 interconnected RIBA stages in a building's lifecycle.

Lean Project Delivery System (LPDS): A comprehensive approach to project management that focuses on eliminating waste and enhancing value through stakeholder collaboration. It aims to improve project efficiency and outcomes by integrating lean principles throughout the project lifecycle (Ballard & Howell, 2003).

Value-based management (VBM) is a strategic approach that aligns business operations and decisions to maximise shareholder value. VBM focuses on economic value added (EVA) and ensures that all actions enhance long-term financial performance (Ameels et al., 2002).

Value Stream Mapping (VSM): A lean tool used to analyse and visualise the flow of materials and information in a process. VSM helps identify and eliminate non-value-adding activities to streamline operations and enhance value delivery (Singh et al., 2011).

Set-Based Design (SBD): A design approach that explores multiple design options simultaneously to foster innovation and reduce rework. SBD supports flexibility by evaluating several alternatives before finalising the most viable design (Toche et al., 2020).

Last Planner System (LPS): A planning tool that improves project scheduling and execution through stakeholder collaboration. LPS enhances workflow reliability and project performance by breaking tasks into manageable units and adjusting plans based on feedback (Ballard, 2000).

Target Value Design (TVD): A design method that aligns project costs with client expectations by setting cost targets early and developing solutions that meet these targets while maintaining quality (Zimina et al., 2012).

Just-In-Time (JIT): A production strategy that minimises inventory and improves site efficiency by delivering materials only as needed. JIT reduces waste and storage costs, leading to more efficient operations (Golhar and Stamm, 1991).

Continuous Improvement (Kaizen): A philosophy focused on incremental improvements throughout the project lifecycle. Kaizen involves regular feedback and adjustments to enhance processes and performance (Singh and Singh, 2009).

Pull Planning: A scheduling technique that develops project plans based on the desired outcomes and requirements of end-users. It involves working backwards from project completion to prioritise and define necessary tasks (Tiwari and Sarathy, 2012).

5S: O'Connor et al. (2017) define the 5S method as a workplace organisation system consisting of five Japanese terms: Sort, Set in Order, Shine, Standardise, and Sustain.

5Cs: The 5Cs framework, as outlined by O'Connor et al. (2017), addresses workplace safety and efficiency through five key elements: Clear Out, Configure, Clean and Check, Conformity, and Custom and Practice.

List of Publications

The following publications, including the manuscript, are outcomes of this PhD research:

1. Conference Paper

Chen, Z., Tweijeer, M.A. and Galvin, S., 2019, November. A lean construction overlay to RIBA Plan of Work. In *ARCOM Doctoral Workshop on Contemporary Advances in Research Methodology in Construction Management*.
A Lean Construction Overlay to the RIBA Plan of Work.

- **Presented at** ARCOM Doctoral Workshop on Contemporary Advances in Research Methodology in Construction Management.
- **Summary**: This paper examines the integration of lean construction principles into the RIBA Plan of Work.

2. Conference Paper

Tweijeer, M.A.O.A., Chen, Z., Dimitrijevic, B. and Agapiou, A., 2021, March. A systematic review to identify grand challenges in adopting lean construction. In *CU Construction Conference 2021: Exploring Contemporary Issues and Challenges in the Construction Industry* (pp. 109-112).

- **Presented at** CU Construction Conference 2021: Exploring Contemporary Issues and Challenges in the Construction Industry (pp. 109–112).
- **Summary**: This systematic review identifies significant challenges in adopting lean construction methods.

3. Conference Paper

Chen, Z. and Tweijeer, M.A., 2022, April. Developing the Modern Methods of Construction (MMC) oriented lean construction body of knowledge. In *International Post Graduate Research Conference (IPGRC) 2022: Resilience in Research and Practice*.

- **Presented at**: International Post Graduate Research Conference (IPGRC) 2022: Resilience in Research and Practice.

- **Summary**: This paper discusses the development of a lean construction body of knowledge tailored to Modern Methods of Construction (MMC).

4. Journal Manuscript (Forthcoming)

Tweijeer, M.A., Etakali, A., Chen, Z., and Agapiou, A. (2025).
A TRIZ Approach to Deriving the Lean Construction Body of Knowledge in Major Project Delivery.

- **To be published in** the *Frontiers Journal*.
- **Summary**: This manuscript applies the TRIZ methodology to develop a comprehensive body of knowledge for lean construction, with a focus on significant projects.

Chapter 1 Introduction

This chapter concisely establishes the framework for the entire study. It begins by explaining the research context, which describes the fundamental problem being addressed and outlines the study's aim and objectives. It also outlines the research methods and explains the process by which the research was conducted. Additionally, this chapter provides readers with guidance by discussing the significance of the study, its possible impact, any research restrictions encountered, and the thesis structure.

1.1 Research Background

Yap, Chow, and Shavarebi (2019) highlighted that the construction sector has difficulties managing time, cost, efficiency, efficacy, and quality. The complexity of multi-disciplined projects exacerbates these difficulties. To address these issues, they proposed that new theories of building and production are required to increase efficiency and efficacy. The primary objectives of applying lean construction concepts are to eliminate inefficient procedures and enhance project value.

The study examines the current implementation of lean techniques in the construction industry and explores the fundamental lean principles of construction. The focus is on understanding and addressing the challenges of applying lean construction techniques in several construction projects, including project planning, waste management, change management, risk management, and uncertainty control (Åhlström, 1997). Lean construction aims to minimise waste and enhance project efficiency by continuously improving processes (Lapinski et al., 2006). It seeks to eliminate waste of time, money, and effort by evaluating each step in a process and modifying or eliminating stages that do not add value. (Womack and Jones, 2015).

Due to its size and importance, the construction industry holds a significant global position (Salem et al., 2006; Mahmoud & Scott, 2002). Although traditional planning methods are used to manage construction costs, time, quality, and sustainability, the industry still faces different challenges. Lean construction is one approach to addressing these problems (Alarcón, 1997).

Research projects by Bertelsen (2004), the Lean Construction Institute (2017), and Lukowski (2010) have shown that the manufacturing industry has successfully embraced lean approaches. However, enhancing efficiency and productivity in the construction sector often involves implementing various time-saving techniques and technologies. As stated by May & Green (2005), lean manufacturing and construction can be viewed as a collection of techniques, an interpersonal style, a socio-technical framework, or a social asset. Lean Construction Institute (2017), Lim (2008), and Howell (1999) noted that Lean emphasises reducing waste, minimising costs, meeting project deadlines, adding value, and satisfying client needs.

Technical integration is crucial for refining the efficiency of construction projects in terms of cost, time, and quality. Conventional design, management, and performance methods are often insufficient to meet productivity demands (Aziz and Hafez, 2013). Progressive construction techniques, including BIM (Building Information Modelling), project management software, and drones, are essential in optimising cost efficiency (Sawhney et al., 2020). For instance, BIM enables detailed digital modelling of projects, facilitating accurate cost estimation and resource allocation, thereby reducing financial concerns. This includes cutting non-value-adding activities and enhancing cost-effective tasks to minimise waste (Han, 2008). Inspired by lean production, lean construction provides a structured approach to managing construction projects. It encompasses several techniques, including the Last Planner system for on-site production management (Vargas Renzi, 2018). Integrating lean construction can improve project quality while reducing waste, defects, and material costs. Although these practices have been successfully implemented in complex projects with tight deadlines and limited resources, their effectiveness in various conditions requires further research (Karaz and Teixeira, 2023).

While not covered in this research, technologies like BIM significantly enhance modelling processes and management (Smith and Tardif, 2009). BIM provides benefits for design and project planning, starting from the early design stages and emphasising client needs and team collaboration. The system's capabilities provide both short-term and long-term benefits (Ballard, 2013).

Effective project management requires balancing three key objectives: Time, Quality, and Cost (Harris et al., 2006). These objectives are interconnected and fall within the broader framework of Sustainability, which includes managing Time, Quality and Cost. Each one is essential to the project's long-term success.

1.2 Problem Statement

The construction industry struggles with inefficiencies, including resource wastage, time overruns, and poor-quality management. Despite adopting various project management methodologies, the principles of Lean Construction have limited integration into the RIBA Plan of Work 2020. This research problem is driven by these challenges and opportunities to enhance project performance through structured integration. Emerging drivers include the industry's increasing focus on sustainability, digital transformation in project management, and demand for frameworks that ensure value addition and stakeholder satisfaction. Addressing these drivers alongside the obstacles provides a strong justification for this research.

This section discusses the challenges and obstacles that the construction industry faces. Globally, construction is often described as a slowly advancing industry (Aziz & Hafez, 2013). Researchers frequently highlighted various persistent issues, such as inadequate safety, low productivity, poor working environment, and substandard quality in construction projects (AlSehaimi et al., 2014; Koskela, 1992) emphasise that these issues continue to plague the sector, impeding the achievement of project goals related to cost, schedule, and quality. Challenges such as increased competition from international markets and a shortage of trained personnel are becoming increasingly pressing (CIOB, 2021; Olawale & Sun, 2010). Other significant issues, including uncertainty, waste, instability, change, conflict, restrictions, and complexity, pertain to the industry.

Several essential reports (Latham, 1994; Egan, 1998) have highlighted the importance of and addressed problems such as low productivity, time overruns, inadequate quality, and poor operational conditions. Moreover, challenges with processes related to resource waste, unclear and quantifiable factors, and a lack of documented information can further complicate the situation. Multi-level organisational structures, unique projects, on-site construction, and the absence of cooperative relationships, coordination, and communication among multidisciplinary professions can harm the industry. Furthermore, the lack of flexible contractual agreements and a focus on customer needs contribute to these challenges (Koskela, 1992).

Sarhan and Fox (2013) investigated the challenges associated with implementing Lean Construction (LC) in the United Kingdom and identified numerous critical obstacles. These include traditional construction management practices, insufficient awareness of Lean principles, inadequate technical skills, an essential level of illiteracy, insufficient training, and a lack of recognition of Lean as an integrated framework. Additional barriers include poor teamwork skills, limited executive commitment, societal and psychological issues, time constraints, commercial challenges, disintegration and outsourcing, procurement and contract difficulties, educational shortcomings, budgetary constraints, and disparities between design and construction.

Scholars such as Mossman (2009) and Bashir et al. (2010) have identified several challenges in the construction field, including the adoption of evolving methods, reduced productivity, project delays, errors, stagnant productivity, budget overruns, subpar outcomes, and general inefficiency. However, potential solutions exist. These include implementing controls and restrictions, enhancing organisation, improving planning, ongoing learning and training, addressing cultural issues, managing building operations, and applying Lean Construction tools. Several studies have addressed this topic (Ballard, 2000a; Green, 2002; Heidar, 2023; Lean Construction Institute, 2012).

Oyedele et al. (2013) found that construction is a significant source of waste. Reducing non-value-adding activities and enhancing the efficiency of value-adding ones is crucial to addressing this issue. Lean Construction, which aims to enhance product quality by minimising waste, defects, and operational costs, has shown considerable progress in recent years. By adopting Lean Construction practices, projects become more organised, improving product quality over time (Heidar, 2023).

1.3 Research Questions

This is the research question that was chosen for the PhD study.

How can Lean Construction principles and methodologies be systematically integrated into the RIBA Plan of Work (PoW) 2020 to improve project efficiency and sustainability across all construction phases?

This question addresses a critical gap in the literature review presented in Section 2.13 of Chapter 2.

1.4 Research Aim and Objectives

The research aims to develop and validate the Total Lean Construction (TLC) Framework, which integrates Lean Construction principles with the RIBA Plan of Work 2020. The term "technical framework" distinguishes the TLC Framework from non-technical ones by focusing on specific tools, methods, and measurable guidelines to optimise construction processes. This is unlike broader management frameworks, which may focus solely on high-level organisational practices without addressing technical execution.

The specific objectives of this research include:

(1) Identifying integration points between Lean Construction principles and the RIBA Plan of Work 2020 through a critical literature review.

(2) Developing the TLC Framework to improve both process efficiency and sustainability in construction projects.

(3) Validating the TLC Framework through empirical research, including interviews with professionals and a case study, a "what if" scenario of the Crossrail project.

1.5 Research Methodology

This research adopts a multi-method qualitative approach to ensure the comprehensive development and validation of the Total Lean Construction (TLC) Framework. Each method was carefully chosen to align with the research objectives and provide a structured, evidence-based process. The methods employed include:

1. Literature Review:

A detailed literature review was conducted to identify theoretical gaps and map integration points between Lean Construction principles and the RIBA Plan of Work (PoW) 2020. This step served as the foundation for the research, highlighting the need for a structured framework that combines the strengths of both approaches. The literature review also guided the framework's development by providing insights into existing methodologies and their limitations (Hancock et al., 2021).

2. Framework Development:

The TLC Framework was iteratively developed, combining insights from the literature review with practical considerations identified during the empirical validation phase. This iterative process ensured that the framework was both theoretically robust and effectively addressed real-world challenges and opportunities. A key focus was to ensure that the framework provided practical strategies for improving project outcomes, such as waste reduction, cost control, and enhanced collaboration (Pandey, 2021).

3. Empirical Validation:

The framework was validated through qualitative methods, including:

Semi-structured Interviews: Interviews with industry professionals provided critical feedback on the framework's applicability and relevance, allowing for refinements based on expert perspectives.

Case Study: "What if Scenario"-The Crossrail project was selected as a case study to evaluate the framework in a real-world context. This analysis demonstrated the framework's potential to address common construction challenges and its ability to align with complex project requirements.

These methods ensured a rigorous, grounded development process, as each phase directly informed the next. The literature review identified the theoretical basis, and the framework development translated these insights into a structured approach. The empirical validation provided practical evidence to assess the framework's feasibility and applicability.

This methodological approach underscores the research's commitment to academic rigour and practical relevance, ensuring that the TLC Framework makes meaningful contributions to integrating Lean Construction principles with the RIBA Plan of Work.

1.6 Significance of Study

The need for a framework that integrates Lean Construction with the RIBA Plan of Work arises from the growing emphasis on delivering efficient and sustainable construction projects. What sets the TLC Framework apart is its structured incorporation of lean principles at each stage of the RIBA PoW 2020, offering a novel approach to project management that emphasises waste minimisation, stakeholder collaboration, and continuous improvement.

Its uniqueness lies in its ability to operationalise lean principles within a widely adopted architectural workflow, addressing technical execution and managerial oversight cohesively.

This section is divided into three parts, presented below. It explains why developing such an integrated framework is important, outlines the benefits of the TLC Framework, and validates a novel technical framework that supports its practical application in lean construction.

This study is significant because it addresses a key gap in the construction industry and offers innovative solutions. This section consists of three parts, presented below, to explain why developing such an integrated framework is important, outline the benefits of the TLC Framework, and validate this novel framework, which supports its practical application in lean construction.

(1) Importance of the Integrated Framework

Developing an integrated framework that combines Lean Construction principles with the RIBA Plan of Work 2020 is highly significant for the construction industry. Lean principles have increasingly been recognised for their potential to improve project delivery processes.

(2) Benefits of the TLC Framework

Creating the TLC Framework is a step towards a more organised and structured method for implementing lean principles in construction projects. Moreover, the framework will provide project managers and stakeholders with a clear roadmap for applying lean construction principles. This will lead to multiple benefits, including increased productivity, reduced costs, improved overall performance, and minimised waste. By supporting the adoption of lean methodologies, this research has the potential to drive positive change and foster innovation within the construction sector.

(3) Validation and Empirical Research

The validation of the TLC Framework through interviews conducted with experts and through a carefully selected case study adds substantial value to the research outcomes. This empirical research not only assesses the feasibility and effectiveness of the framework but also offers valuable insights into its real-world applicability and adaptability. The empirical data gathered will enhance the reliability of the framework, increasing the likelihood of its acceptance and implementation by industry practitioners.

1.7 Thesis structure

The Thesis comprises six chapters, each focusing on a different investigation area. Table 1.1 outlines the content, main points, and thesis structure of each chapter.

Table 1.1 Thesis Structure and Details

Chapters	Contents
1. Introduction	Chapter 1 introduces the central issue addressed in this thesis.
2. Literature Review	Chapter 2 delves into the relevant literature, exploring topics such as construction project management, the principles of lean construction, barriers to implementing lean construction, the RIBA Plan of Work, and waste management in construction.
3. Methodology	Chapter 3 outlines the methodology employed in this study.
4. Framework Development	Chapter 4 suggests that the structure for the building process be developed based on lean principles. Among them are: - Stage 1: Introduction of the framework. - Stage 2: Detailed examination of each stage. - Stage 3: Implement methods for managing Time, Quality, Cost, and Sustainability.
5. Data Analysis	Chapter 5 conducts data analysis, including interviews and case studies, to validate the proposed framework in real-world scenarios. This involves: - Gathering data through interviews and case studies. - Analysing the collected data to assess the effectiveness and applicability of the proposed framework.
6. Conclusion and Recommendations	Chapter 6 presents insights, conclusions, and recommendations for further research based on the findings of this study.

1.8 Summary

This chapter introduces the study's background, problem statement, aim, objectives, methods, significance, and limitations. It provides a roadmap for the thesis, outlining the structure of subsequent chapters. The research integrates lean construction principles with the RIBA Plan of Work 2020 to enhance construction project management and address key industry challenges.

Chapter 2 Literature Review

2.1 Introduction

This chapter provides an in-depth review of existing literature relevant to integrating Lean Construction (LC) principles with the Royal Institute of British Architects (RIBA) Plan of Work (PoW) 2020. It critically examines the significance of project management in the construction sector, evaluates current tools and techniques, and identifies gaps that inform the development of the Total Lean Construction (TLC) Framework. Key focus areas include global frameworks, Lean Construction approaches, and the practical integration challenges they present.

Additionally, the chapter examines global frameworks for construction project management, focusing on practices in the United Kingdom. It reviews the LC approach, the Last Planner Production Control System, and the impact and challenges of implementing lean construction. The RIBA PoW 2020 for construction project management is also analysed. Finally, the chapter discusses the necessity of developing a new framework, providing the rationale for the LC and RIBA PoW 2020 framework, and the theoretical foundations for integrating Lean Construction with the RIBA Plan of Work (PoW). This chapter concludes with a summary of the main points discussed.

The government's Project Delivery Function Strategy for 2025 strongly emphasises increasing efficiency. This strategy encompasses several measures aimed at simplifying procedures, reducing unnecessary bureaucracy, and improving resource management. Technology plays a vital role in achieving these goals by utilising project management applications and data analysis techniques to automate tasks, foster better collaboration, and ensure seamless communication among stakeholders. Among the biggest and most significant industries is the building sector (Salem et al., 2006; Mahmoud and Scott, 2002), mainly because it provides the infrastructure that supports all aspects of society. Although traditional planning approaches are commonly used to manage construction projects, factors such as time, cost, and waste continue to be significant issues in the construction industry (Salem et al., 2006; Solaimani et al., 2019; Alarcón, 1997).

By incorporating lean principles in construction, overall project success will be imperatively enhanced; however, many probable advantages are not yet fully recognised in a smooth mode (Lean Construction Institution, 2017). A few meagre results of the building process led to key negative additions to the projects, such as delays, extra costs, and increased waste (Lean Construction Institution, 2017), which negatively impact the overall performance of any project.

The Lean construction strategy has been recognised as a crucial approach to addressing these issues in construction projects. In Japan, Lean is a standard approach to getting to its feet in the manufacturing industry. Japan is renowned for its top-notch industrial manufacturing and the advancement of innovative fabrication ideas worldwide (Gao and Low, 2014; Tezel and Nielsen, 2013). Lean perception emphasises new notions for preparing and supervising the building procedure while focusing on client worth and waste reduction.

Lean Construction is an industrial method, a viewpoint recognised after the awareness of lean production. Lean management in construction has been verified through various types of construction projects globally and has proven effective (Marhani et al., 2013; Issa, 2013; Aziz & Hafez, 2013; Lean Construction, 2012; Green & Ma, 2005; Alarcón, 1997, 2005). According to Fernandez Solis et al. (2014), lean construction is a relatively advanced approach to managing construction projects.

In a 1994 report, Sir Michael Latham outlined a remarkable building sector that aims to deliver excellent quality and has the potential to increase productivity significantly. In this case, collaboration is essential. Furthermore, according to the report by Egan (1998), the following expressive features are emphasised:

- The client-customer.
- Guarantee to the people.
- Incorporated processes and teams.
- Dedicated Management.
- Quality-oriented program.

The construction industry has undergone a societal transformation. According to Latham (1994), the customers are the centre of the process, and the business needs to cater to their needs. Thus, clients are the first to be implemented (McGeorge and Palmer, 2002). Consumers may be crucial in starting a cultural revolution inside the industry by embracing management ideas such as:

- Concept of value management
- Constructability of Managers

- Setting benchmarks
- Redesigning/Re-engineering practice
- Collaboration
- TQM/ Total Quality Management

Therefore, the measuring tools for performance and accompanying benchmarking have come up as the most crucial factors in project success, and this field has been a focus of a substantial volume of study and devotion (Mahmoud and Scott, 2002; Takim and Akintoye, 2002; Yu et al., 2007; Yang et al., 2010; Aziz and Hafez, 2013). Several instruments and protocols have been created to advance this field. Both Latham and Egan's reports emphasised the importance of output enhancement as a primary factor in construction. For example, research work by Yusof (2018), Chen et al. (2019), and Bassioni (2004), among others, can be considered. Construction projects are becoming more multifaceted than ever, as well as vibrant, significant, and unpredictable compared to those encountered in history. Moreover, the perception and procedure of offering an optimal building has directed the construction practices through the maximum of specialised procedures. The construction sequence and time leading to variability in workflow and increased estimated construction cost and time have been affected (Ochoa, 2014).

According to a research investigation conducted by Pheng (2012), in the current climate, integrated management is necessary to enhance both efficiency and quality, leading to sustainable growth. This is especially true in developing states where construction has been disorganised, influencing project quality and efficiency. Similarly, research conducted in the Gulf region of the Middle East reveals an increasing trend of construction projects meeting the specific challenges of completing them within budget and on schedule (Mohamed, 2016). It is observed that, upon recognising a growing number of evidence and evaluating the standard implementation method, Lean Construction Management can solve the complications.

This chapter consists of the following sections to form a complete process of literature review:

- **Section 2.1.1** Explain the method used to conduct the remaining literature review.
- **Section 2.2** An Introduction to the Significance of the Project Management facts about the garbage now produced in the UK and worldwide and the detrimental effects of building waste.
- **Section 2.3**: Critical Evaluation and Identification of Waste Minimisation Techniques.

- **Section 2.4** introduces the idea of waste handling and reduction, emphasising the region's excellent practices.
- **Section 2.5** A review of the lean construction (LC) approach,
- **Section 2.6** Critical Evaluation of Construction Incorporation of a Lean Construction Process within the RIBA framework for Operations (2020). Theoretical Foundations for Integrating Lean Construction with the RIBA PoW 2020
- **Section 2.7** A summary

2.1.1 Literature Review Process and Keyword Search Strategy

The literature review employed targeted searches across multiple databases, including ScienceDirect, Scopus, and Google Scholar, using keywords such as "Lean Construction," "RIBA Plan of Work," "waste minimisation in construction," and "sustainable construction frameworks." Articles were screened for relevance.

Two key features were investigated:

- To begin with, the key phrase search for construction holds "lean principles." To conduct proper research for the present study, search for terms such as "lean methods," "sustainable growth," "lean techniques and approaches," and "building projects."
- Secondly, when considering Waste, the appropriate literature can be found by keyword search using “waste minimisation,” “waste minimisation techniques,” and “waste minimisation practices.”.” Waste minimisation is highlighted due to its multifaceted benefits. The construction sector generates significant waste, which adversely impacts project efficiency and environmental sustainability. Addressing waste minimisation can:
- **Reduce Costs**: Minimising material wastage and disposal fees (Ekanayake & Ofori, 2000; Tam et al., 2007).
- **Enhance Efficiency:** Optimised resource usage leads to streamlined workflows (Formoso et al., 2002; Love et al., 2018).
- **Promote Sustainability:** Aligns with global efforts to reduce carbon footprints (Ajayi et al., 2015; Ghaffar et al., 2020).
- **Effective waste minimisation strategies**, such as recycling, reuse, and lean construction techniques, are crucial in mitigating these issues.
- Critically, while waste minimisation directly reduces project costs and supports sustainability goals, its broader implications include fostering innovation in material usage

and promoting circular economy principles. However, challenges in integrating waste minimisation practices, such as resistance to change and limited technological adoption, highlight the need for more robust policy frameworks and industry incentives.

An extensive list of relevant research papers is identified and filtered; consequently, pivotal papers are included in this study following a detailed review.

2.2 Significance of Project Management

Project management encompasses ten primary responsibilities, as outlined by the Project Management Institute (2013): cooperation, time management (including scheduling, planning, and project execution), communication, cost management, human resources management, quality assurance, stakeholder engagement, risk mitigation, scope definition, and procurement. Project success can be defined as any project that is considered successful. It must be completed and delivered on schedule, within the allotted budget, and following the technical specifications, ensuring client satisfaction. The primary objectives of project management are quality, time, and cost (Serpell et al., 2015). Similarly, effective project management is crucial to the success of every construction project, referring to operations completed within budget, on schedule, and in compliance with quality requirements. Every stakeholder must be aware of and committed to the project's unique goals throughout the project lifecycle. Therefore, various methods for managing projects may be applied to assist in achieving goals whenever a project is subject to time, money, or limited resources. Plan and command, on the other hand, could be the best instruments for finishing a project quickly and affordably while supporting the required level of excellence.

2.3 Overview of Construction Project Management Issues

Construction project management faces numerous challenges, including cost overruns, delays, inefficient resource utilisation, safety concerns, and environmental impacts. Waste generation remains a critical issue, contributing to environmental degradation and financial inefficiencies. These challenges necessitate the adoption of sustainable practices to improve project outcomes (Koskela, 1992; Love et al., 2018). Key challenges identified in the literature include cost overruns, inefficient resource allocation, and substantial waste generation. Koskela (1992) and Love et al. (2018) highlight persistent inefficiencies that traditional practices fail to mitigate. These issues underscore the importance of adopting Lean principles to streamline operations and enhance the delivery of value.

2.3.1 Project Management and Construction Industry

Project management is central to the construction industry's success, encompassing the management of time, cost, and quality (Serpell et al., 2015). However, traditional project management approaches often fail to address the dynamic complexities of projects, necessitating innovative frameworks such as Lean Construction. Construction has been supported by Shirazi et al. (2010) as a project-oriented sector. As a result, the characteristics of building tasks distinguish them from those of other businesses, as the processes involved are quite different from those in production and distribution (Besner and Hobbs, 2008). Koskela (2000) divides the critical elements of building projects into three primary groups, including

(1) The nature of the project

(2) The outcome of site building

(3) The Provisional Organisation

According to Pierce and Aguinis (2013), a site visit is sufficient to determine the viability of a projected plan; management techniques established from project management are not necessary. In addition, Pierce and Aguinis (2013) noted that the construction sector has undergone changes, and project control and management now require a new strategy.

Construction companies must implement progressive management techniques as projects are becoming increasingly complex and traditional control methods are no longer sufficient (Lalmi et al., 2021). According to investigators like Lalmi et al. (2021), implementing modern management infrastructure, such as flexible and lean manufacturing, will help to foster change, improve client collaboration, and enhance the worth of a project by utilising adaptable conduct to raise the likelihood of success for the project and using lean methods to reduce garbage. Azanha et al. (2017) elaborated that despite the limitations of outdated managing projects techniques and the many benefits of contemporary systems for managing projects (such as lean project administration), the more favourable results were attributable to elevated satisfaction among workers and inspiration, better demand control, and particularly, the higher standard of the imposed system.

The importance of project management in construction is inherited from the firming of the general management definition, as discussed above. The CIOB (2011) describes project management for construction as the complete planning, collaboration, and control over a project from commencement to completion, ensuring that the client's demands are met and a financially and functionally valuable project is produced, which can be finished on schedule within budgetary constraints and to the required standard. Walker and Vines (2000) propose a more comprehensive definition of planning, control, and coordination throughout the entire project lifecycle. Moreover, the deliverables of a project must meet the client's satisfaction in terms of quality, functionality, utility cost, time duration, and relationship building, among other fundamental aspects. Thus, project management aims to ensure that the project outcomes match the customer's needs. Still, meeting or surpassing a client's requirements and anticipations perpetually entails balancing loads among:

(1) Opportunity, cost, quality, and time
(2) Stakeholders have different requirements and anticipations.
(3) Acknowledged demands and unclear prerequisites.

2.3.2 Project Management Qualities in the Construction Industry

Chan et al. (2004) state that the characteristics of a building project consider the project's scale, complexity, type, and level of construction, as well as the individual characteristics of the project participants, their competency in construction management, communication, experience, and potential design changes. Nicholas and Steyn (2008) provided several of the main qualities of construction project management, including:

(1) The project manager oversees the work and acts independently of the subordinate hierarchy. The project is set up and oriented to achieve several objectives with cooperation.

(2) The project manager is tasked with going above and beyond to accomplish the project goals specified by the client or project owners.

(3) The team project management must utilise specialised findings to manage all tasks within and outside the service provider's teams, ensuring the entire project's success.

(4) The project manager is responsible for integrating workers from various functional areas, subcontractors, and specialists involved in the project.

(5) The project manager communicates directly with other duty managers who can oversee the different jobs and employees involved in the project.

(6) The project managers ardently desire to finish a job on schedule and budget. However, functional managers ensure that the project specification is followed, resources are gathered and used wisely, and progress is made to advance the organisation's objectives. Nevertheless, disagreements may arise between the project manager and the responsible party regarding the time and ability to devote to a project.

(7) For the project to be successful overall, the project team and supporting functional units share decision-making, accountability, outcomes, and rewards.

(8) The subcontracting unit that forms the project organisation is permanent, even if it is only temporary. Upon completion of the project, the subcontracting unit returns the individuals, and the project organisation is disbanded.

(9) To complete a project, project management teams divide ongoing tasks into several supporting roles, including supply chain management, human resources, etc.

2.4 Construction Work Process and Management

While considering any waste minimisation technique (the LC is shown to be the most proper), an understanding of the construction management process needs to be identified to ensure transparency.

The phase of construction activities in a building project's life cycle is a key factor in determining the project's efficiency. Numerous scientists, such as Howell and Koskela (2000), have adopted the theory of relying on project completion, which entails compromises in terms of cost, time, sustainability, and excellence.

The building procedure is segregated into three phases: Project Conception, project strategy, and implementation (Chan and Kumaraswamy, 1997). According to Emmitt (2002), it may be defined as a linear project execution method. Furthermore, the construction of the projects is defined as an assemblage through which numerous service providers, including designers and contractors, ultimately turn the customer's requirements into a tangible reality based on drawings. This construction process, also known as the development and production process, is widely used worldwide.

Although numerous districts have acknowledged the building process, the progression of each stage remains unclear (Orihuela et al., 2011). Various institutions, such as the Lean Construction Institute (LCI), the Institution of Civil Engineers (ICE), the Royal Institute of British Architects (RIBA), and the International Group for Lean Construction (IGLC), have proposed that several phases are a way forward, designed for experts. However, the number of levels employed varies greatly and is conditional to the document you declaim (for example, RIBA versus NEC). However, many are ignorant of the specific tasks that must be completed on what schedule. As a result, each project must have its unique building process framework, within which the specifics of each task can be considered. Simultaneously, the construction process. The author of this thesis believes that the TLC Framework could reduce waste and improve the performance of building projects.

2.5 Tools, Techniques, and Methods of Construction Management

Several CM technologies, strategies, and tactics are available to oversee construction projects. A choice was included in Tables 2.1 and 2.2 that highlighted the pertinent ones relevant to this work. Winch (2010) asserts that while Critical Chain and Last Planner address unpredictability issues, they resolve them by delaying task performance rather than directly addressing the process capacity issue; as a result, they cannot be regarded as comprehensive LC solutions.

Table 2.1: Tools Used in Construction Project Management (Winch, 2010; Heidar, 2023)

No.	Technique/Method	Description
1	CPM / Critical Path Method	A technique to find the sequence of crucial tasks that determines the project duration
2	CCM / Critical Chain Method	A method focusing on resource constraints and buffer management to ensure project completion.
3	Technique for Program Assessment and Analysis	A systematic method for evaluating and assessing project performance
4	Traditional Methods	Conventional project management techniques with linear, sequential phases
5	The Waterfall Method	A linear and sequential project management approach where each phase must be completed before the next begins.
6	Project Management with Agile	An iterative approach that focuses on customer feedback, collaboration, and incremental progress.
7	Unified Rational Process	A customisable framework emphasising iterative development and risk management.
8	Intensive Project Supervision	Involves close monitoring and management of project activities to ensure adherence to timelines, budgets, and quality standards.

Table 2.2: Methods for organising projects (Winch, 2010; Heidar, 2023)

No.	Technique/Method	Description
1	The CCM Technique (Critical Chain Management)	Focuses on resource management and project scheduling by finding and managing constraints
2	Analysis of Critical Space (CSA)	A technique used to assess and manage spatial constraints within construction projects.
3	Lean Project Delivery System (LPDS)	A comprehensive approach to project delivery focuses on minimising waste and enhancing efficiency.
4	Last Planner System (LPS)	A subset of LPDS that emphasises collaborative planning and execution in construction projects
5	Lowering Task Length Variability	A strategy designed to reduce variability in task durations, thereby improving project predictability.
6	Matrix of Dependency Structures (DSM)	A tool for managing and optimising the interdependencies among tasks in a project.
7	Arranging Reciprocal Processes	Method for organising interdependent tasks to ensure efficient management of feedback loops
8	Making the Schedule Visual	It utilises techniques such as Gantt charts or BIM to enhance the clarity of project schedules.

Correlation Between Tools (Table 2.1) and Methods (Table 2.2)

There is a clear relationship between tools and methods used in construction management. Tools like Building Information Modelling (BIM) and project management software support the implementation of methodologies such as Lean Construction and Integrated Project Delivery (IPD). For instance:

- **Scheduling Tools**: Utilise support methods such as the Last Planner System (LPS) to enhance task coordination and minimise delays (Ballard, 2000).
- **Simulation Tools** Enable scenario analysis, critical for applying risk management techniques (Sacks et al., 2010).

A critical analysis of this relationship reveals that while tools enhance the operationalisation of methods, their success largely depends on user competency and organisational readiness. For example, BIM's potential remains underutilised without adequate training and integration strategies. Furthermore, the choice of tools should align with project-specific goals to maximise their effectiveness.

2.5.1 LPDS (Lean Project Delivery System)

This section focuses on the Last Planner Delivery System (LPDS). While LPDS is a prominent Lean Construction tool, it is essential to address why other tools and methods are not discussed. LPDS is widely recognised for its capacity to enhance planning reliability and project performance (Ballard & Howell, 1998). However, complementary tools such as BIM and Kaizen could be discussed to provide a broader perspective on Lean Construction applications. A critical perspective questions whether the heavy focus on LPDS might overshadow the potential contributions of other tools. For instance, Kaizen promotes continuous improvement, which could address dynamic challenges not fully captured by LPDS. Similarly, integrating BIM with Lean principles could further streamline processes, warranting a more comprehensive discussion.

Gregory Howell and Glenn Ballard established LPDS in 1997, and the LCI developed the LPS and LPDS construction control systems by applying concepts first used in manufacturing to the building industry (Ballard, 2000a). Project definition, lean design, lean supply, and lean assembly are four interrelated processes that frame LPDS (Sarhan & Fox, 2013).

The Critical Chain Project Management (CCPM) technique states that the Theory of Constraints, a project planning technique that focuses on the resources required to complete tasks within a project, is implemented by CCPM (Goldratt, 1997). As a breakthrough in novel thinking to complete projects, enhance scheduling capabilities, and reduce planned costs, the Project Management Body of Knowledge (PMBOK) also recommends CCPM (Andiyan et al., 2021). The approach considers that the most extended job order, or the one with the smallest amount of slack, gives the project's length and duration, and the events or tasks are grouped in a dependent order. Management should focus on the critical route tasks to ensure that the job or project is completed in the quickest amount of time possible. According to Heidar Barghi (2023), LPS can help address the potential unwillingness to trust or rely on deterministic programming. This might be the case since probabilistic methods (PERT) are more likely to be optimistic than the absolute worst-case scenario, which is not always helpful when building project timetable shifts.

Andiyan et al. (2021) state that the Project Assessment Review Technique (PERT) employs a probabilistic approach, whereas the Critical Path Method (CPM) is a deterministic approach to project scheduling and assessment. Although there is a slight variation, the CPM-PERT approach may be used to analyse project duration because it serves the same purpose. Standard phases for the project management process, which include creating, obtaining, assembling, and delivering, have evolved to develop leaner, quicker, increasingly efficient, and reduced waste based on the Lean Project Delivery System of the Lean Construction Institute (Al-Aomar, 2012). The viewpoints are also shared by Marhani et al. (2013), Abdullah et al. (2009), Jørgensen and Emmitt (2008), Lim (2008), and Koskela (1992), all of whom have confirmed the numerous benefits of using lean construction (LC) in building projects. The principal advantage is reduced building expenses, as proper materials are used and waste is minimised on-site (Suresh et al., 2012). Additionally, the project will be completed more efficiently and with higher quality, incorporating sustainable concepts.

2.5.2 Problems and Issues in Construction Management

Project control guarantees that projects are completed on schedule, within budget, and aligned with other project goals. Project managers undertake a challenging role, requiring them to assess plans and take remedial action as needed continually (Kerzner, 2003). Many project control techniques have been developed over the past few decades, including the Critical Path Method (CPM), Program Evaluation and Review Technique (PERT), and Gantt Bar Chart (Lester, 2003; Nicholas, 2001). Many software programs, including Primavera and Microsoft Project, among others, now support these project control techniques. Despite the widespread application of these techniques and software programs, time and cost overruns still occur in many building projects. Table 2.3 lists several concerns and difficulties related to construction management (Harris et al., 2021).

Table 2.3 Problems and Issues with Construction Management (Olawale and Sun, 2010)

Domains	Categories	Specific Issues
Time	Problems with time overrun	- Delayed projects - Reduced productivity of labour - Conventional planning methods - Extensive supply chain leading to delays
	Shortage of funds and materials	- Inefficient time management - Non-competent contract management - Frequent changes in design - Inaccurate estimations of materials - Shortage of skilled and competent labour - Frequent site condition changes - Poor project planning
Cost	Problems with cost overrun	- Increased costs - Overrun projects. - Cost management and control issues - Extra work additions - Inaccuracies in project design - Increase in material costs due to inflation. - Shortage of construction materials - Economic conditions - Client requirements - Site conditions - Management and supervision issues
	Waste Produced	- Non-value-added work - Transportation issues - Construction and demolition waste - Loss of materials - Defects in construction - Underprivileged specification - Postponements - Lack of technical awareness - Inadequate pre-construction discussions
Quality	Issues with the Quality of Construction	- Unsatisfactory performance - Poor site management - Increased stress - Lack of skilled labour - Deficiency in awareness and understanding. - Design document errors - non-compliant procedures. - Human errors - Lack of team effort and supervision - Inability of suppliers and subcontractors- - Hazards at sites - Pressure from the organisation. - Client requirements - Stumbling High-risk activities - Procedure-related issues
Sustainability	Issues regarding sustainability	- Ecological issues - Communal issues - Financial issues - Sustainability management and control issues

Up-to-date construction projects and buildings remain more complex than ever, both in concept and execution. Furthermore, this industry comprises distinct sets of participants, and the interlinkage among these sets varies for every project. The needs are the source of the distinctiveness that arises from an individual's union with the continuous growth of a specific role (Harris et al., 2006; Al-Jibouri, 2003). Hence, a decent corporate connection should be established between the founding contractor and the contract supervisor, as both are contractually bound to each other for a functioning relationship (Aziz and Hafez, 2013); thus, D&B agreements are accepted as contractual package deals. The term D&B describes a procurement route where a main contractor is selected for designing and executing the work, as opposed to the conventional and outdated construction contracts, in which clients hire design consultants and then appoint a contractor for the construction work. The primary objective of the "Design and Build" (D&B) projects is to enhance quality and reduce costs by improving the constructability of the designs. However, the innovative ability cannot be successfully applied to executing D&B Projects (Aziz and Hafez, 2013).

However, contract management is available as an alternative to Design and Build (D&B) solutions, which do not ensure the designer's independence and separation from the builder. Problems in construction projects can arise through contractual processes and exchanges among project participants. For example, the biggest problem in the construction industry lies in the fact that there are numerous individuals involved in the supply chain, which creates a catastrophe in terms of logistics regarding the supplies transported to a site of the project and, as prominently, the wastage is generated (Al-Jibouri, 2003; Harris et al., 2006).

CDW generates a large portion of waste in Europe (Gálvez-Martos et al., 2018). Even after adapting waste management practices, innovative approaches are needed in the construction industry. Gálvez-Martos et al. (2018) have correlated the top procedures and joined the core values for CDW management (refer to Section 2.5).

The basic theory for drafting standard forms of contracts is that the builder would always have the last say on design decisions, even the little ones. The contractor must ensure the work is "fit for purpose." (NEC; ICE, UK, 2020). However, the following findings are observed within the current processes:

(1) The consumer value is not fully used.
(2) There is not enough waste minimisation.
(3) Resources employed in excess (Heidar, 2023).

2.6 Global Framework for Project Management

During the building process, demolition and renovation of infrastructure and buildings generate massive amounts of C&D waste each year. According to reports, the global annual quantity of trash from C&D has exceeded ten billion tonnes, with the US generating 7 billion tonnes and the EU over eight billion tonnes (Wu et al., 2019c). China generates over 2.3 billion tons of construction and demolition (C&D) waste annually, primarily due to accelerated urban sprawl and increased town planning (Zheng et al., 2017). Hence, construction waste is a significant worldwide concern and one of the sector's most significant issues. For example, in many countries, 15% to 20% of unused resources become waste products, exacerbating these problems (WRAP, 2020).

Osmani (2013) states that various approaches and theories exist for categorising the primary sources and roots of construction waste. For example, Ekanayake and Ofori (2000) incorporated the origin of construction waste into the design, material handling, operational, and procurement origins. Moreover, the lack of drawing information, the selection of low-quality materials, unfamiliarity with alternative materials, and the complexity of detailing are rated as the most important causes of waste. According to Bossink and Brouwers (1996), design waste also leads to errors in contract clauses or results in inadequate contract documents.

Similarly, Treloar et al. (2003) have categorised the origins of construction waste into two phases the preconstruction and construction phases and narrated that during the pre-construction phase, the waste generated during the planning and designing process (such that minimal coordination with the material standardisation and ordering additional material, imprecise estimations), procuring (i.e., extra allowances, and variable dimensions of material) and negotiating with the material suppliers and manufacturers (e.g., damages to goods during transportation or loading). However, Baldwin et al. (2006) have acknowledged numerous design waste causes, inclusive of building complexity (by the advent of a variety of specialised designs and responsibilities for the same project) and collaboration and communication problems because of the multi-faceted nature of design in which the contractor get a piece of highly variable information and open to confusion and misinterpretations which inevitably contributes to waste generation. Equivocally, Osmani (2013) has testified that the inevitable acceptance of waste and the absence of training are the foremost challenges architects face when designing waste.

Conclusively, the further waste generated directly or indirectly by other project participants, such as clients, contractors, subcontractors, or suppliers, made the situation more complex. A consensus is present in the literature that the design alterations requiring rework during the construction phase are vital causes of waste production (Cheng et al., 2011; Osmani et al., 2008, 2006; Poon, 2007; Yuan and Shen, 2011). The leading factors of design changes during execution are linked with the drivers for design variations during construction. They are related to ineffective communication between project participants, incomplete design data, complex designs, an extended project duration, and unforeseen site conditions (Osmani et al., 2011).

Lu and Yuan (2011) have emphasised that three key areas need to be addressed regarding construction and demolition waste to ensure the appropriate management of construction waste, namely:

- Production
- Reduction
- Reusing

According to Eguchi et al. (2007), Japan has demonstrated that a more effective approach is to consider construction waste as a valuable auxiliary material rather than merely a waste product. Hence, much more effort should be made to recycle or reuse waste horizons. However, it is inevitable to describe the waste more prudently as construction waste is produced from three sources: demolition, general construction, and renovation works (Kofoworola and Gheewala, 2009). That is why the origins of waste require a global approach for all types of construction, without being bound to specific stages, i.e., the source of waste generated, and several factors must be considered. Therefore, every type of waste-handling tactic can be considered for developing the financial, legal, administrative, planning, or engineering structure. It is aligned with Construction and Demolition waste management (C&D WM), which is becoming a significant sustainable development problem concerning social, economic, and environmental aspects (Doan and Chinda, 2016).

2.6.1 Global Frameworks in Construction Management

The field employs various global frameworks to standardise practices and improve outcomes. These include impact, design phases, sustainability, and lean-based delivery. The following are among the most widely recognised:

1. **ISO 9001: Quality Management Systems**: Offers a structured approach to quality assurance and continuous improvement across all sectors, including construction (ISO, 2015).
2. **ISO 14001: Environmental Management Systems**: Focuses on minimising environmental impacts and ensuring compliance with environmental legislation (ISO, 2015).
3. **ISO 21500: Project Management: Guidance on Concepts and Processes**: Provides a high-level standard for project management applicable across industries, though it lacks specific construction-sector detail and lean integration (ISO, 2021).
4. **RIBA Plan of Work 2020**: A widely used UK framework that breaks construction projects into eight distinct stages, providing clarity and structure from strategic definition to post-occupancy (RIBA, 2020).
5. **LEED Certification**: A sustainability assessment framework that evaluates and certifies buildings based on environmental performance, energy efficiency, and material use (USGBC, 2021).
6. **Last Planner System (LPS)**: A lean-based planning method that improves workflow reliability by fostering collaborative decision-making and short-term planning (Ballard, 2000).
7. **Lean Project Delivery System (LPDS)**: Developed to align lean principles with project delivery by integrating planning, design, procurement, and construction phases (Ballard and Howell, 2003).
8. **Total Lean Construction (TLC) Framework**: Developed in this research, the TLC Framework integrates Lean Construction principles into the RIBA Plan of Work 2020, offering a lifecycle-based, sustainable, and value-driven model tailored to construction practice.

2.6.2 Comparative Evaluation of Existing Frameworks

Several global frameworks provide structured guidance for construction project management, each with distinct areas of focus, benefits, and limitations. These include ISO 9001 for quality management, ISO 14001 for environmental management, ISO 21500 for general project governance, and LEED for sustainable building performance. Additionally, the RIBA Plan of

Work 2020 (PoW 2020) is a stage-based framework widely adopted in architectural and construction practices across the UK. However, a recurring limitation across these frameworks is the lack of direct integration with Lean Construction principles, particularly in relation to reducing waste, promoting value generation, and improving lifecycle efficiency.

ISO 9001 offers internationally recognised quality management protocols, facilitating standardisation and customer satisfaction. ISO 14001 addresses environmental sustainability, enabling organisations to manage ecological impacts. Despite their strengths, both are general management systems with minimal sector-specific guidance for construction delivery. Neither framework incorporates lean thinking or continuous improvement strategies.

ISO 21500 provides a high-level guide for managing projects across all sectors, outlining standard terminology and generic good practices (ISO, 2021; PMI, 2013). However, it lacks specificity in construction applications and does not align with operational frameworks such as RIBA PoW 2020 or include tools for lean implementation, value stream analysis, or stakeholder collaboration.

The RIBA Plan of Work 2020 is a structured stage-based framework detailing the progression of a project from strategic definition to post-occupancy. It is widely used in the UK due to its clarity and consistency. Nonetheless, it was not developed with Lean Construction principles in mind and does not offer integrated strategies for process optimisation, waste elimination, or value maximisation (RIBA, 2020).

In contrast, the Last Planner System (LPS) and Lean Project Delivery System (LPDS)developed by Ballard and Howell aim to improve planning reliability and reduce variability through collaborative planning techniques (Ballard, 2000; Ballard & Howell, 2003). However, their application is typically limited to the production phase, and they are not inherently aligned with the RIBA's stage-based delivery model, limiting their suitability for holistic integration.

Table 2.4 presents a comparative analysis of these frameworks, highlighting their core focus areas, strengths, and limitations:

Table 2.4: Comparative Analysis of Frameworks

Framework	Focus	Strengths	Limitations
ISO 9001	Quality Management	International standard; promotes consistency and reliability	Limited construction-specific relevance; no lean or sustainability focus
ISO 14001	Environmental Management	Strong sustainability emphasis	Not integrated with construction planning or delivery
ISO 21500	General Project Management	Broad applicability; common terminology	Not sector-specific; lacks lean principles or stage-based alignment
LEED Certification	Sustainable Building Performance	Globally recognised sustainability rating system	High implementation costs; project lifecycle inefficiencies unaddressed
RIBA PoW 2020	Stage-based Project Delivery	Widely adopted; clarity across project phases	Not integrated with lean tools or operational improvement strategies
LPS / LPDS	Collaborative Planning and Control	Enhances planning reliability; lean-focused tools	Lacks strategic alignment with standard frameworks like RIBA
TLC Framework	Lean + RIBA + Sustainability	Integrates lean tools with RIBA stages; sustainability focused	Requires industry adaptation; adoption may vary by project type

While each of these frameworks addresses key dimensions of project delivery, none offer a complete integration of lean methodologies, sustainability goals, and stage-based workflow within a single structure. The TLC Framework developed in this research fills this gap by embedding Lean Construction principles directly into the RIBA PoW 2020. It aligns technical planning and delivery strategies with environmental and operational performance goals, offering a practical, lifecycle-oriented solution for improving efficiency, reducing waste, and enhancing stakeholder collaboration.

This comparative analysis demonstrates that current frameworks, though valuable in isolation, are either too generic, too narrow in focus, or not sufficiently adaptable to complex and dynamic construction environments. The TLC Framework therefore represents a significant advancement by unifying lean practice, sustainability, and stage-based management into a cohesive and actionable model.

2.6.3 Key Observations

A critical review of these frameworks reveals a gap in operational strategies that integrate Lean principles throughout the entire project lifecycle. This highlights the need for a comprehensive framework, such as TLC, that embeds Lean methodologies within the RIBA Plan of Work 2020 structure.

2.7 The Background of the UK

According to Osmani (2013), the construction sector generates an annual revenue of over £100 billion, accounting for approximately 9% of the country's GDP. It offers employment opportunities to more than three million people, hence playing a significant role in the competitiveness and prosperity of the UK. However, it is one of the most significant users of resources and creators of waste among all UK industries and hence takes responsibility for 32% of the total waste production, equivalent to three times the joint amount of waste generated by all households (DEFRA, 2007).

In March 2020, the Government Statistical Services and the Department released their keynote addresses. This indicates that 66.2 million tons of non-hazardous construction and demolition waste (C&D waste) were generated in the UK in 2016, accounting for 62% of all waste produced in the UK that year.

2.7.1 Key Definitions of Waste Management

Waste is defined as "any material or thing which the owner disregards or wants to dispose of" in Article 3 (1) of the 2008 Waste Framework Directive (Directive 2008/98/EC); hence, the act of handling trash is referred to as "waste management." The critical characteristic of waste management is “more efficient use of materials.” It provides the primary influence on the minimisation of limited naturally occurring resources and hence lessens the negative environmental impact of construction, including a reduction in landfill requests. Furthermore, the waste management sector has improved the financial effectiveness of the construction industry and other economies in the UK (WRAP, 2020).

2.7.2 Techniques for Waste Minimisation

Construction and Demolition waste management is an evolving field in the construction sector that aims to minimise the adverse effects of the construction process on the environment. It is assumed to be the key contributor to effective sustainable development (Lu and Yuan, 2011). However, Esa et al. (2017) prioritised the significance of managing construction and demolition waste to mitigate ecological impacts in their study on techniques for reducing construction and demolition waste. They have used this method to highlight that a contemporary building process can reduce waste production during the design and planning stages. In the same way, they suggested that the fundamental ideas and methods for creating an integrated waste management system for construction and demolition debris need to be figured out from the start, and the proper strategies include:

(1) At the designing and planning stage, construction methods and waste management plan
(2) During the procurement phase, increase awareness of regulations and awards
(3) A practical plan for waste management and minimisation must be developed during construction and demolition.

Wu et al. (2019) have stated that Construction and Demolition waste is primarily produced during the phases of destruction and construction. Substantial efforts have been conducted to minimise the waste on the work site of construction (Wang et al., 2010; Hao et al., 2008; Poon et al., 2004). Mainly, the on-site categorisation is acknowledged as an operative method to decrease waste and upturn recycling and reuse (Poon et al., 2001; Wang et al., 2010). Additionally, in recent times, maintenance and renovation of buildings have been recognised as essential sources of construction and demolition waste. However, this waste is produced on a minor scale compared to C&D (Cheng and Ma, 2013; Lu et al., 2016). Several endorsements have been suggested in earlier studies to reduce C&D waste. However, the single remaining issue is a lack of significant approaches to evaluate the efficacy of the activities conducted for waste management. That is why lean construction (LC) is the most suitable method, as stated in the previous section.

2.8 The Lean Construction (LC) Approach

2.8.1 Lean Construction

Lean construction signifies a construction strategy and project management ideology focused on boosting effectiveness, work quality, and worth within the construction cycle. This approach is centred on waste elimination, perpetual enhancement, and maximisation of client value. Lean construction seeks to enhance workflows, minimise delays and errors, and foster collaboration among project stakeholders. The endgame is to enhance processes, bolster communication channels, and guarantee the successful delivery of top-tier projects on schedule and within budgetary constraints (Ansah et al., 2016).

Integrating lean construction and RIBA will consolidate the best qualities that each seeks to achieve, including minimising the project quality and the time needed while maximising the quality of the work done (Loh et al., 2009). To effectively achieve the intended objectives, adjusting the RIBA work plan in critical areas will be necessary to accommodate the unique attributes associated with Lean Construction, such as utilising multi-tasked personnel and automation (Al-Adwani, 2022).

2.8.2 Definition

Lean construction is the complex integration of lean concepts and practices into the construction sector. It involves embracing lean concepts, a management concept based on maximising value and reducing waste. Lean construction seeks to foster a collaborative and efficient building process that minimises waste and enhances project outcomes. According to Radhika and Sukumar (2017), this approach necessitates a fundamental shift in project management practices to cultivate a culture of value creation, ongoing development, and collaboration among project participants.

2.8.3 Fundamental Principles

Several fundamental concepts underpin lean construction, including fostering teamwork, streamlining project processes, eliminating waste, empowering employees, embracing innovation, and continually seeking methods to enhance project performance. In construction projects, adhering to these guidelines can lead to enhanced customer satisfaction, improved quality control, reduced costs, and increased productivity (Gao and Low, 2014).

2.8.4 Benefits of LC

Adopting Lean Construction practices benefits the project stakeholders and the construction industry. These advantages include lower construction costs and waste, as well as greater project productivity and efficiency. Other advantages include faster project completion, improved client satisfaction, and higher standards of project safety. Along with fostering cooperation, integrity, and improved communication among project stakeholders and teams, lean construction encourages shared accountability for completing activities that meet or exceed customer specifications. It also embraces innovation and continuous improvement. (Bookanan and Czap, 2021).

"Lean thinking" or "Lean" refers to a developmental approach that prioritises minimising waste and meeting client expectations. This phenomenon resulted from Toyota's rise to prominence as one of the world's leading and most lucrative automakers (Gülyaz et al., 2019; Yusof, 2018; AlSehaimi et al., 2014; Mariani et al., 2013; Aziz and Hafez, 2013; Khan, 2012; Abdelhamid, 2003).

One of the key elements of lean building is that lean production can provide solutions to numerous issues, as given in Table 2.5 below. Furthermore, to achieve waste reduction, the improvement emphasises eradicating flow activities or non-value-adding steps and converting to actions that offer value more efficiently (Koskela, 2000, 2017).

Table 2.5: Lean production methods and their aims (Pettersen, 2009)

Methods of Lean Production	**Aim**
Just in Time (JIT)	Wait times removal
Time-based competition	Decreased cycle durations
Value-based management	Increasing production value
Total Quality Management	Error elimination
Employee Participation	Employees with higher abilities for superior positions
Total Productive Maintenance (TPM)	Increased emphasis on supplies
Process Redesign or reengineering	Arrange through process view and focus on the method.
Concurrent engineering / simultaneous engineering	To work on the projects concurrently
Visual Management	Managing and standardisation of visual workplace

The diverse considerations of lean construction were presented after several years of development. Different understandings of lean construction have become clear. Different scholars have varying ideas and concepts that define LC in multiple ways. For example, Diekmann et al. (2004) viewed it as a continuous compliance procedure or, more importantly, as pursuing value and eradicating waste. However, Koskela et al. (2002) presented a simple description of Lean Construction:

"Lean construction is a method of designing production systems to minimise material, effort, and time wastage, thereby producing the maximum possible value."

Bertelsen (2004) considers Lean construction from a distinct perspective and proposes it as a big-scale adaptation of Japanese manufacturing principles. This idea is applied in the construction industry. However, Jiang (2005) presented a new management style directed by lean thinking, where lean tools can be implemented to change construction procedures. The primary objectives of Lean Construction (LC) are to eliminate waste, deliver value, and enhance production quality.

Moving ahead, Lim (2008) narrated that the LC is a method of balancing materials, human resources, and other resources. He further explained that it helps reduce costs and eliminate waste, allowing the construction project to be completed on time. Lukowski (2010) explains lean construction, as Bertelsen (2004) explains, which is the direct application of lean manufacturing fundamentals or lean thinking to the construction environment. Moreover, it is also a management strategy that aims to reduce waste and fulfil customers' needs.

In short, many definitions are not encompassed here but can be concise in that the definitions have discussed the lean construction with two distinct aspects:

- The definition provided by Lim (2008) can be assumed as an extension of Koskela, Huovia, and Leinonen's definition (Koskela et al., 2002), which states that "balancing resources, delivering projects on time, and reducing costs are essential for generating maximum value." The definitions presented by Lim and Koskela, Huovia and Leinonen are similar because they all define lean construction from a functional perspective.
- Conversely, Bertelsen (2004) and Lukowski (2010) define LC from the standpoint of development and sources, like the earliest definition proposed by Western researchers. The explanations discuss two common aspects: efforts to reduce waste and provision of value to customers. So, LC can be defined as a continuous process that reduces waste and satisfies customer requirements.

Koskela (1992) first discussed lean construction, and upon investigation, he referred to the modern production viewpoint and its implementation in construction. Lean construction signifies designing production systems to minimise, reduce, and eliminate material, effort, and time wastage (Koskela et al., 2002). It is a strategy to design the construction process to simplify information and material flow, thereby reducing material, effort, and time wastage and increasing output. Conventionally, lean construction has always emphasised reducing construction waste during the execution phase, while environmental waste has been deliberated less often. However, as the concept evolved, construction waste became closely linked to environmental waste (Golzarpoor et al., 2016). So, lean construction processes can give sustainable solutions (Salem et al., 2014). Tommelein (2006) highlighted that using various standardised materials can raise similar issues to cut waste.

The primary goal of the Lean construction concept is to maximise project value for customers (Gülyaz et al., 2019). This is related to the necessity of eliminating the wastes from waste from construction to meet project objectives, such as those of cost, quality, timeliness, and minimising environmental harm, a fundamental tenet of sustainable growth (Howell, 1999; Lim, 2008; Lean Construction Institute, 2012; Sarhan et al., 2019).

Production is viewed as a value-adding activity in lean construction, which states that the company must produce precisely what, how, and when. However, the customer sets the value, and the executioners identify the best way to achieve the goal (Lean Construction Institute, 2012). The eleven basic concepts of the lean construction method were outlined by Koskela (1992), and Aziz and Hafez (2013) included the following:

1) Waste and other non-value-generating activities should contribute less.
2) To boost output value, systematically analyse client needs.
3) Reduction of variability
4) Shortening of cycle times
5) Simplify by reducing the number of components, stages, and connections.
6) Greater versatility in output.
7) A rise in process openness.
8) A concentrated effort to oversee the entire process
9) Constant enhancement of the procedure
10) Keeping equilibrium between converting and flow enhancement
11) Comparison shopping.

However, Womack and Jones (1996) condensed these into just four lean construction principles outlined in Table 2.6. These principles can be implemented to enhance the overall flow process.

Table 2.6: Principles of Lean Production (Womack and Jones, 1996)

Sr.	Lean Concept	Description
1	Value Recognition	Deciding value based on customer demands and implementing it into company processes. This involves finding valuable requirements for both internal and external customers and providing products that meet their needs.
2	Identification of the Value Flow	Understanding the three phases of a value stream: data controls, problem-solving, and physical conversion. This ensures that the production phase aligns with the client's primary ideas.
3	Flow of Value	Optimising the technique by removing barriers between construction industry sectors to provide clients with a continuous value stream. This involves re-engineering processes to ensure a seamless flow of value through departments, operations, and manufacturing entities.
4	Pull	Adopting a production strategy that manufactures products based on customer demand and timing. This approach, often referred to as "pull," enables customers to dictate production requirements, as highlighted by Womack (1996), allowing for customer-directed modifications.

In the same spirit, Koskela (1992) recommended applying the following three fundamental manufacturing rules at the first stages of a project:

(1) Instruments, such as quality circles and kanban.

(2) Production Process

(3) The management philosophies JIT and TQC

Lean construction fundamental concepts are implemented alongside the former ones. For example, Bashir et al. (2011) have presented a diverse occupational health and safety method, namely ISO 45001, for applying lean philosophies. According to Dulaimi and Tanamas (2001), the benefits of lean construction may only be realised through the complete enactment of these principles (this viewpoint was supported by many other writers, e.g., Fewings and Jones (2013), Suresh et al. (2011), Höök and Stehn (2008), and Cullen et al. (2005), etc. Meanwhile, Bertelsen (2004) and Green (2000) argued that due to the differences across sectors, not all principles apply to the building industry. On the other hand, Salem and Zimmer (2005) observed that many of the principles have been demonstrated to apply to the construction business. According to Koskela (2004b), they do not systematically encompass the value-creation features of a construction practice. Höök and Stehn (2008) also discussed the fact that the doctrines have a dearth of concentration on the social characteristics of the labour force, which is an inescapable aspect of the lean process. In addition, according to Forbes and Ahmed (2011), the following five core principles should be embraced by all businesses:

(1) Client attention.

(2) People and culture

(3) Standardisation and workplace organisation

(4) Waste eradication.

(5) Built-in quality and continuous development

Table 2.7 presents the essential lean construction concepts and tools, providing a comprehensive overview of the methodologies and techniques that can be used to enhance efficiency and minimise waste in construction projects.

Table 2.7: Essential LC concepts and tools

No	Tools or Main Concepts in LC	Pertinent Elements	Sources
1	Movement of materials and sections / JIT	JIT goal: Keep the flow of building materials and sections	Bajjou et al., 2017a; Tezel and Aziz, 2018; Koskela, 1992
2	TQC	Assurance of quality	Koskela, 1992
3	TPM	Production Management	Mariani et al., 2013
4	Participation of Employee	Engaging Employees	Bertelsen, 2004
5	Continuous Improvement	Constant evaluation and enhancement of processes	Nahmens and Ikuma, 2009; Miron et al., 2016; Sarhan et al., 2017; Caldera et al., 2018
6	Benchmark	Performance comparison against industry standards	McGeorge and Palmer, 2002
7	Temporal Competition	Competition based on delivery time	(Koskela, 1993)
8	Simultaneous Engineering, Fast-track, and CE	Application during building progression	Koskela, 1992
9	An approach based on values	Client expectations	Bertelsen, 2004; Koskela, 1992
10	Value Management	Maximising project value	McGeorge and Palmer, 2002
11	Visual Management	Promotes process accountability and supervision	Formoso et al., 2002; Tezel et al., 2015; Tjell and Bosch-Sijtsema, 2015
12	Reengineering/Process Management	Significant performance improvements	McGeorge and Palmer, 2002; Small and Yasin, 2011
13	TQM	Connection of client service, engineering, and construction	Čiarnienė and Vienažindienė, 2015; Ullah et al., 2017; Summers, 2005
14	Last Planner System (LPS)	Incorporates value capture and construction flows	Ballard, 2000a; Ballard and Howell, 1998; Kim and Ballard, 2001
15	Value-Based Management (VBM)	Aligns processes with client needs	Constructing Excellence, 2004

The Last Planner System (LPS), also known as "Pull Schedule" or "Reverse Phase Sequencing (RPS)," was developed by Ballard in 1992 and appears to be a key component of Lean Development. It has been used for years by many academics in a variety of nations, including

- Chile by Alarcón et al. (2015),

- Nigeria by Ahiakwo (2015),
- Saudi Arabia by AlSehaimi (2011) and AlSehaimi et al. (2014), and
- Malaysia, as studied by Marhani et al. (2012), Issa (2013), Ochoa (2014), Fernandez-Solis et al. (2013), Adamu and Abdul Hamid (2012), and Fiallo and Revelo (2002).

Lean thinking is an idea grounded in lean production philosophy, as discussed by Koskela (1992, 2000). It is also known as lean thinking, which separates its theoretical basis from the production processes referred to (Tezel and Aziz, 2018; Sarhan and Fox, 2013).

Furthermore, in Lean construction, improving construction flows is an essential aspect (Issa, 2013; Aziz and Hafez, 2013; González et al., 2008, 2009). Lean thinking's basic tenet is achieving a smooth and constant flow for a manufacturing technique, as Sacks et al. (2009) have further described. The LC approach is novel and methodical to building projects (Alarcón, 1997). Hence, Lean is a management strategy for companies that involves various techniques and tools. For example, the Last Planner System is a helpful production control tool on the site (Issa, 2013; Ballard, 2013; Aziz and Hafez, 2013; González et al., 2008, 2009).

Lean thinking at every step of the process is crucial for developing a lean construction system, as noted by Al-Aomar (2012). Similarly, Yusof (2018) presented a methodology for incorporating a lean thinking approach into the engineering process of construction projects, thereby attaining substantial advantages during the design phase, resulting in a significant gain at a crucial segment of the construction project cycle. Nonetheless, the construction industry has gaps compared to other industries, as noted in the Egan Report (1998) and Sir John Egan’s speech to the House of Commons in 2008 (Ward, 2015).

Additionally, a 2011 study by Paul Morrell provided the UK government with recommendations on increasing construction productivity, investment, and sustainable development. In January 2010, the UK government's innovation agency and development lead published an influential study entitled "Low Carbon Construction" (Morrell, 2011a). Along with being the driving force for the rationale of the Government Construction Strategy 64 (published in May 2011; referred to Morrell (2011b), he was also the driving force behind the earlier reports by Latham and Egan emphasising requirements for the building industry to collaborate more and use information technology, particularly BIM, to support the long-standing process and upkeep of its constructed assets. Since 2010, Morrell has been a vocal supporter of BIM, and as of 2016 (see Morrell, 2011c; 2011d; Architects' Journal, 2012), all centrally bought public sector building projects have been mandated to use BIM.

Complexity is a significant factor that influences the application of lean construction (LC) in the construction industry. Building is the intricate process of creating a unique product for a client. Sources of intrinsic complexity in this close interaction include clients, external variables, and site-specific circumstances, among others. Therefore, these intricate exchanges must be well understood to reap the benefits of LC properly.

2.8.5 Fundamental theories behind (and relevant tools for) LC

Additional management approaches available for LC include total productive maintenance (TPM), employee engagement, continuous improvement, assessment, temporal competition, continuous engineering (CE), value-driven management, managerial visualisation, redesign, and lean production. BPR (Business Process Reengineering), CE (Continuous Engineering), and LPS (Lean Production System) were introduced by Alinaitwe (2009); collaboration and VBM (Value-Based Management) were added by Harris and McCaffer (1997).

Six important LC ideas were assessed for their efficacy in the University of Cincinnati garage project by Salem et al. (2005). Data were collected through document analysis, questionnaires, interviews, and on-site observations. The principal ideas at play were:

- Last Planner System
- Increase in Visualisation
- Group Meetings daily
- Initial Research
- 5S processes (maintenance)
- Always go for quality and safety first

Despite a rise in funding, it was discovered that the 5S method of execution and failure safety for both safety and quality fell below projections, based on the results of Salem et al. (2005 and 2006). Training and behavioural modifications were needed for the fundamental principles to be used here effectively. The remaining important ideas chosen for the project were either readily applicable or suggested with minor adjustments.

In a similar vein, Adamu and Abdul Hamid (2012) examined LPS via the application of four fundamental ideas. Then, they verified them in building accommodation units for the

Government of Yobe State in Nigeria. Due to certain limitations, the 5S process was not thoroughly scrutinised. Nonetheless, questionnaires, interviews, and direct participation in production management were all employed as data collection techniques. Based on the results, waste on site has decreased and been eliminated thanks to efficient training, the complete application of the Lean Production System, and the fractional application of additional important ideas. It was also discovered that senior management's assistance was needed to increase shareholder interest in LC.

Suresh et al. (2011) presented nine main LC essential ideas. The listed ideas below are crucial for understanding the execution of Lean Construction (LC) and are foundational to the development of the TLC framework. All these concepts are described below with descriptions of their relevance to TLC framework development:

(1) 5S and 5Cs
(2) Enhanced visualisation
(3) Fruitful meetings
(4) Just In Time
(5) Last planer system
(6) Pilot research
(7) Poka-yoke process/Error-proofing
(8) Pre-casting
(9) Root Cause Analysis: The Five "Whys."

(1) ***5S and 5Cs****:* O'Connor et al. (2017) described the 5S method as a workplace organisation system comprising five Japanese terms: Sort, set in order, Shine, Standardise, and Sustain. The 5Cs framework focuses on workplace safety and efficiency, including clearing out, configuring, cleaning and checking, conforming, and Custom and practising (O'Connor et al., 2017). Implementing 5S and 5Cs in a construction environment fosters a more organised, efficient, and safe workplace, which can be integrated into the LTC framework development to enhance productivity and safety.

(2) ***Enhanced Visualisation***: Enhanced visualisation involves using tools and techniques such as Building Information Modelling (BIM), Gantt charts, and other visual aids to improve the clarity and understanding of project plans and progress (Sacks et al., 2009). Studying these visualisation techniques enables the development of a TLC framework that

incorporates visual tools to communicate project details more effectively and track progress more efficiently.

(3) ***Fruitful Meetings**:* Fruitful meetings are structured and purposeful gatherings that improve communication, decision-making, and coordination among project stakeholders (Suresh et al., 2011). Analysing the effectiveness of these meetings leads to communication strategies that can be integrated into the TLC framework to improve project outcomes.

(4) ***Just In Time (JIT)**:* Just in Time (JIT) is a production strategy that aims to improve a business's return on investment by reducing in-process inventory and associated carrying costs. In construction, JIT means delivering materials only when they are needed in the construction process (Dange et al., 2014). By studying JIT principles, the TLC framework can be more effective in reducing waste and increasing efficiency in construction project management.

(5) ***Last Planner System (LPS)**:* The Last Planner System (LPS) is a collaborative planning approach used in construction projects to ensure reliable workflow and minimise waste. It involves engaging all stakeholders in planning, setting short-term goals, and continuously refining the plan based on actual performance (Hamzeh et al., 2009). Understanding LPS is crucial for developing the TLC framework, which enhances collaboration, predictability, and workflow efficiency in construction projects.

(6) ***Pilot Research**:* van Teijlingen and Hundley (2002) discuss the significance of conducting pilot research to ensure the success of projects. Pilot research involves conducting small-scale preliminary studies to evaluate the feasibility, time, cost, risk, and potential adverse effects of a more extensive study. This step is crucial in the development of the TLC framework, as it enables testing and refining ideas before full-scale implementation, thereby ensuring the robustness and effectiveness of the framework.

(7) ***Poka-yoke Process/Error-proofing**:* Poka-yoke is a Japanese term that means "mistake-proofing." It involves designing processes in such a way that prevents errors or makes them at once clear (Lazarevic et al., 2019). Incorporating Poka-yoke into the TLC framework development emphasises error prevention, which leads to higher quality outcomes in construction projects.

(8) ***Pre-casting***: Pre-casting refers to the manufacturing of construction components, such as concrete elements, off-site before they are transported to the construction site for assembly (Phromduang et al., 2021). Investigating pre-casting methods helps create the TLC frameworks that optimise construction efficiency, reduce on-site labour, and improve quality control.

(9) ***Root Cause Analysis:*** The Five Whys. The Five Whys is a problem-solving technique that involves repeatedly asking "why" to identify the root cause of a problem (Card, 2017). Understanding and applying this method within the TLC framework enables a focus on addressing underlying issues in construction processes rather than merely treating symptoms.

Even while all approaches incorporate minor changes, not every building project needs to utilise every one of these fundamental ideas. The literature search revealed a need for more comprehensive techniques in the current use of LC main ideas alongside other concepts. For instance, Bashir et al. (2011) first presented a health and safety strategy that applies lean concepts.

Furthermore, Abdelhamid (2003) proposed applying Six Sigma prospects in construction sector projects by utilising LPS as the foundation of the LC strategy. Generally, Six Sigma is a well-organized and effective methodology for developing new products and services and improving strategic processes. Using statistical methods and the scientific approach significantly reduces the customer-oriented levels reported by Linderman et al. (2003). If used as a continuous improvement strategy, Six Sigma would offer a comprehensive, integrated, and all-encompassing approach to project continuous improvement (Pepper & Spedding, 2010).

2.8.6 Theories of Lean Construction

It is said that when Koskela's (1992) TFV manufacturing model is used in buildings, performance might be enhanced. There are three main theoretical models of production are used in what is often referred to as the Theory of Factor Value (Sacks et al., 2009; Sarhan and Fox, 2013), and these include

(1) The Transformation of Production
(2) The Production Flow
(3) Production as Value Creation

According to Ohno and Shingo (1988), the Production as Transformation perspective analyses discrete phases that individually provide value to the final product. As defined by Womack and Jones (1996), lean production is a series of actions that alternate between non-value-adding and value-adding, "examining, awaiting, and then advancing." The optimisation of activities that create value is the primary goal. Nevertheless, non-value-adding activities are not overlooked, realising that waste may be found and eliminated to enhance production. We refer to this as Production as Flow. Production is viewed in LC as a process that creates value, referred to as "production as value creation." In other words, a business delivers precisely what the client needs when they need it.

2.8.7 Last Planner Production Control System – A Review

Since Last Planner® has been a comprehensive solution, lean project planning and execution are supported by every component of the system. To enable working toward intended accomplishments, executing what is possible to advance along an established path, and, where that turns impossible, figuring out alternate pathways that fulfil desired goals, the system of production control, the Last Planner®, is required on projects. LPS is recognised as the most sophisticated real-world application of lean construction. Its primary objectives are to mitigate the negative impacts of delays, apprehension, and inconsistency, to make projects more predictable, to provide consistent work schedules, and to foster cooperative planning (Ahiakwo, 2015). While the Critical Chain Method (CCP) is better for formulating and advancing a project principal plan, the Last Planner is an excellent technique for managing actual production at the worksite. The Last Planner, the manager (who is the first-line supervisor of labour), determines which tasks "will" be completed, thereby "shielding" production by reflecting, analysing, and evaluating what tasks "should" and "can" be completed now or at a specific time, say in the upcoming week. Buffers are no longer necessary due to this (Ballard, 2000a, 2013).

2.8.8 Previously used LPS in building projects and its deployment

Ballard has been continuously developing the LPS (also known as the Pull Schedule or RPS) since 1992. He claims that future study directions have been suggested, including quantifying the advantages of more reliable plans for the phases of design and construction and analysing the underlying causes of plan failures (Ballard, 2000a).

AlSehaimi (2011) conducted an action research-based study to evaluate the efficacy of integrating the Lean Production System to enhance the construction planning and control process. The study gathered empirical evidence proving the implementation of Lean Construction techniques in construction projects in Saudi Arabia to minimise related causes of delay.

However, with minor variations, AlSehaimi's (2011) findings “complement those of LPS research conducted in other parts of the world." Put another way, considering the advantages realised, LPS is a general method that works in various settings and climates. Significant advantages are evident in terms of enhancing management techniques, and various delays can be identified and addressed regularly.

Brady's (2014) research "provides an innovative framework along with an approach for implementing Visual Management for scheduling and monitoring production in construction," according to the findings. Additionally, investigations into the application of LPS in Nigeria were conducted by Ahiakwo (2015), aimed at advancing construction procedures in the Nigerian building sector and reducing the obstacles to integrating LPS into Nigerian building projects. Focus group results indicated that the framework could facilitate the proposed implementation procedure.

Employing techniques for LBS (location-based scheduling) methods and lean techniques to organise and align with planned output concerning location, order, and takt time. Biotto's (2019) research aimed to establish a framework for developing, organising, and supervising each phase of development, as well as building projects that involve crossovers among these phases. According to her research, construction firms utilise LBS solutions to integrate design, distribution, and manufacturing. An adjusted last planner system manages production control, verifying and coordinating deliveries with construction. The research's final model can be applied to project supervision in building projects where construction and design periods overlap, such as those involving rapid construction or complex projects where design and construction are developed concurrently.

2.9 LPS Applications Comparison

The following table compares Last Planner System (LPS) applications across various project types, highlighting their uses and outcomes.

Table 2.9: Comparative Table of LPS Applications

Project Type	Application	Outcome	Case Example
Infrastructure	Scheduling & Workflow Management	Reduced delays, improved coordination	Crossrail Project, UK
Residential Buildings	Task Prioritisation	Enhanced resource allocation	Eco-Housing Project, Germany
Commercial Projects	Risk Mitigation	Improved cost predictability	One World Trade Centre, USA

2.10 Challenges in Lean Construction Implementation

2.10.1 Organisational Challenges

Supporters of the last planner approach recommend breaking down each Work Breakdown Structure (WBS) element into its three typical components: labour, plant, and material costs necessary to complete the work. This process is called the cost breakdown structure (CBS). The project's database categories are created with the maximum degree of detail using the CBS and WBS matrix. The Cost Control Cubes are produced by combining this matrix with the OBS (organisation breakdown structure) (Zhang and Fan, 2014; Winch, 2010).

2.10.2 Technological Challenges

The following section first discusses several quality-related concepts before examining the impact of Total Quality Management (TQM), quality management, and control on construction quality. It also discusses how quality control procedures are being increasingly utilised in the construction sector to achieve improved performance. It highlights the reality that every participant in the project must work directly towards achieving quality in the building.

As Gene Miller of Mosher Steel states (cited in Sabbagh, 1989), problem-solving individuals do not bring value, and their diligent efforts to address anomalies may have unforeseen effects on the compliance budget and timeframe. Miller also highlights the problems caused by the culture of broad tolerances.

The four interrelated definitions of quality in construction are the level of standards, compliance, development, and implementation (Low et al., 2012). The principal areas of concentration for QC include value stream mapping, quantitative process control, cause-and-effect diagramming, and performance assessment. Quality assurance (QA) is the aspect of managing quality that ensures quality criteria are met (Winch, 2010).

According to Winch (2010), there are three main categories of quality assurance systems, and they are

(1) Party systems that are the sole and exclusive concern of the organisation in question.
(2) Party platforms, in which clients accredit manufacturers based on exclusive standards, a practice prevalent in the defence ordering and volume manufacturing sectors.
(3) Party platforms that have been certified by an impartial third party for their quality assurance system.

2.11 Hurdles Towards Lean Construction (LC) Implementation

Implementing Lean Construction (LC) faces significant hurdles that impact its effectiveness and widespread adoption. Cultural resistance is a major challenge, as organisations often cling to traditional workflows and hesitate to embrace change (Johansen & Walter, 2007). Additionally, the deficiency in training and awareness about Lean principles limits the understanding and capability of practitioners to apply LC effectively (Alarcón et al., 1997). Technological barriers also hinder progress, with the integration of advanced tools like Building Information Modelling (BIM) requiring substantial investment and expertise, which are not always accessible (Sacks et al., 2010). Furthermore, stakeholder misalignment poses a significant challenge, as conflicting priorities among clients, contractors, and designers can undermine the collaborative approach central to LC (Koskela & Howell, 2002). Lastly, the lack of standardised metrics for evaluating LC outcomes complicates performance benchmarking, making it difficult to assess and compare project results (Formoso et al., 2002). Addressing these hurdles is essential to unlocking the full potential of Lean Construction practices.

Summary of Key Hurdles to Lean Construction (LC) Implementation

The implementation of Lean Construction (LC) faces multiple, interrelated hurdles that limit its effectiveness and widespread adoption. These can be grouped into six broad categories:

1) **Managerial hurdles:** A lack of senior management commitment, inadequate planning, poor communication, and limited delegation of authority are significant barriers. Resistance to innovation and the absence of clear leadership vision further reduce the effectiveness of LC initiatives (Abdullah et al., 2009; Camuffo et al., 2017).

2) **Monetary hurdles:** High consultation, training, and implementation costs, alongside low professional salaries, discourage uptake. Corruption, inflation, and unstable construction markets exacerbate financial risks, while limited incentive schemes reduce motivation for adoption (Enshassi and Abu Zaiter, 2014; Wandahl, 2014).

3) **Literacy and skills hurdles:** Insufficient education and training among construction professionals hinder understanding of LC principles. Low technical expertise and poor knowledge transfer reduce the ability of stakeholders to apply lean methods effectively (Ogunbiyi et al., 2014; Mehra et al., 2015).

4) **Public administration and regulatory:** Inconsistent government policies, weak regulatory support, and corruption undermine LC adoption. Market volatility, taxation issues, and inadequate professional compensation further disrupt implementation (Cano et al., 2015; Small et al., 2017).

5) **Technical hurdles:** Inadequate digital systems, weak performance management tools, and difficulties with BIM adoption present significant challenges. Poor constructability in design, fragmented processes, and extended LC implementation times hinder progress (Enshassi et al., 2019; Omran and Abdulrahim, 2015).

6) **Interpersonal and cultural barriers:** Resistance to cultural change, entrenched behaviours, poor communication, and misalignment among stakeholders weaken collaboration. Incompetent leadership and social diversity issues can increase conflict and reduce project productivity (Johansen & Walter, 2007; Sarhan and Fox, 2013).

2.11.1 Managerial Hurdles

Issues with the proper operation of upper management are examples of managerial obstacles (Abdullah et al., 2009). The complete backing of the company's senior management is always necessary to effectively use lean management. Therefore, the critical elements in the best application of lean management in improving safety measures in an organisation are the highest level of support and commitment from top management (Camuffo et al., 2017). The literature highlights several managerial challenges that must be addressed for lean management to succeed. For instance, a barrier to the best use of lean management in construction projects has been identified as the absence of information throughout the project's definition by management. A thorough understanding of both the goal and vision statements, as well as the problem description that the project aims to solve, is necessary to effectively apply lean management approaches (Ayarkwa et al., 2012). Many newly developed lean management methods, such as establishing a standard set of procedures for maintaining a tidy workplace and analysing hazards before designated work is completed, are currently being used to improve safeguards in building projects (Cudney et al., 2015).

The top leadership should utilise the method of delegation to foster credibility in the workflow rather than granting authority to make decisions for a particular group or individual. Centralising decision-making authority is a significant managerial challenge that must be overcome for lean management to be successfully implemented. It also requires a significant amount of time. As a result, it is a bottleneck for improving workflow. Thus, using a delegating technique reduces the time required for the decision-making process. Moreover, a critical managerial obstacle to the effective implementation of lean methods in the construction sector is a lack of openness. Due to the workers' limited involvement in planning and selecting protective measures, this barrier made it more challenging for construction projects to succeed (Camuffo et al., 2017). Furthermore, it is believed that a managerial obstacle hindering the successful implementation of lean management in the construction sector is the lack of innovative approaches. Occasionally, the contractor chooses not to use novel procedures because they believe it would require a significant amount of time and extend the project's duration (Tseng, 2017).

The absence of crucial notifications and data for leading players in the manufacturing process presents a significant managerial obstacle to implementing lean management principles in the construction sector. According to Attri et al. (2013), an inadequate understanding of the process can lead to improper peer coordination and collaboration, thereby impeding the daily operation of the building project. Inadequate planning is also a managerial hindrance to the practical application of lean management methods. The Last Planner System (LPS), which aims to replace optimistic planning with a more realistic approach that considers worker capabilities, is a crucial tool in the planning process. The effective use of LPS is hampered by inadequate planning (Salem et al., 2014). Another obstacle to applying lean management concepts in building projects is a lack of effective communication among the key stakeholders. This includes discussing safety precautions in construction projects (Sarhan et al., 2017). Furthermore, one of the biggest obstacles to the successful application of lean is the exclusion by top management of projections and potential future investments. An inadequate plan for finishing the lean execution is another significant administrative obstacle (Attri et al., 2013). Inappropriate planning for coordination, which encompasses several significant obstacles, such as inadequate inventory handling and a shortage of supplies and equipment, is categorised as a hindrance to lean management in building projects. The 5S technique, which emphasises workplace organisation, cannot be implemented appropriately if inventory is not planned correctly (Sundquist et al., 2018).

2.11.2 Monetary Hurdles

The significant problems in the LC profession are linked to the global financial failures of businesses. Financial resources are necessary to support worker compensation and benefits, as well as to hire lean specialists for safety improvement in conducting Lean Construction (LC) within an organisation (Bashir et al., 2015). The main monetary obstacles to the LC application are the costs of the consultation fee, training, and workshop fees. Another obstacle to funding the LC execution is the low bidding price (Enshassi and Abu Zaiter, 2014). Low-skilled compensation is one of the elements contributing to the lack of success in adopting lean practice. Employee demotivation is a result of the LC implementation's ineffective compensation scheme. According to Alarcón et al. (2013), providing financial incentives to motivate employees to use new techniques may be necessary. Organisations need to concentrate on improving the compensation structure to motivate their workforce. According to Wandahl (2014), increased compensation may lead to a significant shift in workers' customs, such as reducing littering and improving site safety. Sarhan and Fox (2013) found that instances of price increases and corruption, including bribery, extortion, and fraud, hinder the application of lean construction (LC) because they lead to overcharging, subpar craftsmanship, and the use of inferior materials in production. The organisation faces financial obstacles in the form of increased building budgets if material prices increase.

2.11.3 Literacy as a Hurdle

According to Ogunbiyi et al. (2014), literacy is one of the essential elements required in the construction sector. The process of interpretation, such as grasping the lean idea, may be hampered by an ineffective educational foundation. The entire building process may be hindered by workers' lack of technical expertise and their inability to comprehend the fundamental concepts of LC and how they are applied (Fernandez Solis et al., 2013). When conducting accidental investigations and pre-task hazard analyses, which serve as safety guidelines, significant problems may arise. Mehra et al. (2015) state that literacy obstacles impede general interaction, educational training programs, and information exchange. Insufficient education can also make it difficult to follow guidelines, which could result in unsuccessful actions when LC is implemented.

2.11.4 Public Administration Hurdles

According to Cano et al. (2015), the government's involvement in implementing the LC process is essential in several nations. Planning and executing LC may be hampered by inconsistent and unsuitable government policies on refunds and subsidies. Bashir et al. (2015) suggest that inflation resulting from modifications to government regulations and procedures may affect the building process. Price fluctuations and volatile markets might jeopardise building projects. Due to the import of machinery and other necessary inputs, rules, legislation, and the tax system may potentially jeopardise the building sector.

According to Khaba and Bhar (2017), the management procedure for construction projects requires equipment and inputs to properly execute the LC throughout the execution process, including signage and captions, divisions and warnings, personal protective equipment (PPE), machinery, and protective gear. Additional obstacles encountered during the implementation process due to ineffective government management include price inflation, corrupt practices, uncertain policies, and inadequate professional compensation (Small et al., 2017).

2.11.5 Technical Hurdles

According to Enshassi et al. (2019) have highlighted that technical issues are one of the main obstacles to using LC methods and tools, such as evaluation, simplicity, dependability, and flexibility. One technical obstacle to construction projects is the ineffective implementation of LC methods. The building sector is hindered by the extended period of LC procedures being implemented during the process (Omran and Abdulrahim, 2015). To achieve continual improvement, LC implementation encompasses not only the execution of the LC at the locations but also the creation of a positive staff culture. Training employees in the LC requires a lengthy implementation phase (Ayarkwa et al., 2012). This durability is also linked to how the concepts are applied, which techniques are chosen, how LC is implemented on-site, and how to manage cultural shifts and assess areas for development. Cano et al. (2015) state that the decentralised character of the industry, ineffective systems for managing performance, and inadequate design are design-related impediments to the use of LC in the building process. Construction firms encounter technical difficulties due to compromised integrity in the manufacturing process, which impacts multiple stakeholders, including raw material suppliers, clients, and subcontractors (Sarhan et al., 2017).

2.11.6 Hurdles Related to Interpersonal and Cultural

Human behaviour is one of the most important things to consider while analysing a phenomenon's responsiveness. The personnel are the foundation of every organisation in the construction sector, and their views and deeds matter much to the company (Mehra et al., 2015). When LC is employed in the building process, a lack of competence is the root of the problem. People in the construction business have differing opinions on the managers perceived lack of leadership abilities. Sandeep and Panwar (2016) state that incompetent leadership contributes to workers' reluctance to change. Other obstacles related to human attitudes can be seen as an inability to fit in with the organisational culture, which also affects the method of communication.

Cultural concerns are the primary source of worry for construction industry management, according to Sarhan and Fox (2013), as they hinder the overall building process. Social diversity's human-attitudinal obstacles lead to criticism and mistakes in the work cycle (Al-Alomar, 2012). Cultural boundaries also help prevent misunderstandings among stakeholders. The number of disputes arising from poor communication can be used to gauge cultural barriers. According to Fernandez Solis et al. (2013), the remuneration system for workers has biases based on the workers' sense of belonging, which hinders communication.

2.12 RIBA Framework (for Construction Project Management)

In 1963, the Plan of Work, namely RIBA, was established and standardised for the design and construction of buildings. It also has a considerable impact on global building practices. As an approach link and administration tool, the RIBA PoW 2020 offers the construction sector a well-discussed framework for the organisation and administration of developing projects, which are frequently utilised and provide significant stage references used in a variety of appointments and contracts, as well as best practices guidelines. Over time, it has been modified and updated to consider advancements in procurement arrangements, modifications to regulatory frameworks, and organisational changes within design teams; however, these modifications have typically been gradual and responsive to evolving situations rather than purposefully planned.

Since its commencement, the most recent evolution is represented by the RIBA PoW 2020. It illustrates the RIBA PoW dedication to undertaking the ongoing improvement of the basic guidelines and providing tactical oversight during a period of rapid transformation in the building sector. It embodies the optimal practices of contemporary architectural design and design management. It breaks down the process of planning, creating, and managing building projects into eight phases, describing the primary responsibilities, information sharing, and results at each stage (RICS, 2020). These phases consist of:

- Stage 0: Strategic Definition
- Stage 1: Preparation and Briefing
- Stage 2: Concept Design
- Stage 3: Spatial Coordination
- Stage 4: Technical Design
- Stage 5: Manufacturing and Construction
- Stage 6: Handover and Close Out
- Stage 7: Use

2.12.1 The 2020 RIBA Plan of Work

The RIBA Plan of Works 2020 outlines the primary objectives and deliverables for each phase of the project life cycle, providing a structured method for planning and execution. Due to its adaptability, it can be tailored to meet the project's specific requirements, including every aspect from evaluation to design. According to Segara et al. (2024), following this structure assures successful and reliable project delivery.

2.12.2 Overview

The 2020 overview of the RIBA PoW provides a high-level summary of the framework. It outlines the plan's main goals, guiding principles, and significant stages and deliverables. The introduction also emphasises the benefits of using the RIBA PoW 2020, which include enhanced project management, increased efficiency, and improved cooperation.

2.12.3 Stages

The stages that make up the RIBA Plan of Work 2020 each correspond to a distinct step in the building process. These phases include planning and briefing, concept design, developed designs, building, handover, closing out, and in-use. There are specific goals, tasks, and deliverables for each phase. By breaking the project into many phases, the plan makes it easier to execute the project in an organised and systematic manner. This ensures that all necessary steps are taken, and essential decisions are made at the proper times during the project's duration. (Abanda and Amin, 2019).

2.12.4 Key Changes

The RIBA PoW 2020 differs from its previous versions in several essential ways. The 'Preparation and Brief' phase is a notable addition to the project, emphasising the need for early strategic consideration and customer interaction. The 'Post-Construction Review' phase is an additional step that promotes the use of information gained from completed projects for future ones. The updated strategy also highlights the significance of collaborative teams and data management, emphasising the necessity of cooperation and multidisciplinary working throughout the phases. These crucial adjustments are made to enhance the outcomes of projects while tackling pressing issues facing the sector (Akintoye et al*.,* 2012).

The phases are outlined, detailing the responsibilities and deliverables expected at each phase, which can differ or overlap to suit particular project demands (RIBA, 2020). The Plan of Work by RIBA (referred to as RIBA, 2020) "offers simple plotting for every type of procurement; incorporates environmentally sound engineering methods" and "plots BIM (Building Information Modelling) processes," thereby serving "across a broad spectrum of sectors and project sizes" and "providing adaptability in connection with (town) planning rules."

The RIBA (PoW) does not include a contract. However, it points readers toward several additional tools and key documents that a project team uses, such as service schedules, professional services contracts, project standards, which may or may not be legally binding, and several widely used construction contracts.

Developing a customised project plan of work or practice, including the appropriate acquisition (bidding), programme, and development actions, is made possible by the RIBA Plan of Work

2020, accessible at www.RIBAplanofwork.com. As a result, it can be modified to suit specific projects and customer needs. Structures that are continuously destroyed, repurposed, renovated, and used again are considered by the RIBA PoW 2020. Improved briefing procedures will be needed if building results are to improve. More significantly, finished projects need to have feedback available so that they may guide future ones. RIBA PoW 2020 recognises the stages a building project must go through to be completed and highlights the importance of recording and disseminating information on completed projects. Table 2.10 lists a few of the main advantages of the RIBA PoW; although it was prepared for the previous iteration, it remains applicable to the most recent one, which is 2020.

Table 2.10: RIBA PoW features and advantages (Bailey, 2015)

Advantages of RIBA PoW 2020	**Remarks**
Procedure description to the clients	The work phases are straightforward, and the taskbar structure helps show what is ahead, where the project is, and what services are provided.
Organise your work.	Using computerised files, organising filing and documentation references, and adding identifiers to the (PoW) stages is useful.
It makes the cost structure clear.	The PoW aims to clearly outline the tasks that will be completed at each step, assign prices, and provide a time estimate. This way, the customer can understand exactly what they are paying for, and the fee charges look reasonable for the job that has been done. This also helps reduce a cost component, as lowering the charge lowers the quality-of-service duration and cost, as it is easily connected to a specific section of the service.
Gain control over the design processes.	The Plan of Work is functional for architects to illustrate the benefits of iterative and sequential design methods. Having control over the project's design aspect throughout the process allows the entire design team to enhance design standards and save time.
Enhance your project management techniques.	Task lists for the work stage are created to promote the development, evaluation, and revision of various project management techniques. These techniques provide a solid foundation for optimal project completion and serve as a high-quality management tool.
(PoW) provides program examples.	Delays impact jobs in later stages by altering the time allocated to them and their placement on the schedule. This supports demands for additional space or expedited work.
Use the knowledge exchange.	A reliable and precise track record of the project's development is needed. This is the best way to demonstrate to the customer the value that architects bring to the process.
Promote a whole-process approach.	Employing the PoW to envision the way forward and the way previously travelled could assist the project designer, their colleagues, and all designers in comprehending the work.

Through these advantages, several crucial points are made clear, and these include:

(1) Increase the clarity of the various project phases by using simple, understandable rules (Freire and Alarcón, 2000)
(2) Provides an industry-wide tool that makes commercial sense, as stated (Bailey, 2015).
(3) The establishment of a global professional membership group offered a more disciplined approach via responsibility and a sense of community.
(4) Provide improved infrastructure, more resilient societies, and a sustainable atmosphere.
(5) Additional welcoming by nature.
(6) Establish a foundation for more moral behaviour.
(7) Foster and support more teamwork.
(8) Raise consciousness of environmental issues.

Orihuela et al. (2011) state that although the USA, UK, Australia, and Canada have established a standard building procedure, there remains a dearth of information regarding the specifics of how these stages should be completed. Nevertheless, it is also quite complex in practice (Freire and Alarcon, 2000).

According to reports from institutions, the RIBA PoW only provides recommendations for professionals; hence, these approaches still do not specify precisely what must be done (Yusof et al., 2015). Regardless of the issues faced by practitioners, all the recommendations continue to offer valuable and practical characteristics. As a result, it may provide a practical framework for operations and process management (Nengou, 2019). Research was conducted on the foundation necessary for Sub-Saharan African countries to implement construction laws and regulations effectively. The framework for successful implementation was designed and analysed, drawing on the RIBA Plan of Work 2013. Chen and Atweijeer et al. (2019) identified a critical knowledge gap that needs to be addressed to establish a connection between Lean Construction and the RIBA Plan of Work 2020. This concept has been further developed and fully integrated into the current study.

However, while other standards are important, they may not provide the same level of detail or universal applicability across different project types and scales in the UK (RIBA, 2020). The RIBA PoW 2020 emphasizes structured stages and its ability to accommodate various procurement methods makes it a more substantial choice for exploring the integration of Lean Construction principles.

2.13 Research Gap

Despite the extensive literature on the benefits of Lean Construction, significant barriers to its adoption remain within the construction industry. A clear gap exists in research addressing the integration of Lean Construction principles with the RIBA Plan of Work (PoW) 2020. While many studies focus on individual aspects of Lean Construction or the RIBA Plan of Work 2020, there is a lack of research exploring their combined implementation. Moreover, the impact of this integration on stakeholder engagement, value creation, and project outcomes has not been comprehensively analysed, leaving essential questions unaddressed in the current body of knowledge.

2.14 Background of Combining Lean and RIBA PoW 2020

Chen and Atweijeer et al. (2019) have emphasised that combining LC principles with the RIBA PoW 2020 offers a strategic approach to improving construction project management methods. LC principles are deeply rooted in the Toyota Production System and have been structured according to the requirements of the construction industry. These principles have focused on minimising waste, optimising workflow, and value addition (Ballard, 2000a; Koskela, 2000). Due to their adaptability and effectiveness, these principles have gained considerable recognition as the most effective strategies for enhancing project efficiency and outcomes (Alarcón et al., 2013).

On the other hand, the RIBA PoW 2020 has evolved into a framework for delivering architectural and construction projects. Ahmed et al. (2020) and RIBA (2020) emphasise that the RIBA PoW 2020 reflects the basic needs in construction for coordination, sustainability, and digital integration (RIBA, 2020).

So, the idea to integrate the LC and RIBA PoW 2020 is rooted in the acknowledgement of their complimentary characteristics and shared (Kagioglou et al., 2001) because LC principles line up closely with the objectives of the RIBA Plan of Work, including streamlining the processes, enhancing the communication, and offering the value to clients (Koskela and Howell, 2002). Moreover, there is an escalating demand within the construction sector for more efficient and coordinated project management approaches (Egan, 1998). As construction projects become increasingly complex and stakeholders become more curious about transparency and accountability, a need arises for methodologies that address these challenges without compromising quality (Schmenner and Swink, 1998).

By integrating Lean Construction Principles with the RIBA Plan of Work 2020, the goal is to enhance the strengths of both frameworks while addressing the evolving needs of the construction sector (Smith et al., 2020). This assimilation offers a strategic solution to the demands for faster, more collaborative, and value-driven project management practices, enabling projects to succeed in an increasingly advanced, competitive, and dynamic market.

Table 2.11: Lean construction principles and corresponding RIBA PoW 2020 Stages (Heidar Barghi, 2023)

Lean Construction Principle	**Corresponding Stage of RIBA PoW 2020**
Value Stream Mapping	Stage 0: Strategic Definition
Pull Planning	Stage 1: Preparation and Briefing
Last Planner System	Stage 2: Concept Design
Continuous Improvement	Stage 3: Spatial Coordination
Waste Reduction	Stage 4: Technical Design
Collaborative Project Delivery	Stage 5: Manufacturing and Construction
Visual Management	Stage 6: Handover and Close Out
Lean Supply Chain Management	Stage 7: Use

Table 2.8 presents the alignment of Lean Construction Principles with the corresponding stages defined by the RIBA Plan of Work 2020. Each principle is matched with a stage of the RIBA Plan of Work 2020 according to its relevance and application. However, this configuration highlights the unified integration of Lean techniques into the developed framework of architectural and construction project delivery (Yusof, 2018).

(1) **Value Stream Mapping**: This Lean Construction (LC) technique focuses on identifying and improving value-adding processes, aligning with Stage 0 of the RIBA Plan of Work 2020, which is referred to as “strategic definition.” At this stage, stakeholders define the project objectives and strategic direction, making it an ideal step for mapping out value streams and recognising areas for improvement (Alarcón et al., 2013).

(2) **Pull Planning**: This is a lean technique for scheduling work based on actual demands, aligning with Stage 1 of the RIBA Plan of Work 2020, "Work, Preparation, and Briefing." At this stage, the team develops an initial plan and project brief. It establishes the project parameters, making it a favourable time to implement pull planning methodologies to ensure efficient resource allocation and planning (Koskela and Howell, 2002).

(3) **Last Planner System**: The Last Planner System is a lean method for coordinated scheduling and collaboration, aligned with Stage 2 of RIBA Plan of Work 2020, Concept Design. At this stage, the team develops concept designs and upgrades the project scope, making it essential to implement collaborative planning to ensure the alignment between design intent and project execution (Ballard, 2000).

(4) **Continuous Improvement**: This is the leading theory of the Lean philosophy and aligns with Stage 3 of the RIBA PoW 2020, known as "Spatial Coordination." At this stage, the team collaborates on the spatial layouts and solves design issues and conflicts by providing opportunities for continuous improvement and optimisation of project processes (Koskela, 2000).

(5) **Waste Reduction**: This is a fundamental part of Lean Construction, aligning with Stage 4 of the RIBA Plan of Work 2020, titled "Technical Design." At this stage, the project team develop a detailed technical design and corresponding specifications by making it crucial to recognise and eradicate the waste to streamline the project (Ballard, 2000)

(6) **Collaborative Project Delivery**: This technique emphasises cross-functional and cross-departmental teamwork and coordination, which aligns with Stage 5 of the RIBA Plan of Work 2020, "Manufacturing and Construction." In this phase, the project team executes the designed project activities and manages the project delivery, which requires close collaboration between all stakeholders for project success (Egan, 1998).

(7) **Visual Management**: This is a Lean tool for enhancing transparency and communication, aligning with Stage 6 of the RIBA Plan of Work 2020, "Handover and Close Out." At this stage, the project teams complete the execution of construction activities and hand over the project to the client. Visual management is an essential tool for tracking progress and ensuring the quality of a project (Koskela and Howell, 2002).

(8) **Lean Supply Chain Management**: The LC technique of Lean Supply Chain Management focuses on optimising the material flow and minimising waste in the supply chain. It is aligned with stage 7 of RIBA (PoW), named "In-Use." At this stage, the project

stakeholders occupy and work the executed facility, making efficient supply chain management crucial for current operations and maintenance (Smith et al., 2020).

2.15 The Necessity for the TLC Framework:

The TLC Framework is necessary in the construction industry due to the challenges and limitations faced by project managers and stakeholders (Smith et al., 2020). Construction projects are characterised by their complex nature, involvement of multiple stakeholders, intricate processes, and tight time constraints (Ballard, 2000). So, there is a critical need for an organised and methodical approach to project management in the construction sector that can effectively streamline these complexities and ensure successful project delivery (Al-Khalil et al., 2014).

Conventional project management approaches frequently struggle to address prevalent challenges, including delays, cost overruns, and deficiencies (Koskela and Howell, 2002). Therefore, the framework must enhance project management processes by identifying deficiencies and minimising risks (PMI, 2017). Similarly, the escalating recognition within the construction industry for the value of lean construction principles in improving project outcomes (Koskela, 2000) as stakeholders intend to seek strategies for optimisation of project delivery and maximisation of the value by highlighting the need for a framework integrating lean methodologies into the developed project management framework, i.e., RIBA Plan of Work (Egan, 1998). Moreover, the clients and stakeholders emphasise transparency, sustainability, and effective collaboration in construction projects (Schmenner and Swink, 1998). Hence, the TLC Framework is preferred as a strategic solution to the requirements because it offers a comprehensive and responsive approach to project management, which can be adapted according to changing needs and circumstances (Ballard, 2000).

Conclusively, the need for a TLC Framework arose from addressing the central challenges and limitations of conventional project management techniques in the construction industry, as well as overcoming the barriers faced by lean construction. The framework aims to enhance project efficiency, mitigate risks, and deliver the best value to clients and stakeholders by integrating Lean Construction principles with the RIBA Plan of Work 2020 framework (Smith et al., 2020).

2.15.1 Theoretical Foundations for Integrating Lean Construction with the RIBA PoW 2020

The theoretical framework establishes a solid foundation in literature knowledge, supporting the research objectives. With seven key points outlined below, this section will detail various foundational theories that inform the integration of Lean Construction principles with the RIBA Plan of Work 2020.

(1) **Lean Theory:** The lean theory encompasses lean thinking and lean management, emphasising the reduction of waste and enhancement of value within processes. According to Langston and Zhang (2021), in the context of construction projects, lean construction is reflected in designing production systems to minimise materials waste, efforts, and time, thereby generating the utmost possible value (Langston & Zhang 2021). Lean theory, when applied to lean construction, also suggests practical ways to reduce waste in construction, thereby minimising time and effort through the adequate design of production and timely delivery within the supply chain system. At the same time, we are connecting the lean theory to the RIBA (PoW).

(2) **System Theory:** According to Turner and Baker (2019), this theory reflects the interdisciplinary area of investigating complicated systems within society, nature, and science. The core idea underlying this theory is that systems, regardless of their social, biological, or technical nature, are used to share common categories of principles without considering their specific characteristics (Turner and Baker, 2019). System theory determines every system component and investigates the level of interaction between them. While corresponding with RIBA (PoW), elements are covered that encompass the distinct stages, resources, stakeholders, and technologies involved in the construction project (Charef, 2022).

(3) **Project Management Theory:** This theory emphasises the development of a systematic plan, organisation, and management of resources to attain the project's goals within the determined constraints. This theory serves as the foundation for the principles and methodologies that enable project managers to manage resources, tasks, and stakeholders efficiently, as well as coordinate efforts (Tijani, Jin, and Osei-Kyei, 2023). The central element of current project management is the integration of Lean construction-related principles, which focus on reducing waste, improving efficiency, and promoting

continuous improvement. While emerging with the systematic stages of RIBA PoW 2020, lean construction principles might improve the project's outcomes by developing a comprehensive life cycle framework (Faris, Gaterell and Hutchinson, 2024). An elaborated roadmap is provided by RIBA PoW 2020 for the construction process, categorised into eight distinct stages, including strategy definition, briefing preparation, conceptual design, design development, technical infrastructure design, construction, handover, and utilisation. Every stage figures out tasks and deliverables, confirming the organised progression from the project's inception to operation and completion. Integrating lean construction-oriented principles within the framework may reduce waste, streamline procedures, and enhance collaboration, resulting in sustainable and high-quality outputs (Faris, Gaterell, and Hutchinson, 2024).

(4) **Stakeholder Theory:** This theory provides a framework for understanding the relationship between a firm and a group of individuals who may be influenced or influence the firm through its actions. Stakeholders include customers, employees, communities, and suppliers affected by the organisation's operations. Efficient management of stakeholders involves determining this group, understanding their expectations and needs, and forming strategies for engaging and satisfying them (Barney and Harrison, 2020). Applying lean construction principles, as outlined in RIBA PoW 2020, focuses on developing a robust life cycle framework for constructing projects. Such integration, visualised by stakeholder theory's lean approach, focuses on the value of involving every applicable stakeholder across the project's lifecycle to improve efficacy, collaboration, and the creation of value for them (Segara et al., 2024). In this regard, it is illustrated that the engagement of stakeholders, such as engineers, architects, suppliers, and contractors, within the design process confirms that their feedback and expertise have been effectively integrated, resulting in more feasible and innovative solutions. Asset-based and target-value designs offer continuous enhancement and optimisation of values, managing stakeholders' diverse requirements while reducing inefficiencies and waste (Segara et al., 2024).

(5) **Value-Based Management (VBM):** This theory is related to the approach and philosophy of management, emphasising the development, enhancement, and nurturing of stakeholders' values. The primary goal related to VBM is to align the organisation's strategy, decision-making processes, and resource allocation with long-term value improvement objectives. Such aspects include determining significant value drivers,

managing performance metrics, and ensuring that every organisational level adheres to value creation (Firk, Richter, and Wolff, 2021). VBM focuses not just on financial metrics but also on broader elements of values, such as innovation, customer satisfaction, and the efficacy of organisational operations. The integration of lean construction principles with the RIBA Plan of Work 2020, under the framework of value management, focuses on developing a robust framework for managing construction projects. Such integration confirms that every project phase will raise value for every engaged stakeholder (Adedotun and Pye, 2020).

(6) **Total Quality Management (TQM):** The theory encompasses a comprehensive approach to management, emphasising the continuous improvement of services, products, and procedures to achieve long-term success through customer satisfaction. The principles of TQM encompass a customer-centred organisation, a process-centred approach, total employee involvement, a systematic and strategic approach, an integrated system, fact-oriented decision-making, continuous improvement, and efficient communication (Abbas, 2020). Total Quality Management (TQM) began to be implemented within the construction industry because construction firms need to improve their efficiency to succeed in the market continually. TQM emphasises the systematic approach to logically organising, understanding, and coordinating every activity, which relies on every project team member at every level. Total Quality Management (TQM) remains the primary approach for managing competitive excellence, complementing the management process by enhancing worker and customer satisfaction through increased efficacy and productivity levels, ultimately leading to the successful delivery of high-quality construction projects (Alawag et al., 2023). Through team collaboration, TQM’s performance might improve. TQM’s application has become crucial for enhancing the productivity and effectiveness of construction organisations in today's construction industries. Constant enhancement within Total Quality Management (TQM) is regarded as improving the efficacy level for meeting customers' needs by boosting creativity, enhancing the collaborative efforts of team members, and driving organisational growth. For TQM’s successful implementation, it is essential to provide a clear and high-quality vision of the construction projects, encourage training programmes, promote a culture of quality, maintain tracking of the project’s progress level, manage cooperation and open communication, and continually improve the quality level. In this manner, the stakeholders’ satisfaction can be achieved by successfully carrying out and delivering high-quality projects (Alawag et al., 2023).

While incorporating TQM into the context of RIBA PoW 2020, it is evident that constant enhancement confirms that construction projects operate effectively and meet the needs of users throughout their lifecycles. Lean management principles assist in the ongoing tracking and assessment of performance, enabling proactive optimisation and maintenance. Gathering and evaluating performance data support the formation of informed decisions, which in turn improve the quality of the building as well as its operational efficacy (Nasereddin and Price, 2021).

(7) **Innovation Diffusion Theory:** This theory identifies five significant stages within the diffusion process, including knowledge, decision, persuasion, incorporation, and confirmation (Yuen et al., 2020). This theory focuses on the value of social systems, channels of communication, and the perceived attributes of innovations within the adoption process. Regarding RIBA PoW 2020, during the construction stage, implementing lean principles involves adopting practices such as time delivery, the last planner system, and continuous improvement. Efficient communication channels and leadership support are essential for ensuring that every team member understands and implements lean approaches (Yuen et al., 2020). The study by Martin, Watson, and Brooks (2024) illustrates that BIM's impact on architectural design processes highlights the need for a balanced approach, which enhances creativity, collaboration, and risk mitigation, as outlined in the RIBA 2020 stages. By managing the barriers of communication, cognitive biases, cultural differences, and organisational structures, it becomes possible to track the tension between BIM constraints and design freedom, encouraging the exploration of innovative design while connecting the advantages of technology across the stages of designing construction projects (Martin, Watson, and Brooks, 2024).

2.16 Summary

This chapter provides a critical review of the literature on Lean Construction and its potential integration with the RIBA Plan of Work 2020. Key findings include the benefits of Lean methodologies, barriers to their adoption, and gaps in current frameworks. These insights establish a clear rationale for developing the TLC Framework to address identified inefficiencies and knowledge gaps.

The review includes analysing the lean construction approach, its implementation challenges, and its impacts. The chapter discusses the RIBA PoW 2020 in detail, highlighting the need for a new framework incorporating lean construction principles.

Foundational theories, including Lean, Systems, Project Management, Stakeholder, Value-Based Management (VBM), Total Quality Management (TQM), and Innovation Diffusion Theory, are introduced. Each theory's relevance to construction project management and potential synergies with the RIBA PoW 2020 are examined thoroughly. The chapter concludes by summarising the main points and identifying the research gap, setting the stage for developing and validating the proposed framework.

Chapter 3 Research Methodology

3.1 Introduction

The chapter explains the adopted procedure and research method, providing sufficient details to assess the study's reliability and conclusions regarding the validation of the TLC Framework. Research is defined as a systematic process aimed at achieving specific goals. This process encompasses the methods used to gather data, ensure consistent findings, and identify any limitations that may impact the results. Achieving goals is akin to completing tasks within a specified timeframe to produce specific outcomes (Becker, 1998). Research has been defined as a scientific inquiry that is careful, fact-based, logical, objective, and organised by Sekaran (2003). It is conducted to find answers or solutions to a specific problem. Research helps collect data, enabling researchers to take the right actions to address issues and complete the research. To achieve the study's goals, this chapter outlines and justifies the research ideas, philosophical viewpoint, methodology, techniques, strategy, data collection, and analysis methods used.

3.2 Research Concept

According to Saunders et al. (2012), a well-prepared strategy that combines the most pertinent concepts and procedures with the finest techniques for gathering and analysing data to advance knowledge in line with the research goals is the foundation of any successful study. Identifying the type and design of the research are crucial elements in conducting a study. The significant aspect of the study design lies in its definition of the data collection and analysis processes (Sobh and Perry, 2006). It also requires careful examination and study of several sources to establish a logical connection between the idea and the conversation (Frankfort-Nachmias and Nachmias, 2008). The research approach in this work is guided by the "Research Onion" paradigm established by Saunders et al. (2012). This model's salient characteristics include its succinct ideas, which aid the researcher in selecting the most pertinent elements at each step. The Research Onion model is depicted in Figure 3.1 (Saunders et al., 2012).

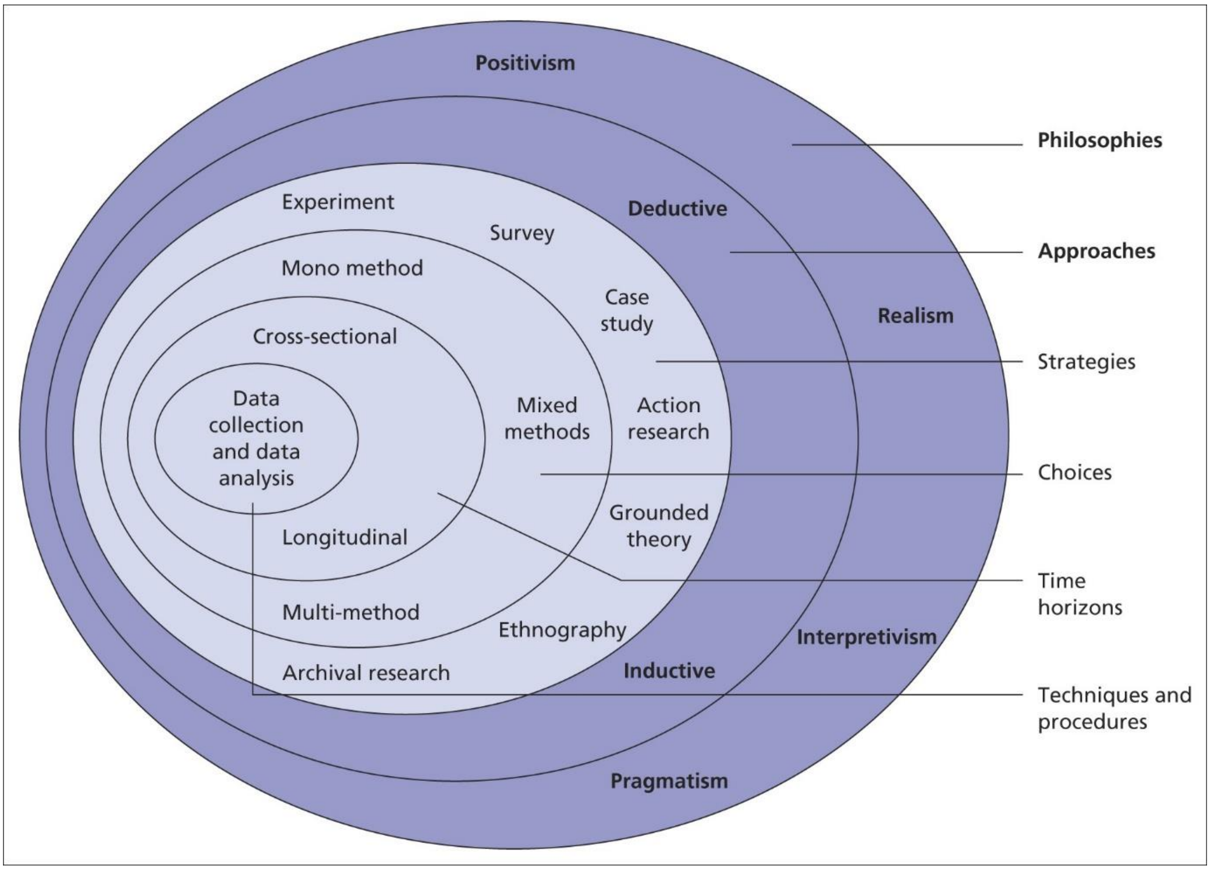

Figure 3.1: Research Onion formulated by Saunders et al. (2012).

The first layer of this paradigm, which pertains to the research philosophy employed in the study, marks the beginning of the research process. The research methodology, influenced by the selected philosophy, is the main topic of the second layer. In the third layer, various methodological possibilities are explored based on the research methodology and philosophical perspective, some of which may be adopted in the study. The fourth layer identifies the most appropriate strategy for the research. This is followed by the time horizon, determined by the study's limitations and requirements. The techniques for gathering and analysing are covered in the last layer and are given the most consideration. The research questions and decisions made at earlier levels guide the selection of one of these methodologies (Saunders et al., 2012). The many categories of research are covered in the next section.

3.3 Types of Research

The study's goal determines the type of research that aids in the researcher's organisation and structuring of the approach. The primary forms of research can be categorised into three types: exploratory, descriptive, and explanatory (Saunders et al., 2012). Additionally, three reflective models, exploratory, qualitative, and explanatory, are often discussed to align with different research purposes.

3.3.1 Exploratory Research

Exploratory research delves into an issue or topic with limited prior knowledge or insights. It focuses on generating a deep understanding of the problem and identifying potential avenues for further investigation. This flexible and adaptive method makes it ideal for uncovering new knowledge and addressing current problems (Collis & Hussey, 2009). Exploratory research often involves comprehensive literature reviews, interviews with industry experts, and informal group discussions to identify underlying issues or trends. The flexibility of this method enables researchers to modify their approach as new data emerge, allowing for the refinement of research questions and the development of a robust framework for subsequent analysis.

The chief advantage of exploratory research lies in its adaptability and openness to discovering unanticipated insights. According to Saunders et al. (2012), this approach is particularly beneficial in addressing complex problems where variables are not yet clearly defined. By employing techniques such as thematic analysis and inductive reasoning, exploratory research helps identify patterns and relationships that may otherwise remain obscured. Additionally, exploratory research lays a foundation for further descriptive or explanatory studies by providing a clearer understanding of the research context and its parameters.

Exploratory research is also instrumental in fostering innovation. As noted by Žukauskas, Vveinhardt, and Andriukaitienė (2018), it enables researchers to investigate emerging practices, offering valuable insights that may challenge existing paradigms or contribute to the development of novel strategies. This is especially important in fields undergoing rapid change, such as construction management, where integrating innovative methodologies like Lean Construction can significantly enhance project outcomes.

3.3.2 Research Application in Context

This research explores the integration of Lean Construction (LC) principles within the RIBA Plan of Work 2020 framework. The primary aim is to enhance the efficiency of the construction industry and address the challenges that hinder the effective implementation of Lean Construction (LC) practices. Exploratory research methodologies provide the foundation for this study, enabling a deep investigation into previously unexamined areas of integration and application.

The integration of LC principles has been recognised for its potential to improve cost efficiency, reduce time overruns, and enhance overall project management. However, existing literature highlights significant challenges in aligning these principles with structured frameworks, such as the RIBA Plan of Work. To address this gap, this study employs exploratory methods, including in-depth interviews with industry professionals, case studies, and thematic analysis. These approaches facilitate the identification of barriers, opportunities, and innovative strategies for implementing LC principles effectively within the RIBA framework.

Exploratory research is particularly well-suited to this context, as it allows for flexibility and adaptation throughout the study. By engaging with practitioners and drawing from diverse perspectives, this research aims to uncover practical insights and actionable recommendations for integrating LC principles. Furthermore, the methodology supports the discovery of novel applications and strategies, ensuring the relevance and applicability of findings across various project types and organisational settings.

The study also leverages exploratory research to examine the broader implications of LC integration, including its impact on project timelines, cost management, and stakeholder collaboration. By building a nuanced understanding of these dynamics, the research contributes to the development of a robust framework for Lean Construction practices tailored to the RIBA Plan of Work 2020.

Exploratory research offers a comprehensive and flexible approach to investigating the integration of Lean Construction (LC) principles within the RIBA Plan of Work 2020. Through this methodology, the study seeks to generate valuable insights and practical strategies that address current challenges and support the effective adoption of Lean Construction practices in the construction industry. The following section delves into the research philosophy, focusing on the first layer of the research onion as described by Saunders et al. (2012).

3.4 Research Philosophy

According to Saunders et al. (2012), a research philosophy is essential for comprehending how knowledge develops and where it originates. They contend that the researcher's perspective on reality and the universe is shaped by the research philosophy they have selected, linked to the theory. These theories highlight differences that influence a researcher's approach, guiding the selection and justification of strategies and methods. Easterby-Smith emphasises three crucial elements (et al., 2008) to demonstrate the importance of research philosophy in methodology. First, philosophy helps justify the research design and supports simplifying research through systematic data collection and analysis. Second, it enables researchers to explore designs most suited to their research questions. Ultimately, philosophy fosters the development of research strategies, regardless of the researcher's prior experience, based on three fundamental philosophical presumptions. Ontology, epistemology, and axiology focus on the nature of knowledge and its development, as noted by Saunders et al. (2012) and Creswell (2009). Easterby-Smith and Hong (2002) argue that a thorough understanding of philosophical concepts is essential for researchers to select, explain, and apply the appropriate research methods effectively. Creswell (2009) also contends that examining various philosophical assumptions and perspectives is especially important in the early stages of a study.

Additionally, research philosophy is closely tied to the theories the investigator explores. Two major philosophical approaches, social constructivism and positivism, are commonly discussed, although they are sometimes confused (Collis and Hussey, 2003; Easterby-Smith and Lyles, 2003). Positivism maintains that reality is subjective, while the theory of social constructivism views reality as existing objectively and necessitating evaluation by impartial means, as it is internally constructed and shaped by social interactions (Easterby-Smith and Lyles, 2003). Furthermore, a research philosophy involves five key assumptions: ontology, axiology, epistemology, rhetorical, and methodological (Creswell, 2009). Methodological and rhetorical assumptions inform the research technique and strategy, whereas epistemology, axiology, and ontology establish the philosophical viewpoint of the study.

3.4.1 Ontology

According to Heidegger (2013), Ontology is the branch of philosophy concerned with the nature of reality. An ontological position is a statement about the nature of reality as it pertains to the thing being studied. Single beliefs or a system of beliefs can be judged according to how well they meet the criteria of a coherent set of beliefs. Within epistemology, a clear ontological view helps determine the most effective methods of knowing (Mulisa, 2022). The essential points to remember are that an ontological position serves as the starting point for research and influences the choice of method, ranging from the nature of the reality being studied to the methods for gathering information about it. Fundamentally, suppose one believes that the subject has an independent reality. In that case, different methods will be employed than if one

believes that it only exists in the minds of those who live in a social context. The former would be what Giddens terms an ontological point, while the latter could be termed a contingent ontological point. In either case, it is a partisan statement regarding the nature of the reality being studied. For example, a study of Indigenous healing practices and the differences between those and formal Western medical practices would be best served by an ontological statement that acknowledges the existence and independent reality of these two entities (Brown and Dueñas, 2020). There are two categories of ontological studies: objectivism and subjectivism (Saunders et al., 2012 and they are interpreted below:
(1) ***Objectivism*** views phenomena as external objects that exist independently of human influence (Bryman, 2008). Objectivism posits that the existence of entities is autonomous from human actions, suggesting that physical laws operate independently of social actors, following a predetermined cycle or established patterns to which these actors conform. Concepts and patterns are homogeneous and general in objectivism, as noted by Saunders et al. (2009).

(2) ***In contrast***, according to Saunders et al. (2012), subjectivism posits that social phenomena are socially constructed and continually shaped by social actors. Subjectivism recognises the values people attach to a phenomenon and emphasises how individuals' perceptions and subsequent actions generate it (Saunders et al., 2009). Social phenomena change constantly as people interact with one another and their surroundings. These social views are directly reflected in the phenomena. Furthermore, Saunders et al. (2009) note that people attempt to understand and interpret their roles in these circumstances.

Hatch and Cunliffe (2006) illustrate this perspective with examples from social science and everyday life. A report from work provides a real-world illustration, promoting the question of what is genuinely occurring versus what the author perceives as happening. They highlight the challenges associated with certain phenomena, such as culture and control, and whether these exist independently or are merely felt. The conversation also explores how people define reality, raising the question of whether subjectivism, which holds that reality exists independently of actual occurrences, or objectivism is more relevant. This research provides a framework for combining the RIBA Plan of Work 2020 with lean construction techniques.

To create a solid and practical framework, this research requires the input of professionals in the construction field who are familiar with lean construction and the RIBA Plan of Work 2020. Their involvement will help confirm the proposed framework. This process will gather various responses, resulting in valuable insights. The justification for adopting the subjectivist approach in this research is that the primary objective is to validate and develop an established framework for integrating the principles of Lean Construction into the RIBA Plan of Work 2020. The adopted research purpose relies on personal experience, insights, and the expertise level of the construction domain professionals. These professionals can offer context-based and nuanced knowledge regarding the research area, which is essential for creating a workable model. Adopting a subjectivist approach is beneficial in the current research, as it provides considerable support for retrieving high-quality and detailed qualitative data by efficiently deploying methods such as case study investigations and in-depth interviews. These methods enable research participants to express their personal views, experiences, and opinions in a detailed manner. The subjectivism philosophy provides details surrounding the opportunities and problems in the direction of integration with the LC principles (Smith, 2011).

3.4.2 Epistemology

The alternative to positivist research methods is interpretivism, where data is often collected in the form of words or images and attempts to make sense of underlying meanings and patterns. Probability and causality are often considered irrelevant to interpretivist research, and knowledge is often gained through seeing and learning. This is incompatible with positivist epistemology because knowledge is deemed a conjecture based on interpretation, and action has no causal end, thus impeding coherent causal explanations. Assuming the researcher has chosen research methods that align with their ontology and epistemology, the compatibility between method and philosophy should lead to more efficient research and produce high-quality results.

Epistemology is concerned with the relationship between how we perceive and understand the world and the nature of the world itself. It is fundamentally about what and how we can know, in other words, what the essential characteristics of knowledge are and whether these characteristics are within the possession of the known (Saunders et al., 2007; Grix, 2002), in complete contrast to ontology, which deals with the nature of reality, epistemology deals with the complexity of the nature of thought. There are various schools of thought on epistemology regarding the issue of whether the object of knowledge influences the method of knowing or whether the method of knowing is independent of the object of knowledge (Ayeni, 1991). This can be simplified to the issue of whether the nature of knowledge is subjective or objective. This concept explains how views are shaped by the ideas of positivism and interpretivism (Bryman and Bell, 2011; Saunders et al., 2007).

(1) Positivism provides a precise and unambiguous understanding of reality. It alludes to what is provided (i.e., something that is real). Positivism seeks to build a better society by employing scientific methods to study individuals and society, thereby gaining insights that can be applied to enhance it. Rather than relying on conjecture, positive science uses firsthand experience. Knowledge in this field is firmly grounded in what is given and does not stem from speculation. Thus, positive science (or positivism) is defined by what is observed through scientific methods. Contemporary positivism remains closely linked to empirical science (Crotty, 1998). The perspectives of natural scientists are informed by positive philosophy, and the resulting findings can lead to general rules that are similar to those found in the physical sciences (Saunders et al., 2009). Technology and scientific advancement are viewed by positivism as

the main forces behind development. The accuracy and certainty of scientific information demonstrate confidence in the scientific method. Positivism is entirely objective. From this perspective, objects in the world have meaning, regardless of whether anyone is aware of them. Additionally, it is crucial to distinguish between subjective, unverifiable information and objective, verifiable knowledge (Crotty, 1998). Under positivism, scientists investigate problems impartially without trying to solve them. Accordingly, quantifiable observations, statistical analysis, and a methodical approach are necessary for positive philosophy (Remenyi et al., 2005). According to Saunders et al. (2009), positivism thus presupposes that researchers offer an unbiased examination and interpretation of the facts gathered.

(2) ***Interpretivism:*** Interpretivism (or phenomenology) is a view that developed as a counter to positivism, aiming to understand human and social reality. This approach seeks interpretations of social life that are grounded in culture and history. Unlike the positivist method, which employs value-free observation to uncover universal truths about humanity and society, interpretivism views the social world of business as too complex to be treated like a physical science. Simplifying it to general rules would overlook important details. Interpretivism acknowledges that each business situation is unique and different from others.

This approach is unsuitable for making generalisations because of the changing nature of organisations, various interpretations by people, and the world's complexity (Saunders et al., 2009). Interpretivism builds knowledge through subjective and descriptive methods to address complex situations rather than relying on objective and statistical approaches (Remenyi et al., 2005). Social research is complex and cannot be explained by strict laws like other sciences. Given the complexities of social sciences, the philosophy behind this research is interpretivism (Saunders et al., 2009).

Realistic research is yet another research ideology associated with scientific investigation. Unlike idealism, realism is based on the notion that reality exists independently of human thoughts and beliefs. Like positivism, realism is an epistemology that bases knowledge on science. Two varieties of realism exist, though: critical realism and direct realism. Direct realism maintains that "what we see is what we get," i.e., researchers observe the natural world accurately, suggesting that what we perceive are merely sensations of reality, requiring deeper analysis (Saunders et al., 2009).

3.4.3 Methodology (Axiological)

According to Saunders et al. (2012), axiological assumptions examine how a researcher's values affect the entire study process. Positivism claims that research should be value-free. However, social constructivism argues that researchers' values shape what is regarded as reality and the interpretations that arise from it (Collins and Hussey, 2003). Axiology examines the emotions associated with value systems and seeks to comprehend their significance (Saunders et al., 2012). According to Bryman (2008), values can be genuine throughout the study process, and the researcher may develop a sense of empathy for them. It is understood that a social phenomenon under investigation cannot be seen entirely as value-free. Because the researcher is a crucial participant in the study, their values significantly impact the methodology and overall analysis. The philosophical perspective of this study will be covered in the following part.

3.5 Philosophical Stance Adopted

The research philosophy forms the topmost layer of this examination and establishes a TLC framework for adapting lean construction principles to the RIBA PoW (2020). This study focuses on the participants' perspectives, knowledge, and comprehension of LC and RIBA PoW 2020. The research adopts an interpretivist philosophy, focusing on understanding the social constructs essential for exploration in the current research work. Deploying Lean Construction principles within the RIBA Plan of Work 2020 is not a technological practice. Instead, this research can be viewed as a social prospect that can be influenced in the direction of the subjective experiences, interactions, and views of the construction workforce. Interpretivism is further beneficial for this research, as it enables the collection of details about social dimensions in an effective manner. Interpretivism supports the retrieval and analysis of high-quality and qualitative data, which can be easily collected through the deployment of narrative insights from participants, often facilitated by interviews (Alharahsheh and Pius, 2020). The narratives gathered through the deployed qualitative method, under the interpretive framework, help to evaluate the complex realities surrounding the deployment of Lean Construction principles in the RIBA PoW 2020. The interpretivism philosophy is highly supportive of granting flexibility levels within the processes of data collection and data analysis. Interpretivism philosophy highly supports the participants, providing close insights and subjective experiences by raising questions and analysing emerging patterns and themes. Interpretivist philosophy is flexible for exploring dynamic and evolving nature surrounding construction-based strategies (Alharahsheh and Pius, 2020).

3.6 Research Approach

Creswell (2003) asserts that the methodological approach is critical in facilitating the researcher's accomplishment of their objectives. Ganesha and Sreeramana (2022) use three categories: inductive (creating theory), deductive (testing theory), and abductive, to categorise research methodologies.

3.6.1 Deductive Approach/Reasoning (General to Specific):

According to a deductive method, correct properties will lead to accurate findings (Saunders et al., 2012). This perspective comes from natural sciences, where established rules help set expectations for a phenomenon, explain its origin, and predict its existence. Therefore, these elements are quantifiable (Saunders et al., 2012). A deductive technique enables the researcher to develop a hypothesis or model, which then informs the creation of a research design to evaluate the hypothesis. Following data collection, the theory or hypotheses about the present hypothesis are analysed (Ganesha and Sreeramana, 2022). The deductive technique proceeds from the general to the particular, whereas the inductive approach proceeds from the specific to the general. This is a fundamental distinction between the two methods.

3.6.2 Inductive Approach/Reasoning (Specific to General):

The inductive approach emphasises that researchers begin by collecting data to explore phenomena, identify themes and models, and ultimately develop a conceptual framework. According to Ganesha and Sreeramana (2022), this approach generates a hypothesis based on data analysis. A vital advantage of the inductive method is its focus on the context in which situations occur, facilitating a deeper understanding of that context. In contrast, the deductive approach does not consider how people perceive the social world but concentrates on the cause-and-effect relationships between specific variables (Saunders et al., 2012).

3.6.3 Abductive Approach/Reasoning (Incomplete to Best Possible Prediction):

The abductive approach integrates both inductive and deductive methods. It explores, assesses, and clarifies relationships among variables within a context (Ganesha and Sreeramana, 2022). Consequently, the abductive approach involves moving back and forth between the inductive process (from data to theory) and the deductive process (from theory to data).

3.6.4 Choice of Research Approach

Considering these factors, this research aims to develop a framework to support the construction industry. The existing literature was reviewed to develop a framework that considers real-world conditions. The study examined and collected relevant data to understand the organisation's and participants' perspectives on the successful implementation of the TLC Framework, aiming to enhance efficiency and improve project performance. Hence, the reason behind deploying both inductive and deductive approaches is that integrating them helps achieve a detailed understanding of the research problem.

The inductive approach facilitates the investigation of new insights and the formulation of critical theories that rely on observed patterns of data. Additionally, the deductive approach facilitates the evaluation of existing theories in light of practical data. The deployment of a dual approach assures an in-depth and detailed data analysis. The initial application of the inductive approach provides flexibility to the present research, enabling the investigation of emerging themes and the exploration of new perceptions during the early stages of research (Goswami, 2010). Thus, the inductive approach is crucial for deploying a framework that focuses on exploring real-world scenarios and industrial practices. However, the deductive approach helps ensure rigidity by examining the validity of models defined inductively, using a structured method for data collection and statistical analysis. Thus, a deductive approach affirms the generalisability and reliability of the procured research findings (Woiceshyn and Daellenbach, 2018).

Table 3.1: Research Design adopted for the current study

Aspects	**Descriptions**
Definition	A research approach that combines elements of both deductive and inductive reasoning.
Purpose	Integrates the strengths of deductive and inductive approaches to provide a comprehensive understanding of the research topic.
Initial Phase (Deductive)	Begins with the application of existing theories or frameworks (e.g., principles of lean construction and the RIBA Plan of Work 2020).
Data Collection	Utilises a range of qualitative methods, including interviews and document analysis.
Analysis (Inductive)	It involves coding, categorising, and analysing the collected data to identify patterns, themes, and emergent concepts.

Aspects	Descriptions
Integration	Combines deductive insights with inductively derived findings to enrich the understanding of the research topic.
Benefits	• Provides a structured starting point based on existing theories or frameworks. • Allows for exploration of new insights and perspectives through inductive analysis. • Enhances the credibility and validity of research findings through triangulation of data sources and methods.
Challenges	• Requires careful integration of deductive and inductive components. • This may necessitate additional time and resources for data collection and analysis

The study's methodological and research choice involves considerations of both theoretical underpinnings and practical research design aspects. Methodology encompasses the overall approach to research, including theoretical assumptions that guide data collection and analysis strategies. Methods specifically pertain to the techniques used for data collection and analysis. Saunders et al. (2009) categorise data collection and analysis methods into qualitative and quantitative approaches. Qualitative methods involve non-numeric data collection techniques, such as interviews, whereas quantitative methods utilise numeric data collection methods, including surveys.

Mono-method research involves a single approach to data collection and analysis, either quantitative or qualitative. In contrast, a multiple-method approach combines different data collection and analysis techniques. This approach can be further categorised into mixed-method and multi-method designs, where mixed-method involves combining qualitative and quantitative techniques within a single study.

As Holloway and Wheeler (2002) emphasised, qualitative research aims to understand phenomena in context without manipulation. It relies on textual interpretation through techniques such as interviews and observations. This study employs semi-structured interviews to collect qualitative data on integrating Low Carbon (LC) principles with the RIBA Plan of Work (2020) to validate the TLC framework. To achieve this, semi-structured interviews were conducted to gather qualitative data. The data were analysed using a triangulated approach, allowing the researcher to consider contrasting views and make comparisons among the findings, which helped validate the analysed data. This research aligns with subjectivism, interpretivism, and value-laden philosophies; therefore, inductive and deductive approaches were chosen. The qualitative approach was deemed the most suitable for fulfilling the study aim, utilising interviews and case studies as essential data collection methods within the qualitative methodology (Kumar, 2012).

3.7 Available Options for Research Methods

3.7.1 Research Strategy

Once the philosophy and approaches have been established, various strategies that apply to the research process are examined. To maintain consistency throughout the study, the chosen strategy must be aligned with the philosophical stance and research approach. A strategy provides the researcher with a plan of action or a roadmap to translate the research aims into achievable outcomes (Yin, 2009; Saunders et al., 2009). The primary goal of this study is to establish the TLC Framework. Figure 3.2, displayed below, presents the research roadmap, which has been developed to reveal the purpose of selecting these four methods for specific objectives.

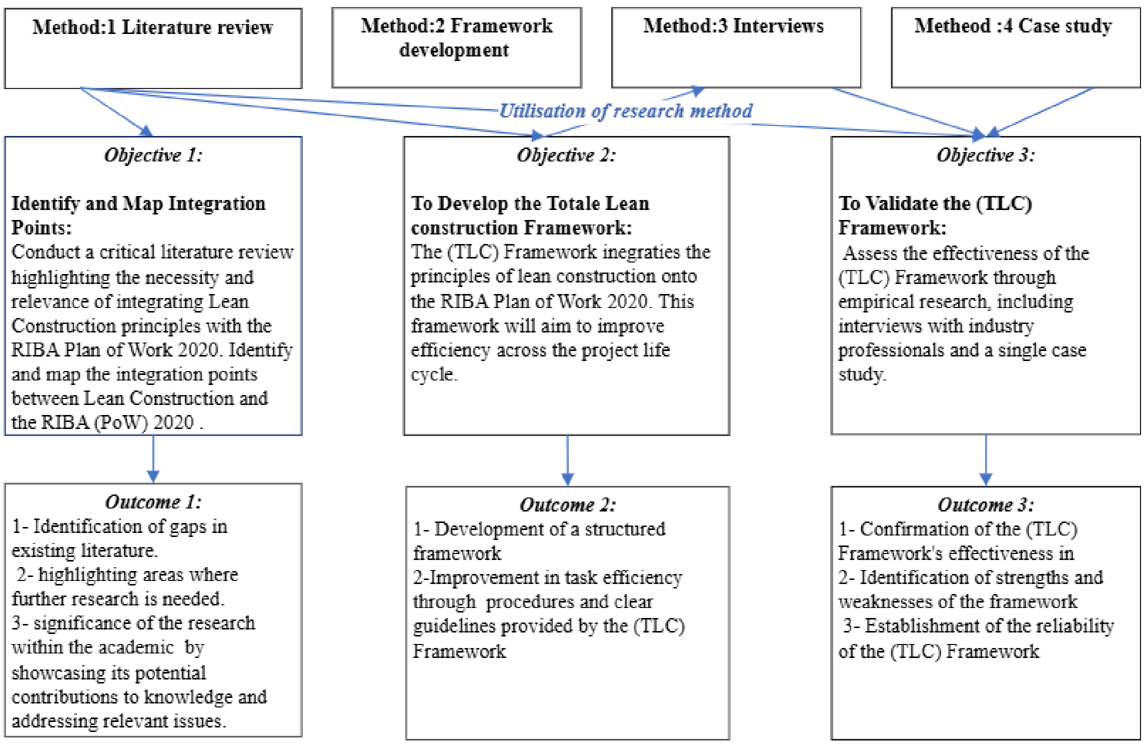

Figure 3.2: The research roadmap for utilising the four methods for obtaining the objectives

3.8 The Chosen Methods

3.8.1 Method 1: Literature Review

A literature review aims to identify gaps in the field of study, which facilitates the formulation of research questions and the discovery of sufficient and appropriate responses through empirical investigation (Eisenhardt and Graebner, 2007). According to Saunders et al. (2009), a literature review facilitates the development of concepts through research and current information, thereby aiding in the formulation of a solid aim and objectives. Furthermore, integrating existing literature helps develop an engaging discourse that validates the investigation and identifies the underlying obstacles that might influence the research issue. Furthermore, the literature evaluation focuses on the descriptive aspects of various articles and journals rather than considering narrative critiques and data sources (Gill et al., 2010). A literature review was conducted to identify the central knowledge gap. According to Bell et al. (2022), a literature review goes beyond merely repeating theories and the opinions of previous scholars and understanding historical theories; it aims to utilise these notions to further a particular viewpoint or conversation. This study's literature review addressed the information gap regarding the implementation of LC within the construction industry and gathered secondary data to establish the TLC framework. Therefore, the literature on LC procedures, adoption elements, guidelines, and frameworks were included in the literature study to understand current ideas and the situation.

The literature review conducted in Chapter 2 provided the researcher with a deeper understanding of lean construction, its implementation challenges in the construction industry, and the latest version of the RIBA PoW released in 2020. It covered a wide range of themes related to RIBA and lean construction. By focusing on keywords like "lean construction," "construction management," and RIBA PoW 2020, the researcher conducted searches across various reputable databases, including the University of Strathclyde Library, CIRIA, British Library, Google Scholar, IEEE, ICE, Web of Science, LCI, and Science Direct, among others. This comprehensive review formed the basis for selecting the incorporation of the study's RIBA PoW 2020 and lean construction.

Using the literature review method for this research is justified, as it enhances the credibility of the present research by highlighting that the projected research is based on a firm foundational base created from existing sources of information. The literature review is beneficial for research workers, offering well-informed insights into previous theories, secondary studies, and theoretical data findings to establish a critically grounded framework (Snyder, 2019).

3.8.2 Method 2: Framework development

This second method stage was the development of the framework. Following the activities in Stage One, the integration framework between Lean Construction and RIBA PoW 2020 will be discussed (Chen, Atweijeer, & Galvin, 2019). is aimed at achieving better results than could have been achieved by either of them, especially in terms of maximising value while reducing the project's cost and resultant wastage (Fletcher and Satchwell, 2019). It is, therefore, imperative that many areas of the work plan be streamlined to align with the resulting integration framework, allowing for a smooth process. Each of these will, therefore, be systematically achieved by taking the integration process through all eight stages of the project cycle. Theories from Lean Construction and other frameworks are utilised in this process to interpret information, providing guidelines for integrating Lean Construction with the RIBA Plan of Work 2020. (Refer to Chapter 2).

(1) Theory of project, where a project is defined as the process of transforming inputs into outputs. Here, the approach of breaking down the project into sub-areas, which are then to each be completed and adequately done in time, is taken (Royal Institute of British Architects, 2020). It is considered here that the quality of a project's various tasks determines its overall quality and that improving the quality of these tasks can lead to enhanced project quality.

(2) Theories of planning and management, where project personnel are grouped into managerial and effector categories based on the level of their responsibilities in the hierarchy of roles (Aslam et al*.,* 2020). The managerial positions are responsible for outlining responsibilities for the effectors and ensuring necessary follow-up to ensure that the work is completed to the required standards within the stipulated time. In contrast, the effectors must execute the project plan and carry out the tasks required to meet the project's objectives (Fletcher and Satchwell, 2019).

(3) The theory of execution involves the role of managerial personnel in distributing tasks to various workstations within the project and ensuring that teams fully understand the required outcomes for each task (Ostime, 2022). The managerial position holders keep

track of when specific tasks are scheduled to take place, providing authorisation where necessary for the tasks to begin.

(4) According to Sinclair (2019), the theory of control stipulates that an oversight group must supervise every stage of the project to ensure adherence to the correct standards throughout its execution. This oversight enables the prompt correction of mistakes, ensuring the project can be realigned to meet its original standards.

3.8.3 Method 3: Data collection and information acquisition (interviews)

The data is gathered through the analysis of semi-structured interviews. A purposeful sample of 19 out of 25 experts in the field of construction participated in the framework validation. Semi-structured interviews were used to gather qualitative data for this research. Additionally, case studies were conducted (refer to Chapter 5). The data was gathered and examined, and the key conclusions were compiled (refer to Chapter 5).

The primary method for gathering information was conducting interviews. Various interviews, including face-to-face and telephone interviews, were employed to gather input from potential users. Based on these findings, the framework was subsequently refined.

Applying the interview method enabled the gathering of illustrated qualitative information, which is crucial for understanding how the principles of the lean concept may emerge within the distinct levels of RIBA PoW 2020, a comprehensive and elaborative framework. Interviews allowed for acquiring experiential knowledge that might elaborate the genuine reasons for which the lean principles might or might not be applied on the distinct levels of RIBA PoW 2020; the interview of professionals covered within the projects of construction, for example, contractors, project management and architects, offers access to practical insights as well as expert knowledge (Hatch, 2023). Their real-time experiences might depict the practical opportunities and challenges of integrating lean principles. The interview offers the flexibility of exploring in-depth fields by posing logical and sequential queries during the interaction with participants. It is specifically helpful in elaborating complex and novel applications of integrating lean principles within the RIBA (PoW). In this manner, the interview approach has been identified as suitable and appropriately applicable for this research project (Hennink et al., 2020).

Interviews have also been valuable for triangulating and validating information from diverse sources, such as case studies and literature-based investigations. These aspects enhanced the reliability and credibility of the research findings. Interviews have provided practical suggestions for enhancing the integration of lean principles and deploying the RIBA framework to improve project outcomes and efficacy. Interview-based outcomes have informed the development of training programs and policies for effectively helping practitioners adopt lean construction practices within the framework of RIBA PoW 2020 (Hennink et al., 2020).

3.8.4 Method 4: Case study (What if scenario)

Case studies promote an in-depth examination of specific cases related to the study topic. When resources limit research, the extent of comprehensive data collection may restrict the number of investigations that can be examined. Case studies can be selected based on their representativeness, like the principles employed in statistical sampling, to represent the population accurately, highlight specific aspects of the subject, or illustrate the range of options. Research using case studies can effectively achieve this by combining various data-gathering techniques.

The approach to the case study also provides a vital assessment of how lean principles can be implemented throughout the entire RIBA Plan of Work, spanning from initial planning to final construction. Case studies provide an opportunity to observe the practical application of lean principles in completed or ongoing construction projects (Okoko, Tunison, and Walker, 2023). The real-life application offers essential insights into the practical application of lean principles in the context of the RIBA PoW 2020. By evaluating real-life illustrations using the case study method, the research focuses on determining the most efficient practices, effective integration strategies, and familiar challenges. Such findings may significantly assist professionals in the construction industry in seeking to improve productivity by applying lean principles. The case study approach provides a robust and rigorous examination of how such principles can be integrated throughout the entire RIBA PoW 2020 and for post-occupancy assessment (Savin-Baden and Major, 2023).

3.8.5 Time Horizon

Saunders et al. (2012) classify research time horizons into two main types: cross-sectional and longitudinal. The cross-sectional approach focuses on examining a specific phenomenon at a single point in time, whereas the longitudinal approach involves gathering comprehensive data over a longer duration. The timeframe for this research is set for an academic year, as the study is conducted within an educational programme. The researcher aims to develop a TLC framework, so this research adopts a cross-sectional time horizon. The following section will discuss the methods used for data collection.

3.9 Data Collection Methods

The research methodologies that comprise the data gathering and analysis procedures are considered in the final layer of the Research Onion, as proposed by Saunders et al. (2012). This study employs qualitative research to clarify the various aspects of the phenomenon, refine some reasonable assumptions that arise from the findings, and gather validated data. The following list of primary data-gathering techniques includes interviews and secondary information. Saunders et al. (2012) confirm that secondary data can be either qualitative or quantitative, which may also be gathered through survey research and case study techniques. Numerous sources, as well as surveys, can be used to get this data. Recorded sources, such as meeting minutes, recorded discussions, diary entries, project reports, books, magazine articles, and public and organisational records, are used to create documented secondary data. Moreover, non-written materials, such as illustrations, movies, photos, audio and video recordings, television shows, and company databases, are used in documentary supplemental information (Robson, 2002). Both qualitative and quantitative analyses might be performed on such data. However, secondary data is primarily employed in triangulating conclusions based on added knowledge obtained through questionnaires and interviews, two methods of data collecting. For this study, semi-structured interviews and case study methods were employed to validate and assess the utility of the framework that was constructed.

A semi-structured interview approach offers a balanced blend of open-ended responses and guided questioning, providing flexibility for both the interviewer and participants. This method enables the interviewer to explore specific areas of interest in greater depth while also allowing participants to introduce new insights, such as those related to integrating lean principles within the RIBA Plan of Work 2020 (Hatch, 2023). Furthermore, using the case study method to investigate the applications of lean principles and relate them to RIBA PoW provides a robust technique for understanding and enhancing the efficacy of construction projects. The retrieved insights provided genuine and valuable assistance in the successful adoption and incorporation of lean practices for managing construction projects in contemporary times (Hennink et al., 2020).

The case study is also helpful in integrating knowledge from multiple sources, such as archival records, documents, observations, interviews, and physical artefacts. Such triangulation improves the reliability and validity of the data findings. The case study also provided concrete illustrations and trustworthy findings, making the theoretical concepts highly relatable and understandable (Hatch, 2023). These might help illustrate and demonstrate the practical application of the theories. Combining semi-structured interviews and case studies provided a robust methodological framework for researching and investigating lean construction principles and RIBA PoW 2020. Such an approach helped provide comprehensive knowledge of the subject area and capture valuable insights and complexities that could inform real-time practices and the scope of upcoming research work (Hennink et al., 2020). In Chapter 5, the validation procedure and analysis are fully described and discussed.

3.9.1 Qualitative Methods of Data Collection

Saunders et al. (2012) declare that the primary goal of qualitative data-collecting techniques is to develop, acquire, record, or utilise non-statistical data through personal observation, comprehensive group discussions, and semi-structured conversations. Using a qualitative data collection approach, the researcher can acquire detailed data and information (Collins and Hussey, 2003). An interview is a deliberate conversation between two people in which the interviewer poses questions, and the interviewee responds. Interviews also support the researcher's collection of data and subsequent validation of the information gathered to address the study's questions and goals. According to Saunders et al. (2012), interviews can be divided into three categories: informal, semi-structured, and formal.

3.9.2 Type of interviews

(1) Structured interviews

As Park and Ahn (2012) noted in their research on strategic environmental management in the construction sector, conducting additional interviews based on the findings will enhance the study's objectivity. Their previous research used content analysis to establish criteria for sustainable construction. The referenced interviews, commonly referred to as researcher-administered questionnaires or structured interviews (Kumar, 2011), consist of questions designed to elicit specific responses from participants (Fraenkel and Wallen, 2006; Gill et al., 2008). According to Gill et al. (2008), these questions are typically straightforward and provide respondents with a predetermined set of options. Participants check the appropriate box to indicate their answers. This format ensures that the same questions are posed consistently during each interview, allowing for comparable responses from study participants. Additionally, all participants are asked the questions in the same context, facilitating the aggregation of their responses and enabling sample comparisons for relevant analysis. The researcher can still gather additional information during the interview to address the research questions (Idris, 2010).

Utilise questionnaires, which typically include a prepared list of questions. Because these interviews collect and analyse statistical data, some refer to them as quantitative investigation interviews, whereas Saunders et al. (2012) refer to these as interviewer-administered questionnaires. A preset and standardised list of questions is used in structured interviews; these questions are frequently asked in the same way and format. According to Gill et al. (2008), structured interviews are beneficial when it is necessary to clarify a specific subject or when there may be potential reading or arithmetic problems with the participants. According to Gill et al. (2008), planned interviews provide only limited participant replies; as a result, they are not helpful when comprehensive data are required for the study.

(2) Semi-structured interviews

Semi-structured interviews are used to gather primary data because they provide greater flexibility in the interview process and facilitate the collection of in-depth information on the topic. These interviews are often classified as qualitative research methods due to their lack of standardisation (Saunders et al., 2012). According to Clifford et al. (2010), semi-structured interviews encourage the interviewer to use pre-planned questions while promoting a conversational approach, allowing respondents time to reflect on the significant events or themes.

These interviews focus on specific themes discussed informally, making them practical for investigating and understanding the sources of people's attitudes, decisions, and behaviours, as well as how particular circumstances and events have shaped their lives. Semi-structured interviews often yield insightful and unexpected findings (Raworth et al., 2012).

Britten (1995) and Gill et al. (2008) also note that informal interviews include vital questions that outline areas for further exploration. This allows the interviewer and interviewee to deviate from the script to delve deeper into a concept or response. This flexibility enables the researcher to ask follow-up questions based on answers that appear particularly relevant (Bryman, 2004).

(3) Unstructured interviews

These are regarded as casual and are used to delve deeply into a shared interest. A preconceived questionnaire list is unnecessary; the researcher must thoroughly understand the topic they plan to study. Interviewees are, therefore, allowed to express their opinions and ideas on the matter (Saunders et al., 2012). Instead of using preset questions created by the researcher, unstructured interviews offer a system of talks fundamentally directed by the respondents. According to DiCicco-Bloom and Crabtree (2006), unstructured interviews are typically employed when an investigator seeks to understand a particular occurrence within a specific setting fully. These interview formats are thus mainly employed in qualitative studies.

According to Naoum (2012), conducting interviews is a crucial method for gathering accurate information and understanding people's inner perspectives. In-person interviews are the norm, and the interviewer asks questions of the subject to elicit information relevant to a specific field of study. Interviews are commonly used to investigate people's beliefs, attitudes, factual knowledge, experiences, and understanding. According to Zhang and Wildemuth (2009), interviews are a valuable strategy for gathering qualitative data and represent one of the most comprehensive approaches in qualitative research. An interview serves as a conduit for information between the interviewer and the respondent, who knowingly seek information or delve into a particular topic of interest (Wengraf, 2001). According to Yin's (2009) perspective, interviews are among the most crucial tools for gathering data, as they yield comprehensive and accurate information based on the perspectives and understandings of interviewees through interactions with others (Blaikie, 2011). In addition, interviews cover a range of questions classified as empirical or statistical; in other words, they are associated with interpretivism and positivist ideologies (Britten, 1995). According to Saunders et al. (2009), conducting interviews aids the researcher in acquiring exact and valid data that satisfies the goals and addresses the study questions.

Semi-structured interviews are chosen to validate the research on Lean Construction and the RIBA PoW 2020 due to their ability to prompt detailed insights, offer flexibility in questioning, engage participants actively, provide opportunities for clarification, and support triangulation with other data sources. These interviews enable a comprehensive exploration of participants' experiences and feelings, thereby enhancing the credibility and validity of the research findings within the construction industry context.

3.9.3 Population and Sample Selection

This study aimed to integrate the principles and techniques of lean construction into the delivery of construction projects across various stages. The participants included people knowledgeable about lean construction and the RIBA Plan of Work for 2020 in the UK, specifically to validate the TLC framework. Out of twenty-five interviews conducted, 19 participants met the required criteria. These included project managers, site supervisors, and civil engineers.

The aim of this qualitative research guided the choice of participants (Shaheen and Pradhan, 2019). A larger sample size could have made the research harder for a single researcher, while a smaller size might have limited the ability to apply the findings more broadly. However, since this is a qualitative study, the goal was not to generalise but to provide valuable insights and understanding of the topic (Shaheen and Pradhan, 2019). The small sample size is typical for qualitative research (Sim et al., 2018) and allows for a more detailed study (Francis et al., 2010). Additionally, the specific focus of this research necessitated a smaller sample size to achieve the study's goals effectively.

Three essential criteria listed below are used to find the participants who are familiar with lean construction and the RIBA PoW 2020 to describe their understanding and validate the TLC Framework:

Criterion 1. *Must have experience with lean construction.*

Criterion 2. *Must have experience with the RIBA Plan of Work as of 2020.*

Criterion 3. *Willing to answer all the questions asked by the researcher.*

3.9.4 Interview Protocol

The protocol provided essential guidelines for conducting the interviews, covering questions, techniques, and ethical considerations. Knox and Burkard (2009) emphasised that interviews aim to understand others' experiences and the meanings they assign to those experiences.

Therefore, developing a robust protocol is vital for achieving research goals and ensuring quality responses (Naoum, 2012).

Before receiving ethical approval from the university, an invitation consent letter for participation was prepared (see Appendix 4) and sent to potential respondents. Once they expressed interest in participating, arrangements were made to conduct the interviews. This step is crucial as it guarantees the confidentiality of participants' responses. The interview instrument comprised three sections, including:

- Section A on the participant's backgrounds,
- Section B on Knowledge of Lean Construction and RIBA PoW 2020, and
- Section C on Lean Construction and RIBA PoW 2020.

3.9.5 Interview Session

Kvale (1996) outlined ten criteria that enhance the quality of an interview:

1. The researcher should have a solid understanding of the subject area.
2. communicate the purpose and intent of the interview to the respondents.
3. Be open and flexible in your approach with the interviewees.
4. Relate your questions to what the interviewees have previously mentioned.
5. Exercise patience with the interviewees.
6. Be prepared to challenge the interviewees' statements when necessary.
7. Use questions and prompts to guide the discussion.
8. Respond to what the interviewee finds important.
9. Provide a summary of the key points discussed during the interview.
10. Ensure that the process fosters a collaborative atmosphere

The criteria mentioned earlier were adhered to during the research interviews. The researcher emailed three colleagues at the University of Strathclyde to gather feedback on the interview structure and ensure that the questions addressed all necessary aspects to validate the framework. Based on this feedback, the researcher revised the interview questions.

The interviews were conducted in neutral locations familiar to the respondents, such as their offices or workplaces. However, many participants preferred to be interviewed via Zoom or telephone due to time constraints and distance. Out of the nineteen interviews conducted, seven were held on Zoom, five were conducted by phone, and seven were face-to-face. The duration of the interviews varied, typically lasting between 30 and 45 minutes, with an average of 33 minutes and 16 seconds.

Before each interview, participants were asked for permission to record the session. Seven interviews were recorded using a digital application, while the others were documented with handwritten notes. At the end of each interview, the researcher encouraged participants to share any additional thoughts they felt were relevant to the study, often leading to valuable insights and new topics. Many interviewees expressed interest in receiving a copy of the completed research, which was a positive sign.

3.9.6 Interview Transcription

Seven of the interviews were transcribed with great care. While this process was challenging, it was a valuable learning opportunity. Transcribing the interviews helps ensure that essential participant responses are not overlooked (Bryman and Cramer, 2012), allowing for a detailed data analysis to highlight key insights. This study transcribed each of the seven interviews right after the session.

3.9.7 Interview Data Analysis Process

Researchers agree that there is no strict method for analysing qualitative data, unlike the narrower approaches often seen in quantitative studies. This flexibility arises from the nature of the data and the researcher's creativity (Henn et al., 2006; Berg and Lune, 2014). Standard techniques for analysing qualitative data include thematic analysis and coding (Bryman and Cramer, 2012; Saunders et al., 2012). In this study, the focus was on gathering data through interviews to validate the framework that had been developed. The transcribed interviews were organised into data sets and analysed using a descriptive-analytic process.

3.9.8 Case study to validate the TLC Framework design and selection of case study

The case study technique is suitable for exploratory studies when the investigation aims to explore rather than quantify. The case study provides in-depth information, aiding in the understanding of the concept (Ranjit, 2011). According to Rowley (2002), case study designs may be divided into two groups: integrated (many) and holistic (single), which correspond to the number of case studies that contribute to the overall structure and the unit of examination in each case study. Numerous case studies are chosen because they highlight the similarities and contrasts between the examples (Gustafsson, 2017), and the combined results would yield compelling findings (Rowley, 2002). Following the completion of interviews, the TLC Framework underwent further improvement through a case study centred on (what if) scenario within the construction industry aimed at validating the developed TLC Framework.

3.9.9 Case Study Selection

This research study was meticulously planned and carefully selected its cases. This was chosen carefully to represent various viewpoints throughout the project life cycle. The Crossrail Railway Construction Project was selected as a case study to demonstrate how lean construction, and the RIBA Work Plan 2020 are applied. Can effectively operationalise projects. The project should be implemented as a model because it integrates the principles of the RIBA work plan and the lean construction mechanism to design, develop, and construct the project. Based on pertinent considerations related to a case-study methodology, as stated by (Creswell, 2012; Bryman and Cramer, 2012) and (Yin, 2014). This study focuses on a specific case study, the Elizabeth Line (also known as the Crossrail project) in London, UK. The author aims to investigate how the TLC Framework can be effectively applied by conducting an experimental case study centred on this significant infrastructure project.

This methodology will facilitate the analysis and comprehension of the most efficacious tactics. The Elizabeth Line, a brand-new urban train service that began operating in mid-May 2023 through the centre of London, is part of the ambitious and well-known Crossrail project. Significant skills are required to overcome the project's organisational and technological challenges throughout its anticipated ten-year design and construction period. Although Crossrail Ltd (CRL), the client, is responsible for completing the project, it faced several difficulties. The integration of several interconnected systems and the shift to the functional changeover period, particularly regarding the research question or procedure under investigation, stood out the most. (Pollalis and Lappas, 2019; Muruganandan et al., 2022).

Crossrail was chosen for this study because it is a prime example of a complex project. It demonstrates the significant challenges in integrating the components of a system of this magnitude. The opportunity to investigate how stability and adaptability are managed within existing structures and procedures while staying adaptable to unanticipated and changing situations during the project execution life cycle was another benefit of this study (Muruganandan et al., 2022) another critical reason for selecting the Crossrail project is the Crossrail Learning Legacy Programme which was established in 2010 to capture, develop and share the wealth of knowledge and experience generated by the Crossrail project and apply these learnings to future projects both within the UK and internationally. The initiative represented a unique opportunity for the global construction industry and others to learn from the significant undertaking, ensuring that the skills and knowledge remain in the industry and are transferred to future significant projects in the UK.

The lessons learned can generate safety, economic, and environmental benefits and catalyse innovation in tunnelling and underground construction. Crossrail set out to lead the field in these areas, and the legacy activity helps ensure that this becomes a reality in practice and theory. The Learning Legacy provides a fully referenced information resource to help organisations overcome the challenges faced by significant projects. It captures a vast array of knowledge in a user-friendly online format and makes this available to anyone who wants to access it. The case studies, technical papers, and reports, as well as descriptions of innovations and decisions made, can enable others to understand whether Crossrail's approach is relevant to their project and, if so, how they should proceed.

Crossrail's transparency in documenting its experience, "warts and all," provides a valuable resource for academic research into project management and delivery. The legacy of Crossrail extends beyond the infrastructure created to encompass the people, their knowledge and expertise, as well as the processes that have been developed and refined. To this end, the learning legacy has focused on capturing the knowledge and experience of the programme in an informative and easily transferable way. Crossrail has identified that documenting meaningful and high-quality case studies is the most effective way to achieve this. Using the Learning Legacy, the author has defined the challenges faced by Crossrail and how the TLC Framework can overcome these challenges.

In this research, the author first searched for documents in public networks and found thirty-seven results. These documents included papers, articles, books, technical papers, brief reports, videos, audio recordings, and best practice documents. After filtering, he carefully decided which documents to include and exclude. He ended up analysing twenty-five documents. The complete list of these twenty-five documents is on page 181 in Chapter 5.

3.9.10 Inclusion and exclusion criteria

According to Dekkers et al. (2022), ensuring that the sources are relevant and undertaking the selection process carefully is crucial. The author has ensured that relevant sources are selected systematically in this research. This involves scanning sources based on their title, abstracts, and content. The standard criteria for inclusion and exclusion are presented below. Table 3.2 shows the inclusion and exclusion criteria.

Table 3.2: Inclusion and exclusion criteria were adopted for the study

Inclusion Criteria	Exclusion Criteria
Data on project procedures, methodologies, and results	Unnecessary or duplicated information
Data specifically about the Crossrail project	Information not related to the Crossrail project.
Documents, reports, and case studies yield substantial details about cost overrun, overtime, and stakeholder engagement within the Crossrail project. Sourced data from project reports, academic publications, official project documentation and developed industrial publications.	
Information on project management practices	Data from unofficial or unverified sources

By applying the inclusion and exclusion criteria mentioned, the researcher ensures the relevance of the collected data and aligns it with the research objectives of validating the TLC Framework within the “Crossrail” project.

3.10 Data Analysis for the Case Study

This study emphasises the importance of collecting data suitable for the research objectives (Smith et al., 2020), and the researcher plays a critical role in understanding the collected data, particularly for data analysis (Jones and Brown, 2018). This study uses document analysis to scrutinise the case study. Document analysis involves examining multiple documents, such as those stored on computers or the internet (Bowen, 2009). It helps us understand and learn from documents, which can be official records, personal writings, or physical objects.

Document analysis is a valuable tool for research of this nature. It helps researchers gain a better understanding of things (Stake, 1995). It is also easy to find documents, which makes it an effective way to collect information. Document analysis involves steps like reading and understanding. It helps organise information and find patterns in it. During analysis, researchers stay fair and sensitive (Bowen, 2009).

Thematic analysis is all about finding patterns in the data. These forms, called themes, form the basis for analysis (Fereday and Muir, 2006). This process involves carefully re-examining the data. The reviewer closely examines selected pieces of data, labels them with codes, and categorises them based on their characteristics. This helps extract themes that are important for understanding the topic being studied. (Refer to Chapter 5 for the complete case study analysis.)

The rationale for using the thematic method is that it is adaptable to various research queries and categories of qualitative information. Such flexibility is crucial for exploring diverse perspectives and levels of experience regarding the lean principles within the RIBA PoW 2020. The thematic analysis enables the identification of both implicit and explicit inferences derived from knowledge based on the qualitative method (Tunison and Walker, 2023). Such depth is crucial for capturing the nuanced and complicated experiences of personnel engaged in construction projects. The approach offers a structured procedure to categorise and codify data, confirming an in-depth analysis. As a systematic approach, the thematic approach facilitates the identification of significant themes related to the challenges, implementation, and effects of lean principles. Through emphasising the themes and patterns, the thematic analysis provided an in-depth understanding of the differences and commonalities within stakeholders' experiences. In this manner, this method has proven essential for identifying potential hurdles and best practices related to lean principles of efficient integration (Hutter and Bailey, 2020).

3.10.1 Ethical Approach to the Research

To meet the requirements for a doctoral thesis at the University of Strathclyde, researchers must adhere to the university's established ethical standards. An application was submitted to the Departmental Ethics Committee in Architecture, and permission to conduct the research was granted. The approval letter is included in (Appendix 2). In line with research ethics, the researcher is obligated to handle and share the collected data responsibly, ensuring the anonymity and confidentiality of the respondents while safeguarding their privacy.

3.10.2 Validity and Reliability

Obtaining accurate data and valid findings (Creswell and Miller, 2000). Reliability refers to the consistency with which a study produces precise results. Given that this research gathers qualitative data, the researcher must address several issues related to validity and reliability that may arise during data collection (Sutter-Dallay et al., 2011). These concepts focus on minimising bias in qualitative research (Golafshani, 2003). Additionally, Yilmaz (2013) emphasises that reliability and validity can be ensured by adhering to specific criteria during data collection and analysis. To achieve this, the researcher provided detailed and concise descriptions of the study findings, which facilitated a thorough discussion of all aspects of data collection, making the results more reflective of reality.

In addition, the researcher sought input from senior colleagues and professionals well-versed in the study to obtain a neutral evaluation of various aspects, such as the alignment between the research question and the data and the depth of analysis and interpretation. This additional step will enhance the overall validity and quality of the study (Creswell, 2014; Silverman, 2015).

The reliability of the collected data was also crucial. Initially, the researcher carefully reviewed all the data, excluding documents irrelevant to the study context. During this phase, the researcher thoroughly read the documents to confirm the accuracy of the information. The reliability of the collected data was also critical, as the researcher initially carefully reviewed all the data, excluding irrelevant documents that were not relevant to the study's context. The researcher thoroughly reviewed the documents at this stage to verify the accuracy of the information. Subsequently, in the next step, the researcher reread the documents multiple times, even after coding, to ensure that the codes had not altered their definitions or meanings throughout the coding process (Gibbs Jr., 2008). This meticulous approach aimed to maintain the reliability of the data collected.

3.11 Summary of Research Methods

Table 3.3 summarises this study's primary research theories, techniques, methods, and their purposes and justifications.

Table 3.3: Summary of Research Methods

Theory/Technique/Method	Description	Purpose in Research	Justification
Literature Review	Comprehensive analysis of existing work in Lean Construction and RIBA PoW 2020	Identify knowledge gaps and integration opportunities	Provides a foundational understanding of the field, guides framework development, and ensures alignment with existing academic discourse.
Framework Development	The iterative process of designing the Total Lean Construction (TLC) Framework by integrating Lean principles and RIBA PoW 2020 stages	Develop a comprehensive and systematic guide for enhancing project efficiency across all lifecycle stages.	Ensures that theoretical findings and empirical insights are systematically translated into a practical, scalable, and validated framework.
Qualitative Interviews	Semi-structured discussions with industry professionals	Gather practical insights and validate theoretical findings	Ensures the research framework accurately reflects real-world industry challenges, effectively bridging theory and practice.
Case Study Analysis	Detailed examination of the Crossrail project	Evaluate the practical applicability of the TLC Framework	Demonstrates how the proposed framework can address real-world project issues, providing empirical validation and context.
Thematic Analysis	Analytical method for identifying and interpreting patterns in qualitative data	Ensure a structured approach to analysing interview and case study data	Provides systematic insights to interpret and organise qualitative findings effectively.
Descriptive Analysis	Quantitative and qualitative analysis of collected data	Validate the TLC framework through measurable evidence from the Crossrail case study	Strengthens the empirical foundation of the research outcomes, providing robust evidence for the framework's applicability.

3.12 Chapter Summary

This chapter emphasised the significance of research methodology in a thesis, detailing the chosen research philosophy, approaches, strategies, data collection methods, and techniques. Careful thought was given to selecting the most suitable philosophical stance, research approach, strategy, methods, techniques, time horizon, and data collection methods. The philosophical stance aligns with subjectivism, interpretivism, and value-laden perspectives, recognising that social actors shape social phenomena. These actors’ relationships with the phenomena depend on their subjective perceptions, which can be influenced by personal opinions and values.

For data collection, semi-structured interviews and case studies were used, as these techniques allow the researcher to gain a deeper understanding of the topic and gather more detailed and accurate information. The data analysis employed descriptive analysis for the interviews and thematic analysis for the case studies. Both methods were instrumental in validating the TLC framework. The next chapter will discuss the development of the framework.

Chapter 4 Framework Development

4.1 Introduction

This chapter presents the development of the Total Lean Construction (TLC) Framework, focusing on integrating Lean Construction (LC) principles with the Royal Institute of British Architects RIBA Plan of Work (PoW) 2020. The chapter is structured to guide the reader through the key steps and stages adopted to create the framework, emphasising its development, rationale, and implementation. A concise outline of these stages includes the motivation, integration methodology, framework design, and practical considerations.

Implementing lean concepts in construction endeavours aims to enhance project valuation, reduce construction waste, and meet project timelines, budgets, and quality benchmarks while minimising environmental harm and promoting sustainable growth. The building industry has demonstrated that implementing lean concepts can enhance the overall performance of a construction endeavour by improving processes. Currently, the potential advantages have not yet been entirely and consistently demonstrated. This chapter proposes a framework that combines lean construction principles with the RIBA Plan of Work 2020. This work effort aims to provide an authoritative source for those interested in exploring the benefits of integrating lean construction practices and principles contained by the RIBA PoW 2020. It provides all the necessary information about building procurement and design management.

Like any other industry, the construction industry must deliver the work effectively, efficiently, and ethically by providing opportunities for the market. It also provides an environment that allows and encourages innovation and continuous improvement. From the beginning, this chapter stresses the benefits of lean implementation. It highlights that lean practice can help reduce waste and improve efficiency by providing value for money, fulfilling client demands, and meeting job deadlines. It emphasises that two foundations of lean, continuous improvement and respect for people, can promote lean construction by fully human potential and creating an innovative working environment. It illustrates the five main principles of lean production: setting up the flow, applying pull, mapping the value stream, defining value, and striving for perfection (Heidar Barghi, 2023). However, implementing lean management in the UK construction industry requires more exploration and advancement than in the operations and manufacturing industries due to the uniqueness of construction projects. Not only because of technological advances but also due to the development of workers' skills, adaptability, and resilience in facing various problems, lean production will be conducted satisfactorily, which means delivering satisfaction.

First, a briefing on the RIBA PoW is given (Sarhan and Fox, 2013). Then, eight stages of the RIBA PoW were introduced. Two main similarities, the 'lean' construction and the 'traditional' construction, are discussed between the RIBA plan of work and the lean production process. Some differences have also been found. The end of this section highlights the potential limitations, the future direction, and the framework as guidance for future research and development for both organisations and individuals. The limitation is the self-recognition from the commercial client, construction consultancy, and project team. Overall, the section on lean production has significantly expanded the comprehension and knowledge of lean production, including the tools and techniques employed. On the other hand, completing the work has been evidence of the successful implementation of lean production on the fabricated production line and the transfer of lean production techniques to realising construction projects (Hughes, 2003).

4.2 Motivation for Developing the TLC Framework

This section outlines the rationale for integrating LC principles with the RIBA PoW. The TLC framework addresses inefficiencies in traditional construction processes, including waste reduction, cost control, and stakeholder collaboration. The motivation stems from the need to align lean principles with architectural workflows, thereby fostering efficiency and sustainability throughout construction projects. It is proposed that industry professionals be offered a practical solution for applying lean construction principles throughout the RIBA Plan of Work 2020, along with a redefinition of each stage of the plan. This framework is expected to significantly reduce waste, improve energy use, reduce emissions, create a sustainable built environment, and, most importantly, maximise client value and enhance productivity. Concurrently, through the expectation alignment section by section of the RIBA PoW 2020, with the performance principle and collaborative working, the need for significant changes in work or reappointment of the project team can be reduced. Doing so will create more opportunities and better project control for stakeholders, fulfilling the design goal of better serving the client than traditional work methods (Faris et al., 2024).

The construction industry is often criticised for being inefficient and adversarial, as noted in various reports and studies, including Egan (1998) and Latham (1994). Various research initiatives and reforms have been conducted to address the issues and improve construction performance. One of the significant findings from earlier research and demonstration projects is that the principles of Lean Thinking when applied in construction, can lead to improved output, as defined by reducing waste and adding value (Hedley, 2010). The term "Lean Construction" was initially coined in 1993 by the International Group for Lean Construction (IGLC) in the UK, and it is embodied in the International Group for Lean Construction, which was founded in 1997 to address the adoption of lean principles in the construction industry (Aziz and Hafez, 2013). That is why the ideas and principles of Lean Construction, including specific techniques and practices, have been widely discussed and promoted in the industry for over a decade. Furthermore, previous research has established the need for innovation in the UK's architecture and construction industry, with senior professionals seeking a step change in the effective use of resources when designing and constructing buildings (Ogunbiyi et al., 2014). The latest RIBA PoW 2020 accredits the method of working that is the standard for building design and documentation in the UK. It includes project management and practice management. The RIBA PoW 2020 outlines the activities from appraisal to operation, highlighting the project outcomes and the European numbering system. It may need to be tailored to specific projects, but it provides a record and management process, improving efficiency and streamlining operations. The benefits of Lean Construction have been evidenced by various successful cases in the UK and abroad (Royal Institute of British Architects, 2020). However, its application in the mainstream construction process, such as using the RIBA Plan of Work 2020 as a guideline, is limited and less explored.

4.3 Steps and Stages in Developing the TLC Framework

The development of the TLC framework involved a systematic process to ensure comprehensive coverage of both LC principles and the RIBA PoW stages. "Coverage" refers to the extent to which lean methodologies are integrated across all phases of a project. The steps include:

(1) Identifying integration points between LC principles and RIBA PoW stages.
(2) Justifying the selection of specific LC tools for each RIBA PoW stage.
(3) Develop a roadmap incorporating inputs, outputs, and feedback loops for each stage.

The TLC Framework was developed to provide a comprehensive overview of integrating Lean Construction principles with the RIBA Plan of Work 2020. This section offers insights into the principles of Lean Construction and the RIBA Plan of Work 2020, facilitating a critical evaluation of the opportunities to leverage the advantages of Lean Construction methodologies.

This study aims to assess the applicability of this method for construction adoption within the industry's culture. The scope encompasses a detailed examination of lean construction techniques and tools, an essential concept that has been significantly under-studied in current practice. Will also discuss the phases of RIBA work and their alignment with the methods of Lean Construction. The research is based on general principal research, which relates to a process that the user needs to redefine to approach best practices steadily.

Then, it can proceed to another successful practice of the process. Lean Construction primarily focuses on using planning practices and mapping desired outputs from the initial stage to reduce waste activities and maximise added value throughout the process. This is quite the opposite of the traditional methods used in construction projects, such as Gantt charts and stage gates. An activity or output is produced based on data. This will also highlight the critical differences between the methods and how challenging it can be to transfer from one to another, as it may require mapping a new practice to best practice ideas and efficiently transitioning the current best practice to a niche practice. The improvements in the process are underpinned by using in-process visual displays to reduce the waste associated with searching for information. This synchronised formation can increase reliability and reduce the cycle time. It can also have a more significant impact on the supply chain. Lean Construction tends to reduce the work-in-progress material, and the tendency is to install the work as late as possible. This also develops the method for production control to limit work in progress and regulate the bit speed. On the other hand, this could be because Lean Construction has not yet gained momentum in its development history. However, the construction industry in the UK is experiencing rapid development (Hedley, 2010). The scope of such a report is to provide a comprehensive overview of the subject. Hence, precise management of priorities, change management, performance measurement, motivation, and supply chain management dynamics are all embedded within Lean Construction (Craig & Dean, 2023).

4.3.2 Rationale for the TLC Framework Development

4.3.3 Complexity of Construction Projects

Construction projects are integrally complex and involve stakeholders, complicated processes, and vibrant environments (Ballard, 2000). This complexity leads to challenges of delays, cost overruns, and quality issues, and a methodological approach to project management is questioned for successfully managing these complex issues and guaranteeing project delivery.

4.3.4 Integration of Lean Principles

It has been recognised that lean construction methods, which focus on waste reduction and workflow streamlining, contribute to better results for relevant projects (Koskela, 2000). However, mismatching lean with existing project frameworks could be a point of failure. Furthermore, according to Kontela and Howell (2002), such a scenario may not bring desirable results. The TLC Framework aims to bridge this gap by combining lean concepts with RIBA Task Work, thereby providing project managers with a comprehensive set of lean project management tools.

4.3.5 Demand for Efficiency and Value

Clients and stakeholders increasingly prioritise efficiency, transparency, and value in construction projects (Schmenner and Swink, 1998). The TLC Framework is designed to meet these demands by optimising project delivery processes, minimising waste, and maximising value throughout the project lifecycle (Koskela and Howell, 2002).

4.3.6 Adaptation to Changing Industry Dynamics

The construction industry is unstable as it continually develops innovative technologies, faces new regulations, and is influenced by shifting market trends that impact the delivery process. However, the TLC Framework has been designed to accommodate this changing context, delivering significant flexibility that enables project managers to address new challenges and capitalise on diverse business opportunities (Ballard, 2000).

4.3.7 Alignment with Industry Standards and Best Practices

This is achieved through the support of lean construction principles by building upon established frameworks such as the RIBA Plan of Work, where the latest ideas are also incorporated into project management to ensure that lean construction practices fit with existing professional practices. The motivation behind the TLC Framework is that the sector aims to address the challenges and situational areas that project managers and stakeholders face within the industry, utilising specific principles and practices aligned with the best industry approaches.

4.4 Construction project lifecycle stages

Highlight the project objectives both sides must meet, the shared tasks, the expected progress at each stage, and how it will be monitored (Chen et al., 2019). The following stages must be followed during the project cycle to ensure the project is completed effectively and on schedule (Atkinson, 1999). Table 4.1 presents the details.

Table 4.1: Project life cycle stages (Atkinson, 1999).

Stage	Main actions
Preparation/Inception	• The client confirms that they want to have a new project. • A project manager is selected and responsible for assessing the feasibility.
Concept design/ Feasibility	• Experts are deployed to assess the project's feasibility and all other details.
Development Design/ Strategy	• The project objectives and the processes to be followed in achieving these objectives are highlighted.
Pre-construction/Production	• Developing the design • Decisions are made regarding time, cost, and project quality. • Compliance with the regulations that govern the project. • Provision of all information in readiness for the construction to begin
Construction/ Specialist design	• The construction of the facility is complete. • The timer and cost are regulated to remain within the planned parameters. • Environmental requirements are also met.
Engineering services commissioning/ Specialist design.	• Ensuring all inspections have been conducted and all regulations have been met. • Keeping all records and certification • Seeking advice on the training of maintenance staff
Completion and handover for inspection	• The facility is handed over to the client. • Initial occupation takes place
Post-completion review/ Closeout report/ Use	• Evaluating the performance of the project • Conducting the project review while comparing it with the objectives.

Projects in the construction industry, like those in many other industries, undergo several steps before being delivered to end-users. The Royal Institute of British Architects (RIBA) PoW 2020 explains the project lifecycle stages in this research. The RIBA 2020 PoW is used due to its international recognition and widespread adoption. Additionally, there is a significant lack of standards and regulations in the building projects (Shawkat et al*.,* Jun. 2018). RIBA (2020) divided the project lifecycle into eight primary stages, and the stages are considered as outlined below:

Stage 0: Strategic definition stage

The project manager is responsible for determining the project's feasibility. At this planning stage, the project's core requirements, including the client's business case, a strategic brief, and any other key requirements, need to be identified (Halliday and Atkins, 2019). This information is essential as it will be used to determine the outcome of the next stage.

Stage 1: Preparation and brief

At this stage, project objectives, including quality expected outcomes, aspirations, budgets, and sustainability, are developed in close alignment with the initial brief. The project schedule and design also craft adequate information regarding risk assessment and proper handover strategies at this phase (Loh et al., 2009). At this stage, a proper project execution plan will also be developed to meet the project's required standards and expectations. Experts are also invited to examine all aspects of the proposed project thoroughly.

Stage 2: Concept design

This phase involves preparing a concept design and a cost analysis with the strategies highlighted to achieve the expected design. At this point, adjustments are made to the initial project brief in areas such as maintenance and operational strategies, project sustainability, risk assessment, and handover strategy to produce a final project brief (Halliday and Atkins, 2019). The project execution plan has also been updated with new strategies that will enhance quality and reduce the cost and time of the project. At this point, a review is also conducted of the health and safety strategies that have already been implemented, and an update is provided on them, along with the security measures associated with the project.

Stage 3: Developed design

In this phase, a developed design, the program's accompanying cost information, and all project strategies are available. At this stage, objectives, approaches, and procedures to be followed during the project's execution are also highlighted.

Stage 4: Technical design

A technical design will outline the responsibilities associated with the already established project strategies. The responsibilities must align with the design program and fulfil the requirements highlighted in the design program. In this phase, a review and update of construction strategies, risk management, the project execution plan, and the handover strategy, among others, are conducted (Dearlove and Saleeb, 2016). This review is conducted to identify any changes that may have arisen from the previous or current phases. The updates are always aimed at enhancing the efficiency of project execution. Design development is conducted here, considering time, quality, cost management, and the project's security requirements.

Stage 5: Construction

This phase involves the on-site construction of the facility, as per the construction program that has been developed and refined. Off-site construction also accompanies the activities of this phase. The phase also involves a review and update of sustainability and handover strategies, given their proximity to the handover process (Loh et al., 2009). Where necessary, changes are also made to the project's health and security strategies to ensure the client receives the best. While construction is underway, parameters such as time and cost are closely monitored.

Stage 6: Handover and closeout

Once the building has been constructed, it is then handed over to the client, a process which is then accompanied by the conclusion of the building contract with the client. All activities listed in the handover strategy are to be conducted at this point, and they should be closely followed by receiving feedback about the project and how it was executed (Halliday and Atkins, 2019). During this phase, the process involves the initial occupation of the facility, evaluating project performance, and reviewing project objectives to assess the extent to which objectives were successfully achieved.

Stage 7: In use

In-use services are then undertaken as scheduled. (Fletcher and Satchwell, 2019). These are also accompanied by evaluating the project's performance and reviewing the project objectives to determine how much was successfully achieved during this phase. The information acquired is then analysed as research to be used in future projects, making work more efficient and cost-effective.

For the project cycle to be complete, all these stages must be followed, even though they may have different names at times. The planning process supports all these processes but, most importantly, initiates a Project, manages product delivery by controlling every stage, and manages the various stage boundaries.

4.5 Lean Construction

Lean construction is a project management methodology that enhances efficiency, improves work quality, and maximises value throughout the lifecycle. This approach focuses on eliminating waste, promoting continuous improvement, and delivering maximum value to clients. By streamlining workflows, reducing delays and errors, and fostering collaboration among all project stakeholders, lean construction seeks to optimise processes, enhance communication, and ensure the successful, on-time, and on-budget completion of high-quality projects (Ansah et al., 2016).

Integrating lean construction principles with the Royal Institute of British Architects (RIBA) Plan of Work offers a strategic advantage by blending the strengths of both frameworks. This collaboration reduces project timelines and costs while enhancing the quality of outcomes (Loh et al., 2009). To fully realise these benefits, adjustments to the RIBA plan should incorporate lean-specific features, such as employing multi-skilled personnel and adopting automation technologies (Al-Adwani, 2022).

4.5.1 Defining Lean Construction

Lean construction involves applying lean management principles within the construction sector, focusing on value maximisation and waste reduction. It advocates for a collaborative and efficient construction process to improve project outcomes. Radhika and Sukumar (2017) highlight that this methodology requires a fundamental shift in traditional project management practices, fostering a culture centred on value creation, continuous improvement, and teamwork among all participants.

4.5.2 Core Principles

The foundation of lean construction is built on several core principles:

- **Collaboration:** Encouraging teamwork among all project stakeholders.
- **Process Optimisation:** Streamlining workflows to improve efficiency.
- **Waste Reduction:** Eliminating non-value-adding activities.
- **Empowerment:** Granting employees more decision-making authority.
- **Innovation:** Embracing new technologies and methods.
- **Continuous Improvement:** Regularly refining processes to enhance project outcomes and results.

Adhering to these principles can help construction projects achieve higher customer satisfaction, improved quality control, reduced costs, and increased productivity (Gao and Low, 2014).

4.5.3 Advantages of Lean Construction

Implementing lean construction offers significant benefits to project stakeholders and the broader construction industry. These include:

- Cost reduction and minimised waste.
- Increased productivity and operational efficiency.
- Faster project completion times.
- Enhanced client satisfaction.
- Improved safety standards on-site.

Additionally, lean construction promotes collaboration, accountability, innovation, and continuous improvement among teams, ensuring projects meet or exceed client expectations (Bookanan and Czap, 2021).

4.6 The 2020 RIBA Plan of Work

The RIBA Plan of Work 2020 provides a structured framework that outlines the key objectives and deliverables for each phase of the project lifecycle. Its flexibility allows adaptation to meet the specific needs of various projects, covering everything from initial evaluation to design and execution. By following this structure, project teams can ensure efficient planning and successful delivery (Segara et al., 2024).

4.6.1 Overview

The 2020 RIBA Plan of Work iteration presents a comprehensive overview detailing the framework's primary goals, guiding principles, and critical stages. It highlights the benefits of its structured approach, such as improved project management, increased efficiency, and enhanced collaboration among stakeholders.

4.6.2 Project Stages

The RIBA Plan of Work 2020 divides the project lifecycle into distinct stages:

1. Strategic Definition
2. Preparation and Brief
3. Concept Design
4. Developed Design
5. Technical Design
6. Construction
7. Handover and Close Out
8. In Use

Each phase has specific goals, tasks, and deliverables, facilitating a methodical and organised approach to project execution. This phased structure ensures that all essential decisions are made at the appropriate times throughout the project's lifecycle (Abanda and Amin, 2019).

4.6.3 Key Updates in the 2020 Version

The 2020 update of the *RIBA Plan of Work* introduces several significant changes:

- **Preparation and Brief Phase:** A new phase emphasising early strategic planning and client engagement.

- **Post Construction Review:** A focus on applying lessons learnt from completed projects to future endeavours.
- **Collaboration and Data Management:** A heightened emphasis on teamwork and effective data management throughout all project stages.

4.7 Lean Construction and the 2020 RIBA Plan of Work Integration

Lean construction techniques can be integrated with the RIBA Plan of Work 2020 to enhance the efficiency and productivity of construction projects (Heidar Barghi, 2023). This combination aligns Lean Construction's principles with the systematic approach outlined in the RIBA Plan of Work 2020, creating opportunities for enhanced collaboration, reduced waste, and improved productivity. This integration will inevitably lead to better project outcomes, naturally fostering better stakeholder collaboration and interaction. Additionally, it establishes the framework for implementing continuous improvement efforts during the task's performance (Fischer et al., 2017).

4.7.1 Significance

Integrating Lean Construction with the RIBA Plan of Work 2020 is crucial, as it can enhance project management practices and overall performance. Although the Lean Construction principles prioritise waste reduction, increased efficiency, and value optimisation, the RIBA Plan of Work 2020 offers a practical framework for project management and process design (Nasereddin, 2019). Construction projects that implement these strategies will undoubtedly experience improved quality, reduced costs, enhanced productivity, and more satisfied clients. Moreover, the integration fosters a cooperative and comprehensive approach among project stakeholders, enabling more informed decision-making and ultimately leading to more successful project outcomes.

4.7.2 Challenges Encountered in Developing the TLC Framework

The application of lean construction principles in conjunction with the RIBA Plan of Work 2020 presents both benefits and challenges, including the need for a shift in the construction industry's culture towards increased collaboration and participation (Balkhy et al., 2021). This entails dismantling ingrained departmental boundaries and cultivating an atmosphere encouraging cooperation and ongoing progress. The necessary precondition for efficient project team collaboration, communication, and knowledge and skill sharing presents another challenge (Gardner and Matviak, 2022). Furthermore, incorporating Lean principles into the present RIBA Plan phases may require modifying existing practices and workflows, which may face resistance (Heidar Barghi, 2023). To enable efficient integration and effective assimilation, it is imperative to address these obstacles and provide sufficient training and support (Dietze et al., 2013).

4.7.3 Strategies Employed in Developing the TLC Framework

Using RIBA PoW 2020 in conjunction with Lean Construction through strategic approaches will help overcome obstacles and promote successful project outcomes (Garcés and Peña, 2023). A key tactic is to formulate a shared vision and goals for all project participants, which fosters a culture of collaboration and ongoing improvement. Consistent communication channels that facilitate information sharing and issue resolution, such as project meetings and training sessions, can be beneficial. Additional tactics include training and instruction on lean approaches and concepts, as well as equipping project teams with the necessary knowledge and skills (Alves et al., 2016). Incorporating Lean principles into current processes and workflows may also ensure a seamless transition. Continuous scrutiny and evaluation of integration progress are also crucial for identifying areas for improvement and implementing necessary modifications (Yadav et al., 2017).

An integration framework between Lean Construction and RIBA PoW 2020 will require thoroughly synchronising processes and plans (Dave et al., 2013). There will be a series of processes in which the frameworks will be consolidated to find a middle ground that will be more convenient for achieving the objectives of a typical project. Key among areas that require consolidation will the role of the supervisors as they will have to decide on the responsibilities required to take place at every stage of work and come up with detailed information on the required workforce as well as the expected timelines for the completion of different tasks (Loh et al., 2009).

One key area where integration will mostly occur is planning and scheduling. During planning and scheduling, decisions will need to be made regarding how the work process will be broken down. It will also be decided how the construction design will be implemented and who will be responsible for it while simultaneously choosing the most convenient construction method. The chosen methods must be convenient for both the constructors and the client while also not compromising the project's quality. Essential decisions on procurement and subcontracting will also be made to ensure that efficiency, quality, and cost-effectiveness are met (Hughes, 2003).

Scheduling at this stage involves establishing specific timelines for various project stages and smaller timelines that cumulatively lead to more extensive timelines for the main project milestones. This time will play a key role in monitoring and ensuring that the project progresses through its various stages as expected, without any stage stalling the entire project (Loh et al., 2009). The cost-benefit analysis conducted during planning and scheduling will be vital in determining other decisions regarding resource utilisation in the project and the workforce required to work on it.

Additionally, the key in the planning stage will be addressing changes experienced in the project's handling due to the integration between RIBA and Lean Construction (Mahmoud and Abrishami, 2020). This integration between the RIBA work plan and lean construction will be implemented through a project cycle comprising various stages, each breaking down the integration process (Heidar, 2023).

4.8 Methodologies Used in Integration

The methodologies used in the projects are documented in a statement that describes the procedures for each stage. This statement includes drawings, diagrams, data, and other visual aids to illustrate the various methods employed throughout the construction process. The following methodologies are listed below. Table 4.2 details the methodologies used in the integration.

Table 4.2: Principles and Methodologies for integration of Lean RIBA framework

Concepts	**Principles**	**Methodologies**
Tendering	Meet the client's needs	Use of the tender method statement
Construction	Meet the project objectives	Construction work method statement
Planning and scheduling	Optimising on time and cost	Planning method statement
Waste management	Comply with waste management regulations	Waste management method statement
Project planning	Quick execution of tasks	Last planner method
Design	Convenience in the design process	Design process model

Further explanations about this integration are given below:

(1) The tender method statement (both internal and external) will be used to provide all information about the tender requirements and the contractor's ability to meet the client's requirements. Once sufficient information has been gathered using the tender method statement, it is then analysed and used to determine how the tender requirements will be made available and the standards of the requirements, ensuring that the client's demands can be met (Sinclair, 2019). This method also stipulates the conditions under which contractors are obligated to produce a high-quality project and outlines the consequences in the event of failure (Clough et al., 2015).

(2) Construction work method statement, which provides information about the contractor's proposed methods of construction, their durations, the activities to be conducted on-site and off-site, and the documentation requirements associated with the methods outlined (Halliday and Atkins, 2019). From the analysis developed using this method, the company can select the most convenient construction methods available and, where necessary, make slight adjustments to tailor them to the project. It is also possible to break down information about the activities to be conducted and distribute it accordingly to the available teams, making the entire process easier and faster (Snowden and Boone, 2007).

(3) The planning method statement provides information about the assumptions made when conducting large projects regarding risk management and the project's planning and scheduling (Cooper et al., 2005). This method is used to analyse the assumptions and identify the possible damage that could result from a particular risk, thereby influencing the decision-making process (Byrd III and Cothern, 2000).

(4) Waste management method statement describing waste collection, disposal, and recycling and how these activities will be conducted to meet the relevant waste management regulations. It also outlines the responsibilities of the various teams involved in the project regarding proper waste disposal (Yusof et al., 2016).

(5) The design process model is a data design method that utilises data flow diagrams and other components, such as task and information flow diagrams, to represent project data (Bhattacharya et al., 2009). This method is convenient during the project management process, as it is independent of the chosen procurement method and can, therefore, be adjusted to accommodate changes in the design flow.

4.9 The Role of the Last Planner and Other Tools in the TLC Framework

Section 4.9 of this document primarily focuses on the Last Planner method due to its pivotal role in the Total Lean Construction (TLC) Framework. However, other tools and methods, such as those listed in Table 4.2, are also crucial in supporting and enhancing project delivery throughout the different stages of the RIBA (Royal Institute of British Architects) Plan of Work. To understand why only Last Planner is highlighted in Section 4.9, it is essential to examine its function within the TLC framework, explore the contribution of other lean tools and methods, and how they complement Last Planner to optimise construction project outcomes.

- **Last Planner in the TLC Framework**

The Last Planner system is central to the TLC Framework due to its focus on ensuring reliable workflow and reducing variability in project delivery (Daniel et al., 2017). It emphasises collaboration among all stakeholders involved in a project, including designers, contractors, and suppliers, particularly at the execution phase. The last Planner directly contributes to controlling the flow of work by:

1. **Creating detailed work plans:** The project team agrees on these plans, which break down tasks into manageable work packages, helping avoid last-minute scheduling disruptions.
2. **Enhancing collaboration:** It promotes communication across all project levels, ensuring that workers, planners, and supervisors are aligned on project goals and timelines.
3. **Fostering continuous improvement:** Regular reviews and updates to the work plan ensure potential problems are identified and mitigated early in the process.

Section 4.9 emphasises the Last Planner system because of its direct impact on project delivery. However, it is important to recognise that it functions as part of a broader set of tools within the TLC framework, all working together to drive efficiency and reduce waste across all project stages.

4.10 Other Tools and Methods in the TLC Framework

As mentioned in Table 4.2, the TLC framework incorporates various tools and methods, each contributing to specific aspects of a project at different stages of the RIBA Plan of Work. These tools enhance project outcomes by providing support at various stages from inception to completion. Explore how each of these tools contributes to the framework and aligns with RIBA stages.

4.10.1 Value Stream Mapping (VSM)

- RIBA Stages: Stage 1 - Preparation and Brief, and Stage 2 - Concept Design

- **Contribution to TLC Framework:** Value Stream Mapping (VSM) is a tool for visualising and analysing the flow of materials and information throughout the project. By mapping out the entire value stream, VSM helps identify inefficiencies, delays, and areas of waste early in the design phase.
- In Stage 1, VSM can be used to analyse current processes and suggest ways to improve them in the design or planning phases.
- During Stage 2, VSM provides insights into streamlining design activities, reducing unnecessary handoffs, and creating a more integrated workflow between stakeholders (Rother & Shook, 1999).

4.10.2 Kaizen (Continuous Improvement)

- RIBA Stages: Stage 3 - Developed Design and Stage 4 - Technical Design
- Contribution to TLC Framework: Kaizen emphasises incremental improvements and involves team members in identifying small, continuous changes that enhance the project's overall efficiency. This method is particularly valuable during the Design Development (Stage 3) and Technical Design (Stage 4) phases.
- In Stage 3, Kaizen supports early design testing and feedback, ensuring continuous refinement and alignment with project goals (Liker, 2004).
- During Stage 4, Kaizen principles can help streamline technical designs and enhance the communication between the design team and contractors, enabling more efficient solutions to construction challenges.

4.10.3 Just-In-Time (JIT)

- RIBA Stages: Stage 5 - Construction
- Contribution to TLC Framework: Just-In-Time (JIT) focuses on delivering materials and resources only when they are needed in the production process. JIT helps reduce inventory costs, minimise delays, and prevent overproduction or wastage. This principle is crucial in the Construction (Stage 5) phase.
- JIT ensures that materials and components arrive at the construction site promptly, reducing the need for extensive inventories and the associated handling costs (Ohno, 1988).
- JIT also helps synchronise the delivery of materials with the specific work requirements, promoting smooth and continuous construction processes.

4.10.4 5S (Workplace Organisation)

- RIBA Stages: Stage 5 - Construction

- **Contribution to TLC Framework:** The 5S methodology (Sort, Set in Order, Shine, Standardise, and Sustain) is a workplace organisation technique that enhances efficiency and safety by maintaining a clean and organised work environment. This method is beneficial during the Construction (Stage 5) phase.
- By organising the workspace, reducing clutter, and creating a safe working environment, 5S helps maintain productivity and ensures that workers can focus on tasks without distractions.
- It also enhances safety standards on construction sites, reducing the risk of accidents and improving the overall working environment for the construction team (Hirano, 1995).

4.10.5 Pull Planning

- RIBA Stages: Stage 5 - Construction and Stage 6 - Handover
- Contribution to TLC Framework: Pull planning, often integrated with the Last Planner system, focuses on ensuring that work is completed in the correct order, with each task dependent on the completion of the previous one. This method helps maintain a smooth workflow and reduce bottlenecks.
- In Stage 5, pull planning coordinates the sequence of tasks between contractors, subcontractors, and suppliers to ensure uninterrupted work progress (Ballard, 2000).
- During Stage 6 (Handover), pull planning ensures all deliverables are completed on time, reducing delays during final inspections and handovers.

4.10.6 standard Work

- RIBA Stages: Stage 5 - Construction
- Contribution to TLC Framework: Standard Work refers to creating standardised task procedures, which helps ensure consistency, quality, and efficiency. This method is beneficial in the Construction (Stage 5) phase.
- It reduces variability and ensures that tasks are performed consistently across workers and teams, thus improving productivity and minimising mistakes.
- Standard Work also facilitates training new workers and helps ensure construction activities are completed according to the established best practices (Liker, 2004).

While Section 4.9 emphasises the Last Planner method due to its direct impact on the execution and scheduling of construction activities, it is important to recognise that the TLC framework relies on various methods and tools, each contributing to different stages of a project. Tools such as Value Stream Mapping, Kaizen, Just-In-Time, and Pull Planning are essential for improving project delivery, reducing waste, enhancing collaboration, and ensuring continuous improvement throughout the entire project lifecycle, from early design stages to final handover. By integrating these tools with Last Planner, construction teams can effectively manage complexity, optimise project flow, and deliver better project outcomes on time and within budget.

4.10.7 Concept Planning and Scheduling

This process involves establishing a clear structure for all project schedules. The concept operates on the principles of project scope, objectives, project calendar, management requirements, and project report requirements. In the event of integration, a schedule report must be generated, highlighting the various levels of scheduling rights, from the highest-level schedule report and executive summary to the lowest, the subcontractor's schedule report. A Work Breakdown Structure is created to define the various elements of the project, organising and allocating the estimated cost and time requirements for each (Halliday and Atkins, 2019). There is also a requirement to monitor progress and utilise the time model to ensure optimisation in terms of resource utilisation and time. It uses methods such as resource analysis, resource aggregation, resource smoothing, and resource levelling (Jain et al*.,* 2010).

4.11 Adept Planning and Lean Construction and Its Integration with RIBA

The analytical Design Planning Technique is a planning model that creates a flow of information required by designers and then optimises the design activities and schedules using matrix modelling (Katona and Fenyvesi, 2024). This typically involves identifying the issues that may arise during the design process and subsequent construction and then conducting a design review to prevent or minimise these problems (Holden, P., 2019).

These techniques collectively work together to achieve a common goal of generating an integration framework that yields better results than could have been achieved by any of them individually (Fletcher and Satchwell, 2019). Therefore, many areas of the work plan must be streamlined to align with the resulting integration framework and facilitate a smooth process. Key areas that we will seek to optimise from the integration are cost-effectiveness, time management, and producing projects of extremely high quality (Yusof et al*.,* 2016). Each of these will, therefore, be systematically achieved by taking the integration process through all eight stages of the project cycle.

4.11.1 Project Planning and Scheduling

The planning process is a rigorous process that requires the sharing of critical information among the parties involved to enable them to make informed decisions about the steps that need to be taken. It is an exceptionally essential element when creating a work plan for any organisation as it provides an outline of how different activities will take place and, in that way, enables the organisation to properly prepare for the work that awaits (Sinclair, 2019). At this level, we identify each worker's responsibilities and the impact of each role on productivity, ensuring a fair distribution of duties while establishing proper timelines for each activity, along with the expected results. Lean Construction supervisors, working in conjunction with the RIBA framework, will need to collaboratively agree on the responsibilities required at every stage of work and provide detailed information on the required workforce, as well as the expected timelines for completing different tasks (Loh et al., 2009). It is at this level that management from the organisation will discuss the common abstractions between the RIBA framework and the Lean Construction framework while simultaneously setting out the terms of integration (Chen and Atweijeer et al., 2019).

During this stage, a team from Lean Construction will outline their intention to integrate with RIBA, encompassing the operational, social, intellectual, and emotional aspects of integration that will lead to improved work outcomes. It will also highlight the intention for both frameworks to be adequately adapted to each other so that they can rightfully partner up during the entire time they are used together to pursue common organisational goals in construction (Jain et al., 2010). At this stage, the organisation will deploy strategic, operational, and coordinating plans to produce a comprehensive plan that addresses all aspects of the project and its development.

Once the supervisors have highlighted the responsibilities of different parties, it will then be the duty of the various teams to plan for their responsibilities and outline how they intend to carry them out, each as a separate entity. Different teams, including contractors, subcontractors, designers, architects, etc., will be expected to outline how they intend to fulfil each responsibility. At this point, the various groups will allocate the responsibilities of distinct categories of members and outline the roles each will play to ensure that the group's responsibilities are well met (Dearlove and Saleeb, 2016). During this planning stage, the various groups must also ensure that their plans are well aligned with the main grand plan for the project or projects.

During planning and scheduling, decisions will need to be made about how the work process will be broken down. The construction design and the team that will be chosen will also be decided upon. The construction method will be convenient for both the constructors and the client without compromising quality (Fletcher and Satchwell, 2019). Essential decisions on procurement and subcontracting will also be made to ensure that efficiency, quality, and cost-effectiveness are met.

Another critical element discussed at this stage is the expected completion date of the project. This decision will be made while considering the client's requirements, the teams' readiness, and the availability of necessary resources. At this stage, the estimated time needed to meet the client's needs will also be determined, ensuring the work is completed to the highest standards (Kurwi et al., 2021). They will also have to decide on the resources to be used for the project and how they will be sourced while maintaining both cost efficiency and quality.

Scheduling at this stage involves setting specific timelines for when various project stages are expected to be completed. These smaller timelines cumulatively lead to more extensive timelines for the main project milestones (Halliday and Atkins, 2019). This time will play a key role in monitoring and ensuring that the project progresses through its various stages as expected, without any stage stalling the entire project. The cost-benefit analysis conducted during planning and scheduling will be vital in determining other decisions regarding resource utilisation in the project and the workforce required to work on it.

Additionally, the key in the planning stage will be addressing the changes experienced in handling the project due to the integration between RIBA and Lean Construction. Key among the changes expected is an increase in resources and the adoption of Lean construction to meet the requirements under RIBA, implying a reduced need to outsource construction materials (Srinivasan, 2011). The integration will also be accompanied by experience attributed to larger teams that include experts who will bring extensive experience in such projects and a variety of approaches to dealing with the various stages of the work. This means work will be done much faster while ensuring the highest quality possible. It will also serve as a benefit, given the increased scrutiny that will come with integration with RIBA, as its ISA requirement for working on Lean Construction will necessitate the implementation of best practices, ensuring that no issues arise (Kurwi et al., 2021). This will benefit the client, as they will receive the best efforts and attention from both teams, along with the highest quality work. There is, however, a slight negative impact that will come with the integration, and it is the fact that working together will limit the flexibility of Lean Construction and its ability to think freely, thereby potentially compromising the best outcome for the customer. (Sinclair, 2019). They will be limited to using only the processes that are entirely sure and have been evaluated as likely to yield a good outcome (Halliday and Atkins, 2019).

4.11.2 Key Integration Strategies

Table 4.3 presents lean principles and their application throughout different RIBA stages. Each principle focuses on specific improvements:

Table 4.3: Key Integration Strategies

LC Principles	Descriptions about Integration	Corresponding Stage of RIBA PoW 2020
Value Stream Mapping (VSM)	Identify and eliminate non-value-adding activities from the project lifecycle.	Stage 0: Strategic Definition
Set-Based Design (SBD)	Explore multiple design options concurrently to foster innovation and reduce rework.	Stage 1: Preparation and Briefing
Last Planner System (LPS)	Enhance collaboration and workflow reliability among project stakeholders.	Stage 2: Concept Design
Target Value Design (TVD)	Align project costs with client expectations to ensure the delivery of value.	Stage 3: Spatial Coordination
JIT (Just-In-Time)	Reduce inventory and improve site efficiency by delivering materials as needed.	Stage 4: Technical Design
Continuous Improvement (Kaizen)	Gather feedback and implement improvements throughout the project lifecycle.	Stage 5: Manufacturing and Construction
Pull Planning	Develop a detailed project plan by defining and prioritising tasks based on project needs.	Stage 1: Preparation and Briefing
Waste Reduction	Minimise unnecessary resources and time during the design phase, optimising technical solutions.	Stage 4: Technical Design
Collaborative Project Delivery	Enhance coordination and communication among stakeholders for efficient project execution.	Stage 5: Manufacturing and Construction
Visual Management	Monitor and control the final stages of the project to ensure completion meets quality standards.	Stage 6: Handover and Close Out
Lean Supply Chain Management	Optimise procurement, delivery, and management of materials for the ongoing use phase.	Stage 7: Use

Some technical descriptions of fundamental LC principles adopted in Table 4.3 are given below:

- Value Stream Mapping (VSM) helps eliminate non-value-adding activities at the early strategic stage.
- Set-Based Design (SBD) and Pull Planning promote innovation and detailed planning during the preparation and briefing stages.

- Last Planner System (LPS) and Collaborative Project Delivery enhance collaboration and workflow during concept design and construction phases.
- Target Value Design (TVD) and Just-In-Time (JIT) optimise cost alignment and resource efficiency in the spatial coordination and technical design stages.
- Continuous Improvement (Kaizen), Waste Reduction, and Visual Management ensure ongoing refinement, resource optimisation, and quality control through the manufacturing, construction, and handover stages.

4.12 The integration framework between lean construction and the RIBA PoW 2020

The RIBA Plan of Work 2020 outlines eight stages, from Strategic Definition (Stage 0) to In Use (Stage 7), guiding a project from its initial concept to operational evaluation. Each stage has defined objectives and outcomes, with core support tasks including brief development, technical design, and statutory processes that ensure legal compliance. The procurement route impacts project delivery, while information exchange ensures transparency. Suitability checkpoints verify alignment with project goals, and lean integration applies principles to enhance efficiency and value. Each stage culminates in specific outcomes, ensuring the project meets its strategic and operational goals. Table 4.4 presents technical details about the TLC framework, which comprises eight tables designed to guide the project lifecycle-oriented adoption of LC across eight interconnected work stages defined by the RIBA Plan of Work 2020.

Table 4.4: TLC Framework

Stage	TLC Focuses	Details
Stage 0: Strategic Definition	Stage Objectives and Outcome	Identify the main project requirements that align with the client's expectations for the project.
	Core Support-related Tasks and Other Tasks	Review past project feedback, prepare a project program, assemble required teams, and draft the strategic brief.
	Core Statutory Processes	Prepare a project program.
	Procurement Route	Identify a suitable procurement approach.
	Information Exchange after Completion of the Stage	Initial exchange with the government, if required.
	Suitability Checkpoints and Planning	Suitability checkpoint 0.
	Lean Integration	Value Stream Mapping (VSM) to eliminate waste and maximise value.
	Outcomes	A strategic brief incorporating client requirements sets the stage for cost-effective project execution.
Stage 1: Preparation and Brief	Stage Objectives and Outcome	Develop the initial project brief and prepare feasibility studies.

Stage	TLC Focuses	Details
	Core Support-related Tasks and Other Tasks	Conduct site surveys, environmental studies, and risk assessments.
	Core Statutory Processes	Obtain initial planning permissions and other statutory approvals.
	Procurement Route	Finalise the procurement strategy.
	Information Exchange after Completion of the Stage	Share feasibility study results and initial project brief with stakeholders.
	Suitability Checkpoints and Planning	Suitability checkpoint 1.
	Lean Integration	• Set-Based Design (SBD) for exploring design options. • Pull Planning for prioritised task planning.
	Outcomes	A refined project brief and feasibility study report outlines the project scope, risks, and requirements.
Stage 2: Concept Design	Stage Objectives and Outcome	Develop concept designs that meet the project brief and client requirements.
	Core Support-related Tasks and Other Tasks	Engage with stakeholders to review design options and select the preferred solution.
	Core Statutory Processes	Continue obtaining necessary planning permissions.
	Procurement Route	Start the tendering process for design consultants.
	Information Exchange after Completion of the Stage	Distribute concept design documents to key stakeholders for feedback.
	Suitability Checkpoints and Planning	Suitability checkpoint 2.
	Lean Integration	Implement the Last Planner System (LPS) to improve collaboration and workflow reliability.
	Outcomes	An approved concept design that aligns with the project brief and client expectations.
Stage 3: Developed Design	Stage Objectives and Outcome	Develop detailed designs based on the approved concept.
	Core Support-related Tasks and Other Tasks	Coordinate with all design disciplines to ensure integration and compliance with standards.
	Core Statutory Processes	Submit detailed planning applications and obtain approvals.
	Procurement Route	Issue tenders for main contractors and suppliers.
	Information Exchange after Completion of the Stage	Share detailed design packages with contractors and stakeholders.
	Suitability Checkpoints and Planning	Suitability checkpoint 3.
	Lean Integration	Target Value Design (TVD) aligns project costs with client expectations to ensure the delivery of value.
	Outcomes	Comprehensive design documents ready for construction.
Stage 4: Technical Design	Stage Objectives and Outcome	Finalise all technical aspects of the project design.
	Core Support-related Tasks and Other Tasks	Perform technical reviews and resolve any outstanding design issues.
	Core Statutory Processes	Ensure all statutory approvals and permits are in place.
	Procurement Route	Award contracts to selected contractors and suppliers.
	Information Exchange after Completion of the Stage	Distribute final technical design documents to the project team.
	Suitability Checkpoints and Planning	Suitability checkpoint 4.
	Lean Integration	• Just-In-Time (JIT) delivery for site efficiency

Stage	TLC Focuses	Details
		• Waste reduction. Minimise unnecessary resources and time during the design phase
	Outcomes	Finalised technical design ready for construction execution.
Stage 5: Construction	Stage Objectives and Outcome	Execute the construction work as per the technical design.
	Core Support-related Tasks and Other Tasks	Monitor progress, manage quality, and ensure safety standards.
	Core Statutory Processes	Comply with all building regulations and safety inspections.
	Procurement Route	Manage contracts and oversee subcontractors.
	Information Exchange after Completion of the Stage	Report construction progress to stakeholders.
	Suitability Checkpoints and Planning	Suitability checkpoint 5.
	Lean Integration	Continuous Improvement (Kaizen): Gather feedback and implement improvements throughout the construction process. Collaborative Project Delivery enhances efficiency and coordination.
	Outcomes	Completed construction work that meets design specifications and quality standards.
Stage 6: Handover and Closeout	Stage Objectives and Outcome	Complete project handover to the client and close out any remaining tasks.
	Core Support-related Tasks and Other Tasks	Conduct final inspections and obtain completion certificates.
	Core Statutory Processes	Ensure all compliance documentation is finalised.
	Procurement Route	Finalise all contractual obligations and payments.
	Information Exchange after Completion of the Stage	Provide the client with as-built documents and operational manuals.
	Suitability Checkpoints and Planning	Suitability checkpoint 6.
	Lean Integration	Visual Management will monitor and control the final stages of the project to ensure completion meets quality standards.
	Outcomes	Successful project handover and client satisfaction.
Stage 7: In Use	Stage Objectives and Outcome	Ensure the building operates efficiently and meets the client's needs.
	Core Support-related Tasks and Other Tasks	Monitor building performance and provide maintenance support.
	Core Statutory Processes	Comply with all operational regulations and standards.
	Procurement Route	Manage ongoing maintenance contracts.
	Information Exchange after Completion of the Stage	Report building performance and user feedback.
	Suitability Checkpoints and Planning	Suitability checkpoint 7.
	Lean Integration	• Lean Supply Chain Management Optimise procurement, delivery, and management of materials for the ongoing use phase. • Continuous Improvement (Kaizen) Implement feedback mechanisms to improve operations and maintenance.

Stage	TLC Focuses	Details
	Outcomes	A fully operational building that delivers long-term value and efficiency.

4.13 TLC framework roadmap across the RIBA stage

Diagram 4.1 illustrates the Total Lean Construction Framework, which integrates the principles of Lean Construction with the structured stages of the RIBA Plan of Work 2020. This comprehensive framework is designed to deliver construction projects more efficiently and effectively by minimising waste, maximising value, and encouraging continuous improvement across the entire project lifecycle. The diagram aligns each RIBA stage with lean methodologies to enhance collaboration, streamline workflows, and ensure value-driven outcomes at every phase.

The diagram highlights key lean tools and practices, including Visual Management (VM) for improved clarity and communication, Set-Based Design (SBD), and Pull Planning to support early-stage preparation. The Last Planner System (LPS) to increase scheduling reliability. Additionally, Target Value Design (TVD) ensures cost-effective design solutions, while Just-In-Time (JIT) delivery and waste reduction streamline the technical design and construction phases.

The diagram also showcases continuous improvement practices through Kaizen and highlights Collaborative Project Delivery, promoting shared responsibility and ongoing development. The final stages focus on post-construction evaluation, supported by Lean Supply Chain Management and continuous feedback, which drives operational excellence and maximises long-term project value. This visual representation ensures that all project activities are strategically aligned, creating a seamless flow from initiation to post-completion use.

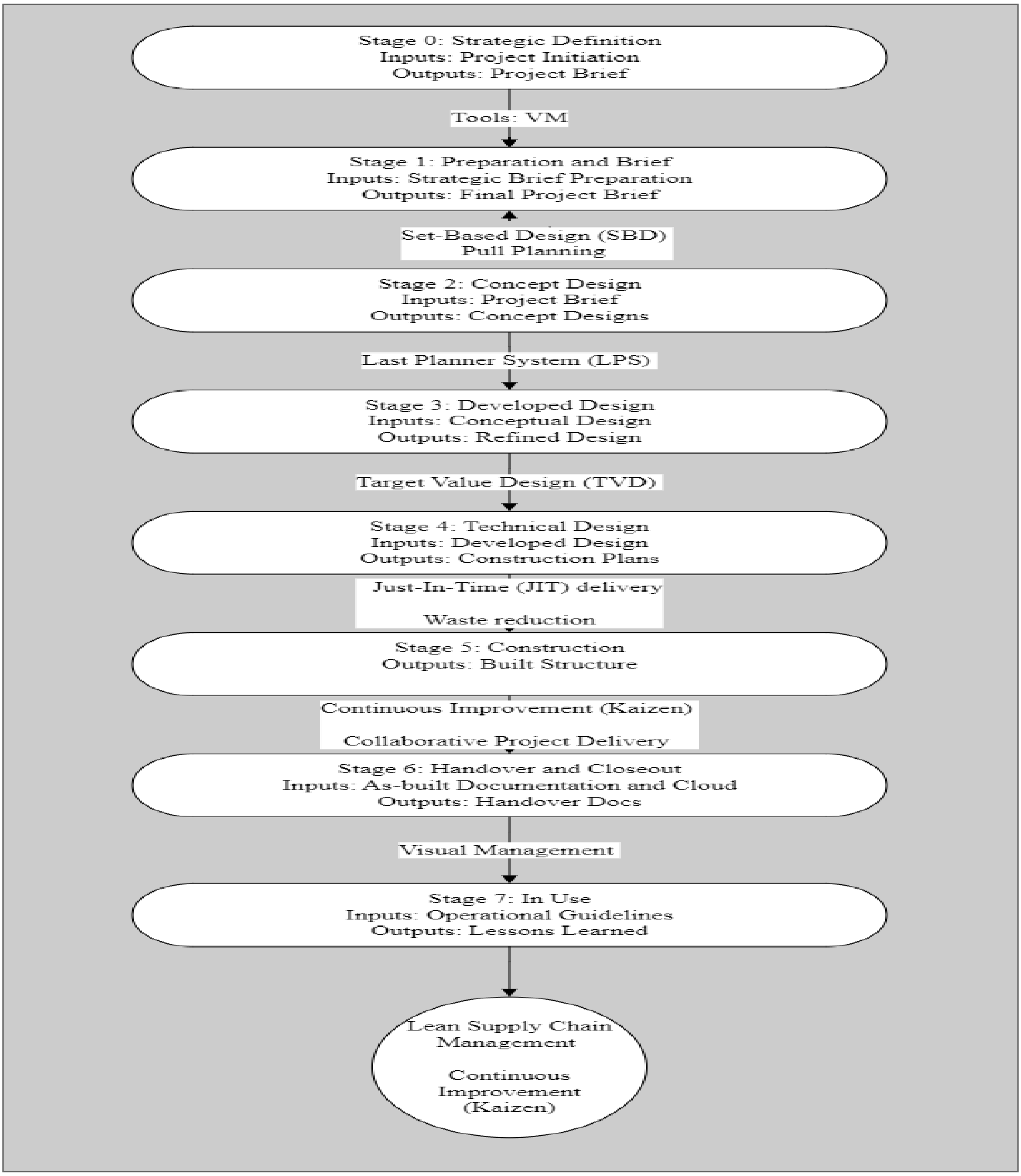

Figure 4.1: Diagram of the Total Lean Construction Framework Integrating Lean Construction and RIBA Plan of Work 2020.

4.14 Integration of Lean Construction Theories with the RIBA Plan of Work 2020: A Guideline Framework

Theories from Lean Construction are applied in this process to interpret information and provide guidelines for integrating Lean Construction and RIBA. A series of further descriptions is given below:

1) Theory of project, where a project is defined as the process of transforming inputs into outputs. Here, the approach of breaking down the project into sub-areas, which are then to be completed and adequately done in time, is taken (Royal Institute of British Architects, 2020). It is considered here that the quality of a project's various tasks determines its overall quality and that an improvement in the tasks can be achieved by enhancing their quality.

2) Theory of planning and management, where project personnel are grouped into managerial and effector categories based on the level of their responsibilities in the hierarchy of roles (Aslam et al., 2020). The managerial positions are responsible for outlining responsibilities for the effectors and ensuring necessary follow-up to ensure that the work is completed to the required standards within the stipulated time. In contrast, the effectors must execute the project plan and carry out the tasks required to meet the project's objectives (Fletcher and Satchwell, 2019).

3) Theory of execution: The role of managerial personnel is to distribute tasks to the project's various workstations and ensure that the teams fully understand the required outcomes from each task (Ostime, 2022). The managerial position holders keep track of when specific tasks are scheduled to take place, providing authorization where necessary for the tasks to begin.

4) The theory of control requires that an oversight group oversee every project stage to ensure that the correct standards are met at each step (RICS, 2020). This is done so that if a mistake occurs at any stage, it can be corrected promptly, and changes can be made to ensure the project returns to its original standards.

5) By linking the framework with Lean theory, it can be evaluated that the application of the lean construction strategies describes that there are effective means for minimisation the wastage of construction resources to decline the efforts as well as time through effective deployment of the production practices as well as ensuring the on-time delivery of the

products across the supply chain. In close integration with the lean theory and the RIBA Plan of Work, it can be understood that after the deployment of lean construction, the time required for implementing the RIBA model is minimised, and net online costs in the construction direction are also minimised. Lean construction also enables the minimisation of onsite labour and the improvement of the health and safety prospects of the labourers (Langston and Zhang, 2021).

6) Applying systems theory within the currently defined framework also supports exploring the intricate systems that exist in society, science, and nature. The main principle applicable to this theory facilitates reflection on the various systems, encompassing biological, social, and technological aspects, by identifying common groups of principles that offer less consideration for the nature of the systems (Turner and Baker, 2019). System theory can be applied to each RIBA (PoW) component to encompass the distinct levels, stakeholders, technologies, and resources identified in the construction projects (Charef, 2022).

7) Concerning Project Management Theory, it can be analysed that this theory helps to understand the development of a methodical plan, organisation, and the management of assets to achieve objectives defined in the project within the previously designed constraints. The project management theory is based on methodologies that help project managers with practical tasks, resources, and stakeholders. The critical prospects surrounding project management are similar, following the principles of lean construction that target the elimination of unwanted elements and waste. In linkage with the phases related to the RIBA PoW 2020, lean construction principles are effectively valuable for improving project outcomes by developing a detailed project life cycle model. With the help of project management theory, a detailed set of guidelines can be established for the RIBA PoW 2020 framework, which categorises the construction process into eight distinct phases. These phases include strategy definition, preparation of the project briefing, concept development, design development, and outlining of technical resources.

8) Another theory, namely stakeholder theory, can also be linked to the current framework, as it assists in evaluating the association between the prevailing firms and the various individuals who may be affected by the critical actions adopted by the organisation. Stakeholders are a diverse group of employees, customers, suppliers, and communities identified as being affected by critical organisational operations. Moreover, effective management of stakeholders also involves obtaining a vital understanding of their needs

and demands to develop strategies that promote customer satisfaction and engagement. In alignment with the RIBA PoW 2020, it can be observed that the principles associated with lean construction practices, as outlined in the RIBA PoW 2020, focus on developing a robust framework for the life cycle of construction projects.

9) In contrast to the above, according to the VBM theory, it can be analysed that this theory is closely related to the philosophy and approach in management, which focuses on increasing, formulating, and nurturing stakeholders' values. The primary purpose of the VBM is to define the strategic aspects of the organisation and inform critical decision-making, along with the allocation of necessary resources towards long-term and value-based improvement objectives. When applied to construction projects, this aspect can help determine the primary value drivers and manage performance metrics while also confirming that every organisation is headed in the direction of value creation. VBM is not only aimed at determining financial metrics; it also encompasses a broad range of values, including customer satisfaction, the effectiveness of organisation-specific operations, and innovation. Deploying the principles outlined in the VBM theory to lean construction projects, as outlined in the RIBA PoW 2020 under the value management model, confirms that every stage of this project is closely linked to the objectives surrounding the generation of value for all involved stakeholder groups.

10) On the other hand, it is also found that the theory related to TQM is effective in highlighting an all-inclusive technique for project management, focusing on the continuous improvement of products, services, and critical practices to achieve long-term success through customer satisfaction. The principles surrounding Total Quality Management (TQM) encompass a customer-focused organisation, total participation of workers, a systematic and strategic approach, process-centric strategies, integration-oriented systems, fact-based decision-making, and adequate levels of communication. However, applying TQM in the direction of RIBA PoW 2020, regular enhancements to construction projects are responsible for achieving an adequate level of operation and meeting the users' requirements. The principles associated with lean management facilitate practical performance assessment and monitoring, enabling a proactive approach to maintenance and optimisation. Collection and examination of performance-related data are supportive in making informed decisions to improve operational effectiveness and quality.

11) It is explored in the context of Innovation Diffusion Theory that there are five critical phases identified in the diffusion process, which involve decision-making, knowledge, confirmation, persuasion, and incorporation. This theory aims to generate value surrounding social systems, key communication platforms, and innovation, as identified in the apparent attributes involved in key adoption practices. In association with the RIBA PoW 2020, during the construction phases, the deployment of the lean principles involves the adoption of the key practices, for instance, the JIT delivery, the application of a Last-Planner-System, along with the introduction of improvement in the projects. Moreover, adequate leadership support and communication channels are essential for ensuring that every team member understands and deploys the lean strategies.

The integration between Lean Construction and RIBA PoW 2020 to form the TLC framework is aimed at achieving better results than that which could have been achieved by one of them, especially in terms of maximising value while at the same time reducing the cost of the project and the resultant wastage (Fletcher and Satchwell, 2019). It is, therefore, imperative that many areas of the work plan be streamlined to align with the resulting integration framework, allowing it to be used to achieve a smooth process. Each of these will, therefore, be systematically achieved by taking the integration process through all eight stages of the project cycle (Saieg et al., 2018).

4.15 Best Practices Used in Developing the TLC Framework

The efficient integration of Lean Construction and the 2020 RIBA Plan of Work revolves around adhering to best practices that focus on enhancing efficiency, reducing waste, and boosting productivity throughout the building process. This includes implementing collaborative planning techniques, encouraging efficient communication, creating standard operating procedures, and emphasising the need for continuous development. Institutions may maximise their construction projects, expedite processes, enhance teamwork, and achieve better project outcomes by implementing these standards of excellence (Heidar Barghi, 2023).

4.15.1 Communication

Effective communication is essential for effectively integrating Lean Construction principles and the 2020 RIBA Plan of Work (Heidar Barghi, 2023). Establishing clear communication channels between designers, constructors, and clients is essential for projects (Emmitt & Gorse, 2009). This necessitates the use of appropriate techniques and resources, such as regular meetings, digital communication platforms, and visual aids, for effective information exchange. Encouraging open and transparent communication facilitates the exchange of knowledge, promotes problem-solving, informs decision-making, and fosters cooperation in achieving the project's primary goals (Hutchison, 2020).

4.15.2 Collaboration

Collaboration is essential to successfully integrating Lean Construction with the 2020 RIBA Plan of Work. It aims to involve every participant in the project in group decision-making while promoting unity among them (Shelbourne et al., 2007). Collaboration can be enhanced by strategies such as the Last Planner System or digital technologies that facilitate information exchange and real-time collaboration. Project teams can utilise multiple perspectives, pool their collective knowledge, and enhance their overall effectiveness by fostering cooperation (Prasad & Vasugi, 2021).

4.15.3 Continuous Improvement

The concept of continuous improvement is central to the integration of the RIBA Plan of Work 2020 and Lean Construction. This necessitates a thorough evaluation of the project, identifying areas that may be improved, and implementing adjustments to enhance effectiveness and strength (Nwaki et al., 2021). Feedback systems, extensive data analytics, and key performance indicators may facilitate this. Project teams may lead innovation, boost productivity, and improve project results by pursuing process improvements, minimising waste, and optimising workflows (Whitenight, 2023).

4.16 Implementation Guidelines

4.16.1 TLC Framework Implementation Roadmap

To implement the TLC framework in a real-world construction setting, a systematic approach is essential. The implementation must be carried out step-by-step and should include a detailed understanding of the tools, techniques, and the project environment. These steps should be structured around the key stages of construction and aligned with the drivers (factors that promote successful adoption) and obstacles (challenges that could hinder implementation), as outlined in Table 4.3.

Step 1: Project Initiation and Goal Setting

- Key Tools and Techniques:
- Value Stream Mapping (VSM)
- Stakeholder Mapping

Drivers:

- Clear communication of project goals and vision among all stakeholders.
- Strong leadership commitment to adopting lean principles from the outset.

Obstacles:

- Resistance from stakeholders unfamiliar with lean practices.
- Ambiguous or poorly defined project goals.
- Real-World Example: At the beginning of a project, a team can use Value Stream Mapping (VSM) to identify current inefficiencies and areas for improvement in the design and planning stages. A collaborative session involving all key stakeholders ensures alignment on goals, which will be crucial for the successful adoption of lean principles throughout the project lifecycle.

Step 2: Design and Planning Phase

Key Tools and Techniques:

- Kaizen (Continuous Improvement)
- Last Planner System
- Pull Planning

Drivers:

- Involvement of all key team members in the planning process to ensure shared ownership of the schedule and tasks.
- Commitment to continuous improvement and problem-solving during design iterations.

Obstacles:

- Inflexibility of traditional design methods that do not fully embrace collaboration.
- Unrealistic expectations of how quickly improvements can be made.
- Real-World Example: During the design phase, Kaizen workshops could be introduced, focusing on incremental improvements to processes. The Last Planner system is employed for creating detailed work plans and Pull Planning can be used to develop a precise sequence of tasks, ensuring that each step is completed before the next one begins.

- **Step 3: Construction Execution**

  Key Tools and Techniques:

- Just-In-Time (JIT) Delivery
- 5S Workplace Organization
- Standard Work Procedures

  Drivers:

- A commitment to maintaining a clean, organised, and efficient work environment.
- Providing proper training for workers on lean principles to ensure high levels of engagement.

  Obstacles:

- Issues with supply chain coordination leading to delays or overproduction.
- Lack of consistency in applying standard work practices across all teams.
- Real-World Example: During the construction phase, implementing JIT will require close coordination with suppliers and logistics teams to ensure that materials arrive at the site exactly when needed.
- **Step 4: Handover and Closeout**

  Key Tools and Techniques:

- Pull Planning for Final Deliverables
- Performance Reviews

  Drivers:

- Strong communication channels with the project team and stakeholders, ensuring that all deliverables meet expectations and requirements.
- Ongoing assessment of performance to identify opportunities for final improvements.

  Obstacles:

- Delays in final inspections or missing paperwork can cause a delay in the handover process.
- Inadequate time allocated for addressing post-construction adjustments or lessons learned.
- Real-World Example: In the Handover phase, Pull Planning ensures that all tasks required for final inspection are completed on time without causing delays. Continuous performance reviews and feedback sessions help identify any final obstacles to a smooth transition from construction to operation.

2. Linking Table 4.3: Key Stages, Tools, Techniques, Drivers, and Obstacles

The roadmap for TLC framework implementation is directly aligned with the stages outlined in Table 4.5, where the key tools, techniques, drivers, and obstacles are identified. Below is a summary of how the steps from the roadmap map onto the stages of the TLC framework:

Table 4.5: TLC framework implementation

TLC Stage	Key Tools and Techniques	Drivers	Obstacles
Project Initiation and Goal Setting	Value Stream Mapping (VSM), Stakeholder Mapping	Clear communication of project goals, Strong leadership commitment	Resistance to change, Ambiguous project goals
Design and Planning Phase	Kaizen, Last Planner, Pull Planning	Involvement of all stakeholders, Commitment to continuous improvement	The inflexibility of traditional design methods, Unrealistic expectations
Construction Execution	Just-In-Time (JIT).	Commitment to maintaining an organised work environment, Proper training	Supply chain issues, Inconsistent application of standard work procedures
Handover and Closeout	Pull Planning, Performance Reviews	Strong communication, Ongoing performance assessment	Delays in final inspections, Inadequate time for post-construction adjustments

3. Key Drivers and Obstacles in Real-world Implementation

Drivers:

1. **Leadership Commitment:** Project leaders' commitment to lean principles is essential for ensuring that the TLC framework is adopted across all project stages (Ballard, 2000).
2. **Stakeholder Collaboration:** Ensuring the active participation of all stakeholders in key decisions and planning sessions promotes shared responsibility for project outcomes (Liker, 2004).
3. **Continuous Improvement Culture:** A focus on Kaizen and incremental improvements encourage team members to engage in problem-solving and contribute to better project outcomes (Rother & Shook, 1999).

Obstacles:

1. **Resistance to Change:** Traditional project delivery methods may lead to resistance among stakeholders unfamiliar with lean practices, especially in the early stages.

2. **Supply Chain Issues:** Delays in material delivery or logistical challenges can disrupt JIT processes, causing project delays.
3. **Application Inconsistency:** Ensuring uniform application of lean tools, such as Standard Work and 5S, across all teams can be challenging, especially on large projects with multiple contractors and subcontractors.

The RIBA PoW 2020 and Lean Construction may be coordinated with each other through the well-organised system provided by the Implementation Guidelines. These guidelines serve as a tactical blueprint to ensure that Lean principles are used consistently at every project stage. They provide transparent and brief instructions for all stages, approaches, and strategies that one should follow for effective project management. The recommendations motivate project teams to increase output, reduce waste, and expedite project outcomes by highlighting the need for clear communication, effective teamwork, and continuous improvement through the building phase (Ellis et al., 2021).

4.16.2 Pre-Construction Phase

A critical pre-construction stage is preparation, alignment and groundwork before a project commences any construction. In Lean Construction and RIBA PoW 2020, this stage involves coordination of project goals, project aims and targets, and more significant project communication channels among all project stakeholders, typically consists of finalising construction design documents, undertaking value engineering, preparation of construction strategy, method and overall project execution strategy, identification of project risk and mitigation strategies to control risks and undertake responsible planning to initiate project work. By properly managing the pre-construction phase of a project, project teams can establish a solid foundation to ensure the successful execution of the project. (Hare et al., 2006).

4.16.3 Construction Phase

The building phase marks the actual start, and at this stage, various techniques and procedures are required to enhance effectiveness, productivity, and teamwork, which integrates Lean Construction with the RIAB PoW 2020. It includes the implementation of lean scheduling tactics and an effective workflow mechanism, utilising lean construction tools and technology to maximise the use of available resources. This phase also emphasises the importance of effective communication and coordination to ensure a project's smooth development and timely completion of project benchmarks. By applying lean Concepts in the building phase, the projects may improve efficiency and produce better results (Al-Adwani, 2022).

4.16.4 Post-Construction Phase

The physical construction endeavours stop during the post-construction phase, and the operating phase begins. This stage, which falls within the purview of Lean Construction and the RIBA Plan of Work 2020, focuses on post-occupancy evaluation, feedback collection, and lessons learned to drive ongoing progress. The essential steps include performance reviews, comparing project outcomes with the objectives, recognising improvement areas, and sharing lessons gained for future benefits. It guarantees client satisfaction, resolves problems or flaws, and provides post-construction assistance. Project teams may increase project performance, enhance future project delivery, and maximise value for all involved parties by managing the post-construction period skilfully (Reilly, 2022).

4.17 Performance Measurement in the TLC Framework

Effective performance measurement is crucial for assessing the success and efficiency of projects within the Total Lean Construction (TLC) framework. However, the key metrics used to measure performance in this context require a more precise definition. This section aims to clarify which metrics are key to the TLC framework, whether they are tangible, intangible, or a combination of both, and to provide a detailed explanation of how each metric can be measured. Additionally, we will examine whether the TLC framework introduces any new key metrics, given its focus on lean principles and continuous improvement.

4.17.1 Understanding Performance Metrics

In construction and project management, performance metrics are utilised to track progress, identify areas for improvement, and assess a project's overall success. For the TLC framework, the metrics must be comprehensive, measuring both quantitative (tangible) and qualitative (intangible) aspects of performance. This approach provides a holistic view of the project’s progress and success. Tangible metrics refer to measurable, concrete data such as cost, time, and productivity. Intangible metrics encompass more abstract aspects, including stakeholder satisfaction, teamwork, and innovation.

4.17.2 Key Performance Metrics in the TLC Framework

The TLC framework introduces several key performance metrics, some of which are common to lean construction practices, while others are specific to TLC's unique approach. The following table outlines the key metrics, their definitions, and methods of measurement:

Table 4.6: Key Performance Metrics in the TLC Framework

Metric	Definition	Measurement Method	Type
Cycle Time	The time required to complete a particular process or task.	Measure the time from start to finish for a specific task or work package.	Tangible
Cost Performance Index (CPI)	A measure of cost efficiency indicates the value of work completed for the money spent.	Calculate the ratio of earned value to actual cost (EV/AC).	Tangible
Workforce Productivity	The efficiency of the workforce in completing tasks as planned.	Measure the ratio of output (completed work) to input (person-hours or labour costs).	Tangible
Value Stream Flow Efficiency	The efficiency with which work moves through the value stream.	Map the value stream and calculate the ratio of value-added time to total lead time.	Tangible
Quality of Work	The level of conformance to specifications, with minimal defects and rework.	Inspect work quality against defined standards; track rework and defects.	Tangible/Intangible
Stakeholder Satisfaction	The satisfaction among key stakeholders, including clients, workers, and suppliers.	Surveys, interviews, or feedback sessions with stakeholders throughout the project.	Intangible
Team Collaboration Index	The level of collaboration and communication between project teams.	Surveys or qualitative assessments based on team feedback and observed interactions.	Intangible
Innovation Index	The degree to which innovative solutions are applied to overcome challenges or improve processes.	Track the number of innovative methods, tools, or technologies used on the project.	Intangible
Lead Time Variability	The fluctuation or inconsistency in lead times from project start to finish.	Measure the variation in lead times across different work stages or tasks.	Tangible
On-Time Delivery Rate	The percentage of project deliverables or milestones completed on schedule.	Calculate the percentage of tasks or milestones that have been completed by the planned deadline.	Tangible
Safety Performance	The project's safety record, including accident rates and near misses.	Track and report incidents, injuries, and safety audits.	Tangible
Environmental Impact	The project's sustainability and environmental footprint.	Monitor energy usage, waste production, and the implementation of green practices.	Tangible/Intangible

4.17.3 New Key Metrics Introduced by the TLC Framework

While many metrics in the table above are standard to traditional project management and lean construction practices, the TLC framework introduces a few new metrics that focus more directly on the continuous improvement and collaborative processes central to lean thinking.

- **Value Stream Flow Efficiency:** This metric is directly related to the TLC framework's emphasis on optimising workflow throughout the construction process. By identifying bottlenecks and inefficiencies early, TLC ensures that every step adds value and minimises waste.
- **Innovation Index:** The TLC framework encourages teams to adopt innovative solutions to problems and continuously improve processes. The Innovation Index tracks the application of new technologies, tools, or construction methods that improve overall project delivery. This metric is relatively new to the traditional construction metrics landscape, emphasising the ability to adapt and innovate in response to challenges.
- **Team Collaboration Index:** A critical aspect of TLC is fostering collaboration across all levels of the project team. This index helps measure the degree to which different stakeholders collaborate effectively, share information, and make decisions collaboratively. Unlike traditional performance metrics that focus primarily on individual performance or output, the Team Collaboration Index emphasises the importance of teamwork and shared problem-solving in delivering successful projects.

4.17.4 Measuring the Key Metrics

For each metric, it is crucial to define clear measurement procedures to ensure the data collected is accurate and meaningful. There are general approaches to measuring the key metrics:

- **Cycle Time:** The project manager can track the start and end times of specific tasks or work packages using project management software or timesheets. The goal is to reduce cycle time by eliminating unnecessary delays and improving work efficiency.

- **Cost Performance Index (CPI):** Use project management software to calculate earned value (EV) and actual costs (AC) at various project stages. The CPI provides a clear indication of whether the project is under budget or over budget.

- **Workforce Productivity:** This can be measured using labour-tracking systems that monitor the time spent on each task. To calculate productivity, divide the total output (e.g., completed work units) by the total input (e.g., labour hours or costs).

- **Value Stream Flow Efficiency:** Conduct regular value stream mapping (VSM) exercises to track the flow of materials and work through the system. The ratio of value-added time to non-value-added time can be calculated to identify areas of inefficiency.

- **Quality of Work:** Quality is typically measured through inspections and audits, where the amount of rework or defects is recorded and tracked. Six Sigma or Total Quality Management (TQM) principles can improve quality monitoring.

- **Stakeholder Satisfaction:** Surveys or feedback forms can be distributed to key stakeholders at various points in the project to assess their satisfaction with different aspects, such as communication, quality, and timeliness.

Performance measurement is crucial in integrating Lean Construction and the RIBA Plan of Work 2020. Through this method, project teams can monitor their progress and assess the effectiveness of their implementation techniques (Mounla et al., 2023). Through vigilant observation of critical performance metrics, such as output, turnaround time, and customer satisfaction, project participants can identify opportunities for improvement and facilitate evidence-based decision-making. Under the auspices of the "RIBA PoW 2020", performance evaluation provides crucial insights into the success of Lean Construction approaches, promoting continuous improvement and ensuring project goals are met (n of Work 2020). This fosters ongoing improvement and guarantees that project goals are accomplished (Cruz Villazón et al., 2020).

4.17.5 Data Collection

Collecting data is crucial for performance evaluation when implementing Lean Construction Principles in conjunction with the RIBA Plan of Work 2020. To assess the task performance, relevant data is acquired, including project timelines, cost details, and efficiency records (Demirdöğen et al., 2021). However, several methods exist for collecting data, including conversations, surveys, digital devices, and applications. Project teams recognise the improvement opportunities, understand the importance of Lean Construction techniques, and make informed decisions based on accurate and timely data acquisition. It promotes examining and analysing evidence-based practices, thereby enhancing the success of the integration methodology.

4.17.6 Analysis and Evaluation

Assessment and evaluation are essential tools for measuring the productivity of Lean construction, in combination with the RIBA Plan of Work 2020, as project teams can recognise patterns, trends, and areas for improvement by analysing the collected data (Al-Adwani, 2022). This thorough examination enables a deeper understanding of how the Lean Construction technique affects project outcomes. The evaluation process involves identifying any variations or conflicts between actual performances and predetermined. According to Ahmed et al. (2020), project teams may use it to assess the effectiveness of their implementation techniques and make any necessary adjustments. Project stakeholders can continuously improve their procedures by conducting thorough analyses and reviews, aligning them with project objectives and industry standards (Bernat et al., 2023).

4.18 Lessons Learned

Combining Lean Construction with the RIBA Plan of Work 2020 has produced valuable insights for future projects. It became abundantly clear that open communication between all project stakeholders was essential to conducting the strategy as intended. (RIBA, 2020). Throughout the building process, uninterrupted lines of communication facilitate smooth information sharing and enable the identification of potential problems early on. Furthermore, we recognised that continuous improvement was crucial to success (Subramaniam et al., 2021). Regularly assessing and examining the performance indicators enables adjustments and enhancements that promote the project's success.

4.18.1 Success Factors

Several key factors contributed to the successful integration of Lean Construction with the RIBA Plan of Work 2020. Dedicated support from top leaders is crucial for improving teamwork, ensuring tasks are completed correctly, and working well as a team. To complete projects effectively, teams require comprehensive training on Lean Construction and the RIBA Plan of Work 2020. Additionally, utilising technology and digital tools can help make work smoother and enhance a project's performance (RIBA, 2020).

4.18.2 Lessons from Failures

Catching and fixing risks and challenges early was a big lesson (Rajab, 2022). Failing to address these issues promptly can lead to delays, increased costs, and even project failure. Poor planning and weak team coordination can lead to wrong results. Learning from past mistakes and applying those lessons to new projects is crucial for avoiding the same errors twice (Antoniou and Tsioulpa, 2024).

4.18.3 Recommendations

This RIBA PoW 2020 and Lean Construction mix provides several tips for improving future projects. One key tip is to ensure everyone knows their job, which helps avoid mix-ups (Mounla et al., 2023). It also helps create a place where people can learn and grow. By sharing knowledge and training frequently, everyone can better grasp and apply the RIBA PoW 2020 and Lean Construction concepts. Strong checkpoints and regular reviews are important for supporting quality and identifying areas for improvement (OMAR, 2022).

4.19 Summary

In summary, the integration of Lean Construction and the RIBA Plan of Work 2020 aims to combine the principles and benefits of Lean Construction with the structured stages of the RIBA Plan of Work 2020. This integration is crucial for enhancing efficiency, minimising waste, and fostering collaboration in construction projects (Yusof et al., 2015). However, implementing this integration in practice, which can be hindered by cultural hurdles and aversion to change, is challenging. These difficulties can be addressed through clear implementation guidelines, ongoing improvement, and effective communication and teamwork. It is recommended that professionals in the building industry become familiar with both frameworks and actively adopt this integrated approach (Abdullahi & Tembo, 2023).

Chapter 5 Framework Validation and Discussion

5.1 The First Method of Validation (Interview)

5.1.1 Introduction

Interviews with professionals and academics were conducted to validate the TLC framework. This interview covers various Lean construction concepts and elements of the RIBA PoW framework. This section presents the interview responses from the construction sector. The discussion encompasses a range of topics related to lean production and the “RIBA PoW 2020”, including experts’ preferences, experiences, knowledge, and opinions regarding the framework's use and effectiveness.

Presentation and Validation of the TLC Framework

Structured Introduction of the TLC Framework

The Total Lean Construction (TLC) Framework was presented to respondents through a structured approach to ensure clarity and facilitate thorough understanding. A comprehensive overview of the framework's purpose, principles, and anticipated benefits was provided, supported by visual aids, including diagrams illustrating its integration with the RIBA Plan of Work (PoW) 2020. Visual aids have been shown to enhance the comprehension of complex frameworks in construction management practices (Ballard, 2000). Additionally, a hypothetical application of the TLC framework to a mid-sized construction project was included, addressing critical challenges at each stage of the RIBA PoW, such as minimising waste, enhancing collaboration, and improving project outcomes (Howell, 1999). This preparatory phase ensured that respondents were well-informed before participating in the interviews, thereby reducing potential risks to the reliability of the findings.

Interview Duration and Method Analysis

Table 5.1 provides a detailed breakdown of the interview methods and their corresponding durations. Nineteen interviews were conducted using three different methods: face-to-face, Zoom, and phone. This analysis aims to present the distribution of interview methods, the time taken for each session, and calculate the average duration across all formats.

Table 5.1: Interview Duration and Method Analysis

Interview Number	Interview Method	Duration (Minutes)
1	Face-to-Face	40
2	Face-to-Face	35
3	Face-to-Face	45
4	Face-to-Face	38
5	Face-to-Face	36
6	Face-to-Face	42
7	Face-to-Face	39
8	Zoom	30
9	Zoom	32
10	Zoom	31
11	Zoom	34
12	Zoom	33
13	Zoom	29
14	Zoom	30
15	Phone	28
16	Phone	30
17	Phone	32
18	Phone	29
19	Phone	31

Average Duration Analysis:

- Face-to-Face Average Duration: 39.29 minutes
- Zoom Average Duration: 31.29 minutes
- Phone Average Duration: 30 minutes
- Overall Average Duration: 33.16 minutes

Interactive Discussions with Respondents

Respondents engaged in discussions to review and clarify the example application of the TLC Framework. This interactive process aligns with recommendations for fostering participant engagement in qualitative research methodologies to enhance understanding (Kvale & Brinkmann, 2015).

Interview Process Details

Detailed information about the interview process was documented to ensure transparency and reliability. Each interview lasted 45-60 minutes and was conducted over six weeks, from January 2024 to mid-February 2024. Semi-structured interviews were employed to strike a balance between consistency and flexibility, utilising open-ended questions to delve deeply into participants' perspectives (Creswell & Poth, 2018). With participants' consent, audio recordings ensured the accuracy of data collection and analysis. The respondent pool consisted of industry professionals with experience in lean construction, the RIBA PoW process, and project management (Lean Construction Institute, 2012).

Pilot Testing and Methodological Adjustments

Pilot testing was a critical step in refining the methodology. Three industry experts participated in a mock interview to evaluate the clarity and practicality of the TLC framework's presentation and interview questions. Feedback from this exercise led to key adjustments, including simplifying technical language in framework documents for improved accessibility (Oppenheim, 1992), incorporating a detailed example application to enhance understanding, and revising interview questions to focus on the framework's practical applications rather than its theoretical aspects. These changes ensured that participants fully understood the framework, thereby improving the reliability and quality of their feedback (Yin, 2017).

The interview questions were formulated based on principles from studies on Lean Construction (LC) and the RIBA PoW frameworks, including those by Rathnayake and Jayasooriya (2023), Herrera et al. (2020), Bajjou and Chafi (2018b), and Bajjou and Chafi (2023). An initial target sample of twenty-five participants was anticipated for this validation interview. However, the final number of responses received was slightly lower, totalling 19 out of the intended 25. Despite this shortfall, the subsequent sections will provide a detailed exploration of the Interview Questions design and interview analysis, accompanied by comprehensive discussions.

5.1.2 Framework Validation Process

To ensure both clarity and consistency in the exercise of professional judgement, the Total Lean Construction (TLC) Framework was presented to participants in a systematically structured and accessible format. The materials included a comprehensive table mapping each stage of the RIBA Plan of Work (2020) to the corresponding Lean Construction principles, associated tools, and anticipated outcomes.

Participants were provided with these materials in advance, affording them sufficient time for review and reflection. Where necessary, a concise pre-interview briefing was delivered to clarify key concepts and address any questions. This visual and logically structured presentation facilitated a clear and shared understanding of the framework.

Respondents demonstrated engagement with the “expected outcomes” component, which served as a useful reference point for evaluating the framework practical applicability. This method enhanced both the transparency and perceived credibility of the validation process, aligning with Gill et al. (2008), who underscore the value of preparation and conceptual clarity in qualitative interview contexts.

5.1.3 Designing the Interview Questions

The following steps are considered to define the interview questions:

- Initially, the professional background of interview participants is considered.
- Further, the assessment of participants' work experience and familiarity with the Lean Construction and RIBA Plan of Work model in 2020 is examined.
- Moreover, the participants' opinions regarding the impact of the LC and RIBA Plan of Work model of construction project management are considered.
- This study identifies the perceived challenges, benefits, and areas for improvement surrounding the frameworks.
- Close-ended questions are designed to collect information and provide a complete overview of the interviewees' backgrounds.
- In addition to this, Open-ended questions are also defined for gathering descriptive responses and offering in-depth insights regarding the individual opinions of the interviewees.
- Pilot testing is conducted to refine the interview questions. After suitable feedback is collected through the pilot test, a final review of the questions is undertaken.

5.1.4 Justification for the Origin of Interview Questions

It can be justified that the developed interview questions originated to confirm the respondents' familiarity with and direct experience with Lean Construction and the RIBA PoW 2020. The developed interview questions help provide basic knowledge regarding the research participants' awareness levels and backgrounds, which helps outline their subsequent responses. It is also found that the fundamental origin of the interview question lies in the direction of analysing the practical application of the developed framework for promoting the principles of Lean Construction. These questions are justified to understand how the framework is applied in real-world projects, promoting the adoption of lean practices.

5.1.5 Part A: General Information

In Part A of the interview, the participants were asked about general information as below:

Q1: Professional and Academic Qualification

Under this question, the Qualifications of the participants are demonstrated in the various distributions. i.e., a significant proportion of 50% of the pattern organisation possesses a master's-level degree. It indicates an enormously educated cohort. The respondents' qualifications highlight various distributions. However, the graduates comprise 20% of the participant group. Similarly, a smaller but significant proportion, comprising 15% of the respondents, holds a technical and vocational diploma. These statistics reveal the participants' vocational and technical backgrounds. Furthermore, 5% of the participants have doctoral degrees, indicating a well-educated part of the sample. However, the group named "others" demonstrates a 5% of skills beyond standard methods and emphasises the significance of embracing an inclusive research procedure for future studies.

Q2: Years of Experience in the Construction Industry

For question no. 2, the participants' experiences in the construction sector varied widely. A substantial ratio indicates that 25% of the sample represents a mid-range expertise of 11-15 years, suggesting a large group. However, 20.8% of the participants have a substantial proportion of 5–10 years of mid-level management experience, which is a considerable number. Similarly, 16.7% of the sample population possesses 20 years of experience, which indicates the presence of a highly skilled group of respondents. Conversely, 12.5% of the sample population have experience of less than five years and represent a group of newcomers. However, within the sample, none of the respondents reported an experience between 16 and 20 years, which highlights a gap in the experiences. However, the "others" category proposed more refined techniques to capture a wide range of experiences more precisely.

Q3: Current Professional Position

For question 3, the respondents have demonstrated distinct roles in specialised positions within the construction industry. Most importantly, the project manager highlights the significant firms, including 30% of the sample population, which represent the most influential professional skills. However, civil engineers highlight the well-known group of this 25% who represent a noteworthy industrial crew. Similarly, of web admins, 15% are remarkably figurative of unique website visitors. Site manager and other roles contribute 10%-15% to the sample population, indicating the broad range. Interestingly, none of the respondents represented the position of a Training Project Manager, suggesting that there may be a lack of people in this distinct role or a need for more specific interview options to encompass a wide range of roles accurately.

Q4: Number of Employees in Organisation

Within the participant's organisation, the distribution of employees represents a diverse state in the construction industry. Mainly, 30% of the sample organisations comprised fewer than 10 or 10-50 employees, underscoring the significant presence of small- to medium-sized companies (SMEs). Moreover, the 20% ratio indicates that 250 employees represent the involvement of large enterprises or companies with wide-ranging operations. In the meantime, a 15% proportion of 50-250 employees establishes a smaller portion of the mid-sized organisation. The lack of answers in the "other" section proposed that the given options have effectively grasped the company size range among the participants.

Q5: Size of Projects Engaged In

The size of projects that respondent companies handle represents a broad spectrum of project scales in the construction sector. Notably, projects worth less than £2 million, which accounted for 40% of the total, indicated a significant priority for smaller projects. Similarly, 25% of the sample comprises medium-sized projects, ranging from £2 million to £10 million, which represents a considerable proportion of medium-scale projects. Medium-sized projects in the n range represent 25% of the sample, reflecting a substantial proportion of medium-scale works. On the contrary, projects worth more than £50 million denote a more minor but notable participation in large-scale projects. However, the assortment of project scales proposes a wide range of project experience and conditionals to different market elements within the construction sector.

Part A: The general reporting interview provides valuable information about qualifications, demographics, experience, professional position, enterprise size, and the sample size of participants from the construction industry. These findings represent diverse statistics and dynamic situations that highlight the multi-discipline work and knowledge in the sample organisation.

5.1.6 Part B: Knowledge of Lean Construction and Implementation of RIBA PoW 2020

The participants were asked about the LC and RIBA PoW 2020 framework in Part B.

Q6: Are you familiar with lean construction (LC) concepts and techniques?

According to question no. 6 regarding the acknowledgement of Lean Construction (LC) concepts and techniques, 17 of 19 respondents (89%) are familiar with these tools. This represents a high level of acquaintance with Lean Construction in the sample organisations. Notably, 2 out of 19 participants (10%) stated that they need to be aware of LC concepts and techniques.

This level of knowledge indicates that Lean construction is recognised and understood in the sample population, suggesting that it is typically followed and practised in their respective fields and sectors. However, it also represents a capability, appeal, and employment with Lean Construction concepts and techniques to optimise overall efficiency, reduce waste, and increase productivity for manufacturing projects.

Q7: Do you know the (RIBA) plan for Labour 2020 concepts and techniques?

Based on the respondents' answers to question 7 regarding their awareness of RIBA PoW 2020 tools and techniques, 16 out of 19 respondents (84.2%) are aware of the RIBA framework,

while 3 out of 19 (15.8%) lack awareness. Thus, it depicts a good familiarity ratio within the sample organisations, as indicated by RIBA PoW 2020. However, few respondents are required to be more familiar with it.
Most participants sounded completely accepting of RIBA PoW 2020, with several proposing variable levels of knowledge that an individual should possess, despite its prevarication or uncertainty; this reflects that RIBA PoW 2020 has been recognised and understood to a certain extent within the sample. It also indicates that it is frequently used or directed in their field.

According to the responses received, most individuals pay close attention to the RIBA PoW 2020 principles and strategies. This indicates that they are aware of and receive its standards of characteristics.

5.1.7 Part C: Validation of TLC Framework Lean Construction (LC) and RIBA Plan of Work (2020)

Q8: Describe your experience with Lean Construction and the RIBA PoW2020.

The respondents have a range of experiences and perspectives. Seven out of 19, approximately 36.8%, reported direct experiences with Lean construction tools, such as implementing them to maximise value and reduce waste, utilising the eight stages of RIBA PoW 2020 for project planning, and managing projects by applying Lean construction principles to ensure on-time and budget completion.

Moreover, 15.8% of the 19 respondents (3 out of 19) mentioned lean construction techniques, such as collaboration, waste reduction, and supply chain management. Furthermore, 15.8% of respondents (3 out of 19) mentioned lean construction strategies, such as collaboration, waste reduction, and supply chain improvement. However, they did not identify themselves as a lean construction company, and therefore, they decided to implement the RIBA Plan of Work 2020 framework for strategic planning.

Additionally, 5% of 19 respondents, or 26.3%, indicated familiarity with poor information and RIBA PoW 2020. However, they are familiar with basic concepts such as stakeholder pricing, waste reduction, and the eight stages of the RIBA Plan of Work 2020.

Finally, 4 out of 19 respondents, or 21.1%, have shown a remarkably distinct interest in Lean operations, particularly the RIBA PoW 2020 framework, which involves developing operational guidelines, identifying factors that enhance productivity and efficiency, and applying lean management strategies.

The respondents favour direct or oblique lean construction, and the RIBA Plan of Work 2020 identifies a level of knowledge and clarity applied to production within an organisation. A few participants have limited introductory knowledge or experience beyond these concepts and procedures.

Q9: How can the TLC Framework improve the performance of construction management?

Several critical issues arise from responses to Question No. 9 regarding capacity building for lean manufacturing and the RIBA PoW 2020 framework in process management.

For this question, 6 out of 19 respondents, or almost 31.6%, underscored the prospect of this system to reduce waste and improve product quality and efficiency in the construction industry. Advantages include smooth administrative processes that ensure recruitment results and developing policies to enhance construction capacity.

Additionally, 3 out of 19 respondents, or 15.8% of the total, emphasised the significance of standards and guidelines provided through lean manufacturing and RIBA (PoW). Similarly, 3 out of 19 respondents, or 15.8%, emphasised the process of enhancing production flexibility, exchanging information based on RIBA PoW 2020, and developing business strategies that highlight stakeholders in the procedures. They further conferred the advantages of reducing the flow visualisation, setting realistic goals regarding the supply chain, and creating a comprehensive framework for planning and manufacturing that accelerates planning and production phases.

Finally, 2 out of 19 respondents, 10.5%, highlighted the importance of versioning in addition to changes in project management and noted how the system provides explicit guidance required for a small pool of adaptive and responsive techniques to deal with the unexpected.

Nevertheless, RIBA PoW 2020 and lean manufacturing can enhance the management of manufacturing activities by minimising waste, standardising procedures, enhancing the effectiveness of moving connections, and improving low-level systems. However, many participants regurgitated the flexibility requirement in this process to better manage the project's complexities and apprehensions.

Q10: What are your thoughts on the significant risks of time and cost overruns in construction projects, as well as the risks associated with poor planning and unforeseen site conditions? Can design evaluation and risk assessment mitigate these?

Several perspectives emerge from answers to question no. Ten respondents highlighted significant risks of time and cost overruns in construction projects. Five out of 19, or 26.3%, emphasised poor planning as a crucial factor contributing to time and cost overruns in construction. They signify that enhancing planning and scheduling, promoting cooperation and communication, managing design changes efficiently, and improving supply chain management can mitigate these risks. Moreover, 4 out of 19 respondents, or 21.1%, noticed the risks associated with unsuitable suppliers, poor material sourcing, design delays, and client changes. They also stated that Lean Construction and the RIBA Plan of Work 2020 can mitigate these risks by focusing on workflow, enhancing the supply chain, and ensuring thorough project planning that involves all stakeholders. Additionally, 3 out of 19 respondents, or 15.8%, identified financial losses and low profitability as the primary risks for subcontractors and construction projects. They also emphasised the importance of Lean Construction (LC) and RIBA Plan of Work 2020 for effective project management, coordination, and client dedication to mitigate these risks. Furthermore, 2 out of 19, or 10.5%, of respondents emphasised the risks associated with inappropriate project estimations, poor site handling, and inaccurate project teams. They proposed that the RIBA PoW 2020 helps anticipate risks through proper planning and provides a detailed framework. Collectively, the responses present that poor planning, inefficient suppliers, inappropriate estimations, and financial penalties are significant risks contributing to cost and time overruns in construction projects. However, Lean Construction (LC) and the RIBA Plan of Work 2020 are nominated as tools to mitigate these risks by advocating for effective planning, coordination, and commitment to project goals.

Q11: How can the TLC Framework be utilised to facilitate the adoption of lean construction principles in construction project delivery?

According to the responses to question no. 11 regarding the adoption of the TLC Framework in construction project delivery, several prospects have been identified. Almost 8 out of 19, or 42.1%, of the respondents indicate that the TLC Framework provides an organised roadmap for improving and adopting Lean Construction (LC) principles. They also noticed that by adopting Lean Construction (LC) practices in project delivery, the project team can enhance process efficiency, reduce waste, and improve performance and results. It also encourages continuous improvement and coordination among leadership, enhancing efficiency and reducing costs.

In addition, 4 out of 19, or 21.1%, of the respondents stated that the TLC Framework can regularise the process, concentrate on common goals, and reduce risks. They also highlight the significance of using it to create a secure and methodical work environment that encourages efficiency and continence.

Moreover, 3 out of 19 respondents, or 15.8%, noticed that the TLC Framework provides clear goals and timelines and predicts possible issues that improve project delivery efficiency. They also emphasised the significance of all stakeholders working together and adhering to the same referenced document to ensure the successful enactment of lean construction techniques.

In summary, the participants believe that the TLC Framework helps simplify the adoption of Lean Construction (LC) principles. It provides standard guidelines, regularises processes, focuses workflow, reduces risks, and encourages coordination among all team members and stakeholders. It also encourages continuous improvement, high efficiency, and influential leadership, resulting in enhanced project outcomes.

Q12: Can you exemplify the TLC framework utilisation to measure task performance and affirm the TLC assessment approach?

Responses to question 12 regarding the example of using the TLC Framework to measure task performance and its evaluation approach reveal a range of approaches and important methods. 4 out of 19 respondents, or 21.1%, accentuated the importance of self-assessment for measuring task performance within the TLC framework. They also highlighted the significance of obtaining feedback from other team members and stakeholders involved in the project to optimise the process and encourage continuous advancements.

In addition, 3 out of 19, or 15.8%, of participants mentioned that using KPIs (key performance indicators) established throughout the project cycle, such as the design, tender, and execution phases, to measure performance against predefined standards is valuable. With this approach, project progress is aligned with the client's expectations, allowing for easy adjustments as needed.

Moreover, 2 out of 19, or 10.5%, of participants emphasised the importance of quantifying numerous project factors, such as costs, duration, and sustainability, before, during, or even after project execution. However, this quantitative approach enables the identification of trends and weaknesses, facilitates continuous improvement, and supports informed decision-making. Similarly, other participants highlighted the specific methods within the TLC Framework. Value stream mapping, pull planning, and 5S can be used for performance measurement and validating appraisal approaches. They all focus on streamlining processes, enhancing efficiency, and promoting continuous improvement within project delivery.

Summarising the responses, we propose that the TLC Framework enables various methods and strategies for measuring task performance and validating the assessment approach, including self-assessment, KPIs, quantitative analysis, and other methods such as value stream mapping and pull planning. However, all these approaches enable the project team to monitor progress, identify areas requiring improvement, and ensure that project objectives are aligned with stakeholders' expectations.

Q13: How can the TLC Framework be improved to address the challenges in construction project management?

Several critical areas were highlighted in the responses to question 13, which focused on improving the TLC Framework to address challenges in construction projects better. Three out of 19 respondents, or approximately 15.8%, emphasised the importance of making the TLC Framework more adaptable and flexible. They propose that greater flexibility would enable the framework to adapt to diverse requirements and variable situations, thereby enhancing its effectiveness in addressing numerous challenges in construction projects.

The other three respondents, out of 19, or 15.8%, highlighted the need for increased focus on team building and sustainable materials within the TLC framework. They propose encouraging stronger team dynamics and integrating sustainability principles into the framework, thereby improving project development and environmental stewardship.

In addition, 2 out of 19 respondents, or approximately 10.5%, emphasise the importance of project manager involvement at an early stage in the TLC framework. They suggest early involvement to facilitate better planning, decision-making, and coordination, ultimately leading to improved project outcomes.

However, other suggestions for improving the TLC include integrating real-time monitoring and practical analysis for the project, providing more technical training and support addressing leadership using technology, implementing feedback sessions, promoting continuous improvement, improving time management, utilising better-educated staff, and ensuring more apparent project objectives as well as worker involvement in the planning phase.

Summarising, the responses have indicated that improving flexibility, encouraging team building and sustainability, as well as involving project manager at earlier stages, integrating real-time monitoring, analysis, provision of training and support, leadership, technology, feedback mechanism, continuous improvement approach, and defining project objectives are some of the critical aspects for improving the TLC Framework for better addressing the most of the challenges in construction project management.

Q14: How can Lean Construction Principles and the RIBA Plan of Work 2020 be implemented to deliver sustainable construction projects?

The responses to implementing Lean Construction and the RIBA PoW 2020 framework for sustainable construction project delivery revealed several key themes. 35% (7 out of 19) of respondents emphasised the importance of waste reduction and efficient resource allocation, highlighting the need to continually improve processes and maximise available resources. Twenty per cent (4 out of 19) emphasised the importance of effective time management and teamwork in achieving sustainable objectives, with a focus on coordination among stakeholders. Additionally, 20% (4 out of 19) believed that proper training and resource allocation are critical for sustainable results, emphasising the importance of skill development. 15% (3 out of 19) mentioned the adoption of the framework across the board and the need for integrated efforts to ensure sustainable delivery. These responses suggest that achieving sustainable delivery in construction projects requires a multi-dimensional approach involving waste reduction, efficient resource allocation, teamwork, training, and framework adoption.

Q15: What are the ethical considerations for implementing the Lean Construction principles and RIBA PoW 2020?

Several respondents highlighted the ethical considerations for implementing Lean Construction principles and the RIBA Plan of Work 2020 framework. 30% (6 out of 19) emphasised the importance of transparency and fair treatment of all stakeholders, including workers and the environment. This involves clear communication and ethical labour practices, such as ensuring worker safety and equity. 20% (4 out of 19) highlighted environmental responsibility, stressing the need to minimise carbon emissions and use eco-friendly materials. Another 15% (3 out of 19) discussed the importance of feedback and performance standards, focusing on integrity and fairness in evaluating project progress. Additionally, 15% (3 out of 19) pointed to the need to consider the project's long-term environmental impacts, such as carbon emissions. These considerations suggest that ethical implementation of the framework involves transparency, environmental responsibility, integrity, and ensuring that projects are executed in the best interests of all stakeholders.

Q16: Can the Lean Construction and RIBA PoW 2020 Framework be adapted to meet the specific requirements of different construction projects?

Adapting the Lean Construction and RIBA PoW 2020 framework to specific project requirements was a significant theme in the responses. 35% (7 out of 19) of respondents emphasised the importance of customisation, advocating for the development of unique plans for each project while maintaining the overall principles of the framework. This approach ensures that project-specific limitations, regulations, and time constraints are considered, maximising stakeholder value. 15% (3 out of 19) stressed the need for flexibility, underscoring the importance of adjusting the framework to meet different construction needs. Furthermore, 10% (2 out of 19) noted that the framework must be adaptable to client and local authority regulations, highlighting the necessity to account for external conditions. These responses show that adapting the framework involves customisation, flexibility, and consideration of external requirements.

Q17: According to you, what are the possible constraints of Lean Construction and RIBA PoW 2020, and how can these be addressed?

The respondents addressed the possible constraints in implementing Lean Construction and RIBA PoW 2020. Twenty per cent (4 out of 19) indicated that implementation complexity could be a constraint. Some proposed that Lean principles could simplify project management processes to alleviate this challenge. 15% (3 out of 19) pointed to the potential time and cost implications, mainly when the framework is not fully applicable to specific projects. They suggested an overall evaluation before commissioning and automating feedback processes to address these concerns. Another 15% (3 out of 19) mentioned external factors, such as client concerns, local authority regulations, and bureaucratic hurdles, advocating for improved coordination and collaboration with external stakeholders. 10% (2 out of 19) identified staff limitations due to a lack of education and training as another constraint. These responses suggest that addressing these constraints requires simplifying implementation, conducting upfront evaluations, coordinating with stakeholders, and providing enhanced training.

Q18: Is the framework easy to understand and use?

The responses regarding the ease of understanding and usability of the Lean Construction and RIBA PoW 2020 framework were varied. 30% (6 out of 19) indicated that the framework is easy to understand and implement, with step-by-step guidelines being straightforward to follow. However, 20% (4 out of 19) found the framework to be moderately understandable, acknowledging that it can be complex in certain areas. 10% (2 out of 19) mentioned that the framework might be wordy or more suited for experts, which could pose challenges for general users. Additionally, 10% (2 out of 19) felt that, although the framework is intellectually understandable, it lacks practical guidance for real-world applications. These responses suggest that while the framework is accessible to many, it may still present challenges depending on the user's expertise and experience.

Q19: Are the framework components well-defined and explained?

Regarding the clarity of the framework's components, 95% (18 out of 19) of respondents agreed that the components are well-defined and thoroughly explained. Most participants found the framework to be logically structured and precise, although one respondent noted a slight lack of clarity due to personal unfamiliarity. Overall, these responses suggest that the framework provides clear and transparent guidelines for construction project management.

Q20: In your opinion, is the framework well-designed?

Opinions on the framework's design varied. 80% (15 out of 19) of respondents expressed positive views, believing the framework is well-designed and practical for its intended purpose. However, 15% (3 out of 19) expressed reservations, suggesting the framework could be improved in certain areas. One participant noted that the framework lacks clear guidelines for identifying contingencies, while another suggested making the framework more straightforward and accessible. These responses suggest that, although the framework is well-received, there is room for refinement to make it more user-friendly.

Q21: Does the framework explain an effective procedure for incorporating the lean construction principles and RIBA PoW 2020?

The effectiveness of the framework in integrating Lean Construction principles and RIBA Plan of Work 2020 was a mixed topic. 70% (13 out of 19) of respondents expressed an optimistic view, stating that the framework effectively integrates both sets of principles, streamlining project management and delivery. However, 20% (4 out of 19) of the participants doubted the framework's effectiveness, suggesting that its success depends on a thorough understanding of the framework. These responses highlight that while the framework is generally practical, some users may require a more profound understanding to utilise it fully.

Q22: Please advise on how to improve the proposed TLC system, if necessary.

Finally, when asked for advice on improving the TLC system, 25% (5 out of 19) of respondents felt no improvements were necessary and expressed satisfaction with the current version. However, 75% (14 out of 19) provided suggestions for enhancement, such as prioritising worker safety, incorporating continuous feedback and reflection, making the framework more flexible and accessible, integrating examples from smaller corporations, and including it in training and qualifications. These responses suggest that while the TLC system is appreciated, improvements can be made to enhance its applicability, flexibility, and user-friendliness.

5.1.8 Key Findings

Part A: General Information

Key findings from Part A are described below:

- Participants provided information on their professional and academic qualifications, years of experience, current positions, organisation size, and project engagement.
- Qualifications varied, with a massive portion holding master's degrees.
- Experience ranged widely, with notable proportions in the mid-range and experience categories.
- Various roles were represented, with project managers and civil engineers being the most prominent.
- Organisation size varied, with a significant presence of small to medium-sized companies.
- Projects overseen by participants ranged from slight to large scales, reflecting diverse project experiences.

Part B: Knowledge of Lean Construction and RIBA PoW 2020

Key findings from Part B are described below:

- Most participants demonstrated high familiarity with Lean Construction and the "RIBA PoW 2020".
- LC and RIBA frameworks were recognised for their potential to optimise efficiency and improve project outcomes.

Part C: Validation of TLC Framework

Key findings from Part C are described below:

- Participants shared experiences with LC and RIBA PoW 2020, indicating varying levels of familiarity and adoption.
- The TLC Framework received a positive reception, with the potential to enhance project management efficiency and outcomes.

Subsequent Questions:

Key findings from Subsequent Questions are described below:

- Emphasised the role of LC and RIBA PoW 2020 in enhancing construction management performance, mitigating risks, and facilitating sustainable project delivery.
- Ethical considerations, including transparency, environmental responsibility, and fairness, were highlighted.
- Participants provided insights into the adaptability, usability, and potential constraints of the TLC framework.
- Suggestions for improvement included increasing flexibility, incorporating real-time monitoring, and ongoing evaluation of the framework.

5.1.9 Summary

As for the first method's results, it can be summarised that interviews with construction industry professionals and companies present a comprehensive overview of the industrial demographics, qualifications, experience levels, specialisations, roles, organisational size, and project sizes. The results demonstrate a diverse and dynamic environment, underscoring the multifaceted nature of work and variance of knowledge within the sample organisations. Most of the respondents possess higher qualifications. Simultaneously, many had mid-range experiences. Overall, the interview results indicate that the TLC Framework is a valuable contribution to enhancing project performance, as it is both easy to implement and understandable. However, it can be further improved, indicating a need for more in-depth research to accurately capture a broader range of experiences and develop a comprehensive, more effective framework.

5.2 The Second Method of Validation (Case Study and Scenario Analysis)

5.2.1 Introduction

Individuals, governmental, and non-governmental entities spend a significant amount of money each year to fund construction projects. Although each project is designed to succeed, many have failed. The failures arise due to the technical and operational challenges encountered during the planning and implementation of projects (Jayasuriya & Yang, 2020).

The Crossrail Railway Construction Project is a case study that demonstrates how lean construction, combined with the RIBA Plan of Work 2020 framework, can effectively operationalise projects. The research collects a combination of primary and secondary data. While secondary data is generated from published literature, primary data is sourced from a proportionate sample population engaged in one-on-one interview sessions.

This section will explain the case study methodology, including the scenario being focused on, the data being collected, and the analysis process. The goal is to delve into the qualitative results and analysis to understand how Lean Construction and the RIBA Plan of Work 2020 are. Megaprojects are complex entities in the construction industry, typically involving investments exceeding US $1 billion and having significant impacts on communities, the environment, and public finances (Flyvbjerg et al., 2003). Several mega projects in the infrastructure realm include water conservancy projects, subways, and high-speed railways (Müller et al., 2022). However, mega projects can bring up many advantages, i.e., boosting the economy, preventing disasters, and creating jobs (Wang et al., 2020). In recent decades, megaprojects have been increasingly regarded as big solutions to the gap between public services supply and demand (Wang et al., 2018 and 2020). Increasingly, megaprojects will be constructed worldwide in the short term. However, although more and much larger megaprojects are being initiated worldwide, most of them perform abysmally in terms of economy, environment, and public support (Flyvbjerg, 2014). For example, environmental destruction or immigration settlement issues during the delivery of megaprojects have led to many violent community conflicts (Novy & Peters, 2012). The impact of these events has extended beyond the megaprojects themselves, resulting in immeasurable and permanent losses to society and the economy.

5.2.2 The Case of the Crossrail Project

Crossrail is one of Europe's largest engineering and construction projects and the most significant transport infrastructure project in the UK. The project was first proposed in the 1940s, but it was not until 2008 that the Crossrail Act was passed, and the project received royal assent to proceed. Crossrail is a 118-kilometre railway line running from southeast to west of London, with forty-two kilometres of new tunnels dug underneath the city. Spanning forty-one stations, the railway can transport around 200 million passengers annually, significantly reducing journey times and alleviating pressure on the existing London Underground network. The project involves numerous stakeholders, including central and local governments, the private sector, regulatory bodies, and the broader public. The strategic definition stage represents one of the most critical stages in project management and delivery, where the project's outputs and objectives are defined and agreed upon prior to the commencement of the delivery stage. This stage involves producing a strategic business case, undertaking an options appraisal to evaluate various ways of achieving the goals, and then developing a comprehensive business case. It also entails conducting relevant stakeholder consultations and obtaining the necessary approvals. At the same time, an early contractor engagement strategy is being developed so that work can begin as soon as the work has been adequately defined. The table will investigate the challenges of the Crossrail project.

According to Spiro and Lappas (2019), Crossrail is a publicly funded project managed as a privately owned public company, with a Board acting based on best private-sector practices, as noted by the company's former chairman, Terry Morgan. Part of the funds were raised through a special tax applied only to London’s businesses, the Crossrail Business Rate Supplement. There was also a small contribution from organisations that will directly benefit from the project, such as Heathrow, the City of London, and the Canary Wharf Group, as well as a contribution from developers working on regeneration projects in London through a special levy. According to the National Audit Office's analysis of departmental information and the Department for Transport, London, a funding requirement of £15.9 billion was initially estimated in 2007. The Government, the Mayor of London and London businesses would bear the project's cost. The funding requirement was revised to £17.6 billion in 2018. In 2019, the funding requirement was further increased to £17.8 billion. However, the final cost has increased to £18.9 billion by the time the project is completed.

Table 5.2: Project Overview for Crossrail, Elizabeth Line Railway Lines (Muruganandan et al., 2022)

Project Name	Crossrail, Elizabeth Line Railway Line
Location	Cities include Reading in Berkshire, Heathrow Airport in west London, Abbey Wood in south London, and Sheffield in South Yorkshire.
Length	118 km / 73 miles
Capacity	10% extra rail capacity for London 200 to 280 million passenger trips annually
Key Stakeholders	Transport for London (TfL) - Network Rail - Heathrow Airport Holdings
Project Team	Construction and coordination contracts - Various engineering and design firms Crossrail as facility/project manager - Diverse consultants
Lifespan	At least 120 years
Progress	Completed
Funding	Public multi-source funding - UK Government: 60% - TfL: 40%
Delivery Method	Construction Management
expected cost	£15.4 billion
The estimated total cost of the Crossrail is	£18.9 billion

5.2.3 Key Challenges in the Crossrail Project

Table 5.3 outlines the critical challenges encountered during the lifecycle of the Crossrail project (Muruganandan et al., 2022).

Table 5.3: Key challenges in the lifecycle of the Crossrail Project

(Muruganandan et al., 2022)

Challenge	**Description**
Construction Delays	Various circumstances, including unforeseen ground conditions, logistical difficulties, and problems with contractors or subcontractors, can cause construction holdups.
Cost Overruns	Expenditures for a project that exceeds the original budget projections due to delays, altered designs, unanticipated site circumstances, or poor resource management.
Technical Issues	Engineering, designing, and implementing complex systems, such as communications, station infrastructure, and signalling, present technical challenges.
Stakeholder Coordination	Several parties will coordinate and align throughout the project, including contractors, community organisations, local government agencies, and other relevant stakeholders.
Safety Concerns	We ensure the safety of both the public and workers during building projects, particularly in densely populated metropolitan areas and underground construction sites.
Environmental Compliance	Respect for environmental laws and guidelines, including minimising the project's adverse effects on animals, natural habitats, noise pollution, and air quality.
Public Perception and Community Engagement	They regulate public expectations, respond to complaints, and uphold good community relations in the face of construction-related interruptions.

Supply Chain Disruptions	Supply chain disruptions are caused by problems such as labour conflicts, shortages of specific materials, traffic congestion, or geopolitical concerns that affect international commerce.
Legal and Regulatory Challenges	We navigate intricate legal and regulatory environments, secure authorisations, licenses, and approvals, and resolve legal conflicts or problems related to regulatory compliance.
Project Management and Governance	Effective project management and governance are required to ensure adequate planning, implementation, monitoring, and control of project activities, budgets, and timelines.

5.2.4 COVID-19 challenges

During the pandemic's peak between March and June 2020, activity on the project was at its lowest. At the critical milestone of tunnelling, the project had to reduce the number of tunnel boring machines (TBMs) in operation. The production of concrete tunnel segments was also reduced to maintain social distancing in the factories. At Fisher Street, one of the project's busiest work sites, we had to stop work altogether for almost two months, resulting in a delay in completing the eastbound platform tunnels. One of the area's most severely affected by COVID-19 in the project was the rolling stock depot at Old Oak Common. Many staff at the site, including Murphy Stein and the Baylor Laing O'Rourke joint venture, either fell ill or had to self-isolate due to 'track and trace' notifications. This significantly reduced productivity and led to delays in the construction programme.

The pandemic has also affected the planned completion dates for the stations. At Bond Street, the delays caused by social distancing measures and workforce shortages have led the station's principal contractor, Costain Skanska Joint Venture, to state that it is unlikely the station will be ready for trial running in 2021. This means that additional time will be required to plan and conduct trial runs to achieve the start of intensive operational testing (IOTAS). The impact of COVID-19 continues to pose a challenge for Crossrail.

The reduced workforce numbers and the need to maintain social distancing, along with adherence to government and Public Health England guidelines, mean productivity is still affected at all worksites. Crossrail has produced a Recovery and Renewal Programme, which includes a section specifically focused on the continued management of COVID-19. This is in addition to the Health and Safety Re-induction process, which was implemented and required all personnel to be re-inducted to work on the project from ten trade contractors. The dedicated COVID-19 section outlines the programme's aims, which are to continue preventing and reducing the spread of coronavirus on the project, to prepare for potential future outbreaks given the ongoing scale and risk of the virus, and to ensure a consistent approach to managing COVID-19. Crossrail continually monitors and follows Government and Public Health England guidance and appreciates that new directives may be issued following the current easing. This process helps the project align with changes in Government guidance and allows Crossrail to adapt its planning and procedures accordingly.

5.2.5 Collaboration between Academia and Industry

According to Perkmann et al. (2013), Academic engagement refers to knowledge-related interactions between academic researchers and non-academic organisations, distinct from teaching and commercialisation. These interactions encompass collaborative research, contract research, consulting, and informal activities, including providing ad hoc advice and networking with practitioners. Academic engagement warrants attention as an essential part of academics' portfolios of activities, distinct from commercialisation and teaching. The increasing focus of science funders on innovation is important because academic engagement is regarded as a necessary vehicle to render science more impactful (Upton & Cook 2014). For instance, UK Research and Innovation states, “Encouraging even greater collaboration between business and the research base is crucial to achieving this ambition [of a more significant impact].”

The collaboration between academia and industry is crucial in ensuring that academic research is effectively used to achieve the project objectives. Such collaboration could take various forms, including secondment or direct employment of academic partners within industry and project teams, placements at academic institutions for industry researchers, the exchange of technical experts, and the establishment of joint steering groups to drive research agendas (Nsanzumuhire & Groot, 2020). The benefits of the Crossrail Project include the close working relationships between academia and industry, which foster effective knowledge transfer through the transmission of academic research results into industry and project practice or via the initial training of early-stage researchers in engineering doctoral programs.

5.2.6 Impact and Benefits of Academic Research in Crossrail

Academic research in the Crossrail project has driven the development of many innovative practices. By approaching problems differently, academic research helps enhance project efficiency and makes the latest technologies and techniques more readily available to the industry. For instance, an innovative spraying system that can complete tunnel lining concrete works three times faster than traditional methods was developed through research undertaken on the Crossrail project. This new system significantly reduces the time a tunnel must be closed for lining works, often at night. As a result, the cost and time used for conducting this type of activity can be reduced. Meanwhile, one advantage of academic research in the Crossrail project is the improvement of sustainability and safety measures (Davies et al., 2014).

Since safety is the project's top concern, Crossrail aims to make everyone's workplace safer. Modern technologies are developed through academic studies to enhance industry safety procedures. For example, breakthrough innovations, such as the development of a new tunnel boring machine and an innovative monitoring system for hand-arm vibration syndrome, have contributed to making the project more sustainable and safer. Such technologies provide researchers and on-site workers with real-time data during work, indicating if any potential risks have been identified. This will help to prevent accidents that might happen and ensure a safer working environment. It also increases sustainable options in construction processes (Dodgson et al., 2015).

The Crossrail project has faced many logistical and technological challenges throughout its development. It commands attention, unlike most other construction projects, and continually innovates (Mead and Gruneberg, 2013). Installing specific components in Crossrail’s stations and tunnels is one key aspect of the project. In projects like Crossrail, researchers and practitioners will find the justification for breakthrough innovation, as academic research has been proven to drive technological progress and innovation biases in construction (Muruganandan et al., 2022). In the digital age, project teams need the right skills and knowledge to build infrastructure that meets the competitive needs of both the industry and the economy. It has been widely recognised that collaboration between industry and academia is the driving force of progress. The links between innovations and commercial success in Crossrail could be made by allowing funding opportunities and establishing community networks. Studies have shown that cultivating a culture of innovation in the workplace has wide-ranging benefits for advancing individuals' careers and organisational development (Davies et al., 2014). The meaningful impact of academic research on Crossrail could aid in increasing cultural development, reducing research costs, and enhancing innovation progress regarding future infrastructure schemes and national economic growth (Dodgson et al., 2015).

5.2.7 Qualitative Data Collection

The case study approach has been widely used in construction project research for various purposes, as evidenced by multiple studies (e.g., Moatazed Keani IV and Ghanbari Parsa Sechi, 1999; Gibb, 2001; Sutrisna & Abbott, 2002). In these investigations, data are typically sourced directly from project stakeholders in the construction industry, either through interviews or indirectly through access to relevant documents and project observations. Importantly, these industry practitioners constitute a significant audience for the research findings, often among the primary beneficiaries of research aimed at identifying gaps and enhancing construction practices (Sutrisna and Abbott, 2002).

However, the documents gathered for the case study as part of this research encompassed a variety of information sources, including case studies, technical and research papers, micro-reports, good practice documents, journal publications, datasets, videos, and audio recordings. However, inclusion and exclusion criteria were applied to ensure alignment with the research's specific objectives. As a result, 25 out of 37 of these documents were considered suitable for the case study data analysis.

Table 5.4: Documents included in the research method after exclusion and inclusion

Document Titles and Citations	Document Types
Achieving Sustainability in Megaprojects: Lessons from Crossrail (Smith, 2019)	Journal Article
Addressing Environmental Challenges in Megaprojects: Crossrail Case Study (Wilson, 2019)	Journal Article
Addressing Quality Management Challenges in Megaprojects: Crossrail Experience (Clark, 2015)	Journal Article
Communication of Results, Feedback and Performance Improvement Planning (Richard, 2016)	Micro-report
Crossrail Baseline Evaluation, May (2022). (Local Authority, 2022)	Case study report
Crossrail Management Plan (Crossrail, 2017)	Good Practice Document
Crossrail project to Elizabeth line operations: Operational approach and lessons learned (Howard, 2023)	Journal Article
Crossrail: Lessons Learned in Infrastructure Management and Delivery (Jones, 2017)	Book
Crossrail's approach to Police liaison (PC June Saunders, 2017)	Micro-report
Designing Out Waste (Mike, 2018)	Good Practice Document
Employment Relations on a Major Construction Project (Eldred, 2018)	Case Study
Enhancing Supply Chain Collaboration in Megaprojects: Lessons from Crossrail (Anderson, 2017)	Journal Article
Evaluating Cost Management Techniques in Megaprojects: Crossrail Experience (White, 2017)	Journal Article
Impact of Stakeholder Communication on Megaproject Success: Evidence from Crossrail (Taylor, 2015)	Journal Article
Lessons Learned in Megaproject Governance: Crossrail Perspective (Patel, 2017)	Journal Article
Making Innovation Happen in a Megaproject: London's Crossrail Suburban Railway System (Davies, 2015)	Journal Article
Managing Risk in The Later Stages of Crossrail (Underwood, 2018)	Micro-report
Project Lifecycle Stakeholder Engagement (Simon, 2017)	Video
Revisiting the growth coalition concept to analyse the success of the Crossrail London megaproject (Mboumoua, 2017)	Journal Article
Role of Digital Technologies in Megaproject Management: A Crossrail Perspective (Lee, 2018)	Conference Paper
Systems integration in infrastructure projects: Seven lessons from Crossrail (Jennifer, 2022)	Journal Article
The Role of Lean Construction in Enhancing Project Performance: Evidence from Crossrail (Kesavan, 2022)	Journal Article
The Role of social media in Stakeholder Strategies to Influence Decision-Making in a UK Infrastructure Megaproject: Crossrail 2 (Sunila, 2020)	Journal Article
Validating Project Information (Vasiljevaite, 2018)	Micro-report

5.2.8 Qualitative Data Coding and Analysis

Following the data collection phase from the selected case study, the next crucial step is data analysis. This analysis begins with a comparative approach, examining the major research themes that emerge from the collected data. For instance, data gathered from the Crossrail project is contrasted to identify essential themes that help understand its complexities and challenges.

As Langley (1999) outlined, the analytical process merges insights from the literature and established theories with emerging patterns derived from secondary data, adopting an abductive approach. This analysis cycle, which alternates between data collection and writing stages, enables initial analyses to inform subsequent data collection efforts. The main tasks in this analysis include categorising secondary data and utilising process theorising to compare different sources, ultimately achieving theoretical saturation (Muruganandan et al., 2022).

A comprehensive analysis of documents related to the Crossrail Project was conducted to identify crucial themes and sub-themes in construction management (Akponeware et al., 2022). These themes were derived from the findings and emphasised critical facts extracted from reviewing existing project documents. The validity of these themes was further established through a thorough examination of the Crossrail project documents.

The analysis of the Crossrail project reveals several central themes essential for understanding its complexities and challenges. These themes include:

1) **Stakeholder Alignment and Objective Setting**: This theme emphasises the importance of aligning all project participants on shared goals and objectives, ensuring that everyone, from government bodies to local communities, works towards a common purpose (Randall et al., 2018).
2) **Value Optimisation and Risk Mitigation**: This theme emphasises the importance of strategic planning in balancing stakeholders' complex requirements, addressing technical uncertainties, and managing budget constraints while integrating sustainability considerations (Hofstede, 2024).
3) **Effective Team Integration**: This theme emphasises the importance of cohesive teamwork during the design stage, where integrating diverse disciplines is essential to address the

complexities of design coordination, technical integration, and stakeholder involvement (Sergeeva et al., 2019).

4) **Design Optimisation**: This theme focuses on refining design elements during the developed design stage to manage the complexity of design interfaces, ensure technical integration, and balance cost and quality (Baharuddin et al., 2022).
5) **Collaborative/Comprehensive Design Coordination and Compliance**: This theme ensures that the project meets regulatory standards, manages costs effectively, and maintains quality and risk management throughout the technical design phase (Wei et al., 2023).
6) **Efficient Execution and Safety Management**: This theme is crucial for ensuring project success by emphasising the importance of effective communication, site management, and safety performance. Efficiently executing safety management plans is crucial for mitigating risks and ensuring a safe working environment (Yiu & Chan, 2018; Zhang et al., 2021). Integrating safety and quality management programmes leads to more efficient resource utilisation (Wanberg et al., 2013). Developing a culture of health and safety is crucial for the successful execution of construction projects (Nouban & John, 2020), with safety management components being essential for producing safe and sustainable construction projects (Hassan, 2021). Data mining technology can enhance safety management by providing targeted decision-making support (Tao et al., 2023).
7) **Seamless Transition and Documentation Management**: This theme ensures smooth project transitions and effective documentation practices. Stakeholders' satisfaction metrics are significant in large engineering projects (Windapo & Qamata, 2015). Involving all personnel in quality management systems at all stages of construction projects can enhance project quality (Madyaningarum et al., 2019). Using BIM for scaffolding planning can improve construction site risk analysis and safety management (Feng & Lu, 2017). Investigating the relationship between the activities of project management offices and stakeholder satisfaction is crucial for project success (Güngör & Gözlü, 2017). Ensuring environmental safety in construction project management is vital for sustainable practices (Luchkina, 2023).
8) **Operational Efficiency and Stakeholder Satisfaction**: This theme is key for achieving project success by focusing on efficient resource utilisation and stakeholder contentment. Analysing the effect of fabrication and installation work on cost overruns is essential for effective construction management (Rajagukguk & Yallbert, 2022). Stakeholder satisfaction is a critical outcome measure for project success (Güngör & Gözlü, 2017).

Efficient safety management contributes to stakeholder satisfaction and project success (Windapo & Qamata, 2015). Managing safety, quality, and productivity is essential for enhancing operational efficiency and stakeholder satisfaction in construction projects.

5.2.9 Justification for the Exclusive Use of Qualitative Data in the Crossrail Project Analysis

In this study, the use of quantitative data was deemed unfeasible due to the inherent nature and scope of the research, which was primarily qualitative. The central focus was to explore processes, stakeholder experiences, and the practical application of the TLC framework within the specific context of the Crossrail project. This necessitated an in-depth investigation of subjective elements, such as management practices, stakeholder engagement, and decision-making process factors, which are most effectively examined through qualitative methods, including interviews, observations, and document analysis (Creswell & Poth, 2018).

Moreover, access to comprehensive quantitative data such as cost breakdowns, time metrics, or safety statistics was either limited, unavailable, or insufficient for robust analysis. Even if such data had been accessible, it would not have fully captured the broader, systemic impacts of the TLC framework. Given that the research objective was to assess potential outcomes through scenario analysis rather than retrospectively evaluating past performance, relying solely on quantitative data would have been inadequate for this purpose (Bryman, 2016).

Consequently, the study exclusively employed qualitative data to generate rich, contextual insights into how the TLC framework could address project challenges and enhance outcomes. This approach allowed for a nuanced understanding of complex interactions and organisational dynamics insights that purely quantitative measures would not have effectively revealed (Denzin & Lincoln, 2018).

Theme 1: Stakeholder Alignment and Objective Setting

***Relation**:* The theme of Stakeholder Alignment and Objective Setting is crucial for ensuring that all project participants, from government entities to local communities, are aligned on the project's goals, risks, and resource needs. This alignment is fundamental during the strategic definition stage, setting a solid foundation for project success. Several specific challenges arose during this stage of the Crossrail project, each having a significant impact on the project's progress and success.

The Importance of Stakeholder Alignment and Objective Setting

Effective stakeholder alignment ensures that all parties involved in a project share a common understanding of its objectives, risks, and resource requirements. This alignment is crucial during the strategic definition stage, as foundational decisions will significantly influence the project's direction. According to Bourne and Walker (2006), stakeholder engagement is essential for project success, as it fosters a sense of ownership and commitment among participants. The promotion and execution of the Crossrail programme required extensive communication with both directly impacted stakeholders and the broader community. Crossrail prioritised clear and consistent communication from initial engagement during route option selection to pre-authorisation consultations and the Hybrid Bill process. This approach continued throughout construction, emphasising community relations and broader public engagement. However, some weaknesses in communication were identified, particularly in early stakeholder engagement. Implementing the TLC framework could address and improve these communication weaknesses, thereby enhancing project objectives.

Sub-themes 1.1: Definition of Project Objectives. Defining the project objectives was an arduous step. There was a need to clarify and define the project objectives among stakeholders, including government entities, transportation authorities, and local communities. However, due to a lack of interest and diverse priorities, having a consensus on projected project goals proved to be a considerable challenge.

Justification: Clear and consensus-based project objectives are crucial for guiding the project's direction and decision-making processes.

Sub-theme 1.2: Risk Management and Identification. During this stage, risk identification and management emerged. The complexity of the project scope, budget, schedule, and technical prerequisites necessitated a thorough analysis and collaboration among all project stakeholders. However, it also required meticulous attention to detail and a profound understanding of vulnerabilities to accurately identify and assess the risks.

Justification: Identifying and managing risks early in the project lifecycle is crucial to mitigating potential issues that could jeopardise the project's success. The complexity of the Crossrail project necessitates a robust risk management approach that involves all stakeholders to anticipate and address potential vulnerabilities.

Sub-theme 1.3: Allocation of Resources. Several strategies derived from adopting Lean Construction and the RIBA Plan of Work can be implemented to enhance the Crossrail project, particularly in terms of resource allocation. This involves carefully considering funding, personnel, and technical expertise to support project planning and decision-making, considering budgetary constraints and strategic priorities.

Justification: Efficient allocation of resources, including funding, personnel, and technical expertise, is crucial for effective project planning and execution. TLC Frameworks emphasise early stakeholder involvement to align resource needs with strategic priorities and ensure resources are used effectively.

The Lean Construction and RIBA PoW 2020 framework emphasises the early and continuous involvement of stakeholders to ensure alignment between project objectives and expectations. So, early stakeholder engagement proved to be a key strategy. Crossrail could use stakeholder engagement workshops, public consultations, and focus groups to gather information and feedback on the project's goals, priorities, and concerns. By engaging the stakeholders in the strategic definition procedure, Crossrail could reach a consensus, enhance project support, and proactively address challenges and conflicts.

Undoubtedly, risk management and contingency planning strategies were also crucial. Lean Construction and RIBA PoW 2020 provide risk management through risk identification, assessment, and management at every stage of the project's life cycle. Crossrail could follow the Lean Construction principles, i.e., risk analysis, mitigation, and contingency planning, to tackle uncertainties and minimise potential disruptions. In this regard, conducting risk workshops, sensitivity analysis, and scenario analysis would help identify and prioritise the risks, develop mitigation plans, and allocate resources for managing the project's potential risks and qualms.

Moreover, Lean construction techniques such as value stream mapping and target value design could optimise the project objectives and resource allocations. Optimising project scope, prioritising value-adding activities, and aligning project objectives with the stakeholders enable Crossrail to achieve cost-effective results that meet the stakeholders' expectations and project requirements.

Ultimately, the integration of sustainability was crucial to the project's success. As the TLC framework includes sustainability checkpoints, ensure that sustainability considerations are assimilated into the project planning and decision-making process. However, Crossrail could influence LC principles of lifestyle thinking, sustainable procurement, and environmental impact assessment to integrate sustainability objectives into the strategic definition process. By setting sustainability goals, identifying green design strategies, and engaging with environmental stakeholders, project sustainability and resilience can be enhanced while achieving strategic objectives. Crossrail could establish a solid foundation for the successful planning and execution of Europe's most ambitious infrastructure projects by addressing the challenges mentioned above within the TLC Framework.

What-if Scenario Analysis: If the TLC Framework is Applied to the Crossrail Project

A "what-if" scenario analysis could be conducted to understand better the potential benefits of applying the TLC framework to the Crossrail project. This scenario analysis would involve exploring how the TLC framework could have been used to address specific challenges in stakeholder alignment, risk management, and resource allocation and identifying the key drivers and obstacles to its successful implementation.

1. **Stakeholder Alignment**: Early and continuous engagement is a key driver of successful stakeholder alignment within the TLC framework. In this "what-if" scenario, Crossrail could have utilised TLC principles to facilitate a more inclusive and transparent engagement process. Workshops, focus groups, and public consultations could have been used to gather feedback from stakeholders at the outset, resulting in more clearly defined project objectives. By adopting these strategies, Crossrail could have overcome challenges arising from differing priorities and interests, ensuring a more precise alignment of project goals.
    - **Obstacle**: Resistance from stakeholders with conflicting interests could have significantly hindered the implementation of the TLC framework. Managing these conflicts would have required a proactive approach, clear communication and negotiation strategies to address concerns and reach a consensus.
    - **Strategy**: Crossrail could have employed conflict resolution techniques and mediation processes to manage this obstacle, engaging stakeholders through structured dialogue and feedback mechanisms to build trust and ensure alignment.

2. **Risk Management**: In the scenario analysis, the TLC framework's emphasis on early risk identification and collaborative management could have significantly improved Crossrail's approach to risk management. Lean Construction principles, such as risk workshops,

sensitivity analysis, and scenario planning, could have been employed to identify potential risks early and develop effective mitigation strategies.

- **Obstacle**: The project's large scale and inherent complexity would have made comprehensively assessing risks across all stages challenging.
- **Strategy**: To manage this obstacle, Crossrail could have broken the project into minor phases, conducting risk assessments for each phase. This approach would have enabled more detailed risk analysis and tailored mitigation strategies.

3. **Resource Allocation**: The TLC framework's focus on resource optimisation could have helped Crossrail allocate funding, personnel, and technical expertise more effectively. Utilising Lean Construction techniques, such as value stream mapping and target value design, could have streamlined the resource allocation process, ensuring that resources were focused on value-adding activities and aligned with strategic priorities.

- **Obstacle**: One of the challenges in resource allocation was aligning the diverse expectations of stakeholders for resources, particularly when budget constraints and external pressures influenced decision-making.
- **Strategy**: Crossrail could have utilised TLC's emphasis on collaborative resource planning, engaging stakeholders in discussions about resource needs and constraints. This approach would have helped to align expectations and ensure that resources were allocated efficiently.

4. **Sustainability Integration**: The TLC framework also stresses the importance of integrating sustainability into project planning. In the "what-if" scenario, Crossrail could have incorporated sustainability goals more effectively during the strategic definition stage. Lean Construction principles such as sustainable procurement, environmental impact assessments, and lifestyle thinking could have ensured that sustainability objectives were met while keeping the project on track.

- **Obstacle**: A potential obstacle in integrating sustainability would have been the complexity of balancing environmental considerations with other project objectives, such as cost and time constraints.

- **Strategy**: Crossrail could have established clear sustainability goals and collaborated closely with environmental stakeholders to identify and implement feasible green design strategies. Regular sustainability check-ins could have ensured these goals were integrated into the decision-making process.

Theme 2: Value Optimisation and Risk Mitigation

Relation: In the preparation and brief stage, it is essential to balance the complex requirements of stakeholders, technical uncertainties, budget constraints, and sustainability considerations to optimise project value and mitigate risks. Crossrail faced a multitude of carefully considered and strategically planned challenges during this stage.

To effectively mitigate risks, the Crossrail project employed a range of strategies. Identifying potential risks at the outset is critical, as emphasised by Gitau et al. (2021), who highlight the importance of proactive risk assessment in maintaining project timelines and budgets. Additionally, implementing robust risk mitigation strategies, as outlined by Fariq et al. (2022), can significantly reduce the likelihood of adverse events impacting project progress.

Sub-theme 2.1: Multifaceted requirements of stakeholders. The project had to facilitate the complex stakeholder requirements. These include government bodies, transportation authorities, local communities, and environmental groups, each with demands and expectations. So, Crossrail had to ensure effective collaboration and communication among all the stakeholders to align project objectives and mitigate potential conflicts.

Justification: Addressing the diverse demands of stakeholders requires effective collaboration and communication to align project objectives and mitigate conflicts, ensuring all voices are heard and integrated into the project plan.

Sub-theme 2.2: Technical Uncertainty. The project had an ambitious scope and complexity; there was uncertainty about certain ground conditions, as well as unclear challenges in the regulatory regime and engineering uncertainties regarding the feasibility of specific proposal features. While uncertainty risks might be inherent in project planning and execution, a project that is fully unproblematic of these ambiguities may still require navigational work to identify and manage potential risks. In response to such ‘technical uncertainty,’ the mantra ‘always forward’ mandated an initiative-taking approach.

***Justification**:* Managing technical uncertainties through initiative-taking risk identification and mitigation strategies is crucial to avoid project delays and cost overruns. Understanding and addressing these uncertainties early on ensures smoother project execution.

Sub-theme 2.3: Budgetary Constraint. This was also the previous reason why the budgetary aspect bounds Crossrail. This simply means that it is challenging to determine the accuracy of the budget for a mega project. When the project scope estimation is incorrect, resources are required, and cost inflation arises, it becomes challenging for Crossrail to determine the accurate budget value for the project to be sustained throughout its lifecycle.
Justification: Accurate budgeting is both challenging and essential for ensuring project sustainability. Effective cost management strategies, including lean techniques, can help maintain financial control while meeting project objectives.

Sub-theme 2.4: Sustainability principles and considerations. In the project brief, to make the sustainability principles (triple-bottom-line) transparent to the reader, consider incorporating aspects of the environment, social equity, and prioritizing energy efficiency. Here, the main elements throughout the project lifecycle are considerations and stakeholders' inputs to ensure sustainability. By implementing the TLC Framework, various strategies can be employed. As early stakeholder engagement emphasises the accessible and continuous involvement of stakeholders, it has emerged as a critical strategy. Crossrail could organise stakeholder engagement workshops, public consultations, and focus groups to gather input and feedback on project goals, concerns, and priorities. So, Crossrail could build consensus, enhance the project, and mitigate clashes by involving stakeholders from the outset. However, Target Value Design and Value Stream Mapping were also the main techniques that Crossrail could implement; this framework could contribute to optimising the project's objectives and resource allocation. Crossrail could also achieve cost-effective results according to project requirements and stakeholder expectations by prioritising value-adding activities and aligning project objectives with the stakeholder needs. Moreover, contingency planning and effective risk management were imperative, and Crossrail could enhance risk analysis and mitigation, effectively address ambiguities and minimising potential disruptions by adopting this area. So, conducting risk workshops and scenario analysis could enable Crossrail to effectively identify and prioritise risks, develop mitigation strategies, and allocate resources.

Justification: Integrating sustainability goals into project planning ensures long-term benefits for the environment, society, and the economy. The Lean Construction and RIBA PoW 2020 frameworks provide tools for incorporating sustainability into every project stage.

Another important aspect we will examine is the priority of integrating sustainability. Through Crossrail, sustainability aspects can be incorporated into the planning process, allowing for a plan to be developed in accordance with lean construction and the RIBA 2020 standard. Lean construction and RIBA PoW 2020, which focuses on sustainable plans, environmental strategy, and engaging environmental stakeholders, could help Crossrail build a solid base for planning and implementing projects in the future, thereby increasing the project's sustainability.

What-if Scenario Analysis: If the TLC Framework is applied to Crossrail for Value Optimisation and Risk Mitigation

Scenario analysis is beneficial for exploring how the TLC framework could have been applied to optimise value and mitigate risks during the Crossrail project. This analysis could examine how the TLC framework could have addressed the key challenges faced during the preparation and briefing stages, particularly in terms of stakeholder engagement, risk management, budgetary control, and sustainability integration.

1. **Stakeholder Collaboration and Communication**:
   - **Driver**: Early and continuous stakeholder engagement, as emphasised by the TLC framework, could have enhanced communication and collaboration among diverse stakeholders. Crossrail could have used stakeholder engagement workshops, public consultations, and focus groups to gather feedback on the project's goals, concerns, and priorities. This early engagement would have allowed Crossrail to identify potential conflicts and align project objectives with stakeholder expectations.

     - **Obstacle**: Conflicting interests and concerns from stakeholders with different priorities could have prevented alignment.
     - **Strategy**: Crossrail could have used structured mediation and conflict resolution techniques to address conflicting stakeholder interests, ensuring that project objectives were aligned, and all voices were heard.
2. **Technical Risk Management**:

- **Driver**: The TLC framework's emphasis on proactive risk management could have helped Crossrail navigate technical uncertainties more effectively. By applying Lean Construction principles such as risk workshops, sensitivity analysis, and scenario analysis, Crossrail could have identified and assessed technical risks early, ensuring that mitigation strategies were implemented before issues arose.
- **Obstacle**: The project's scale and complexity might have made anticipating every potential technical risk complex.
- **Strategy**: Crossrail could have implemented a phased approach to risk management, conducting detailed assessments for each project phase and adapting mitigation strategies as new technical challenges emerged.

3. **Budget Management and Resource Optimisation**:
    - **Driver**: The TLC framework's focus on resource optimisation could have helped Crossrail control costs while ensuring efficient resource use. By applying techniques such as target value design and value stream mapping, Crossrail could have identified and prioritised value-adding activities, optimising resource allocation to meet project objectives and budget constraints.
    - **Obstacle**: Inaccurate budget estimations and unforeseen resource needs could have threatened financial stability.
    - **Strategy**: Crossrail could have used Lean Construction principles to establish a robust contingency plan, adjusting resource allocations to stay within budget while maintaining project quality.
4. **Sustainability Integration**:
    - **Driver**: The TLC framework's focus on sustainability could have guided Crossrail in integrating environmental, social, and energy efficiency goals into the project. By engaging with environmental stakeholders and employing sustainable procurement practices, Crossrail could have ensured that sustainability was a core consideration throughout the project lifecycle.
    - **Obstacle**: Balancing sustainability goals with other project requirements, such as cost and time constraints, could have posed challenges.
    - **Strategy**: Crossrail could have developed clear sustainability benchmarks and engaged with stakeholders to identify feasible green design strategies. Regular sustainability check-ins would have ensured that sustainability objectives were achieved without compromising other project priorities.

Theme 3: Using a Team Integration Approach

Effective team integration is crucial in large-scale projects, especially during the design stage, where the intricacies of design coordination and stakeholder involvement can significantly impact project outcomes. The Crossrail project encountered numerous obstacles during this phase, necessitating a strategic approach to overcome them. As noted by Olawale and Sun (2010), effective scope management is crucial for aligning the project's various components and ensuring project success.

Sub-theme 3.1: The Complexity of the Design. Coordinating the designs presented another challenging task. Because the rail had multiple underground and overground tunnels connecting various parts and spaces, coordination was challenging for the diverse design disciplines, including architecture, engineering, and systems integration. As a result, keen attention to detail and efficient teamwork became necessary to cope with the interface design complications and ensure that the various parts with which it was in contact would function smoothly.
Justification: Coordinating intricate design elements across various disciplines requires meticulous teamwork and communication to ensure all components function seamlessly.

Sub-theme 3.2: Technical Assimilation. Technical integration was crucial, as it is essential to organise all the systems and components, such as signalling, ventilation, electrical, and track systems, safely and meet safety administration standards. At the same time, operations will run smoothly. However, cost management was also a significant challenge as the project needed to balance designing and creating standard regulations while complying with performance and regulatory requirements in a reliable fashion. Besides, timing, strategic decision-making, and appropriate cost-management strategies would be needed to run the development process to specific standards while maintaining the budget.
Justification: Integrating technical systems, such as signalling and ventilation, is crucial for operational efficiency and safety. This requires strategic planning and adherence to regulatory standards.

Sub-theme 3.3: Stakeholder holds the key. Stakeholder involvement was crucial to project success, which was achieved through effective communication and collaboration with stakeholders, including local communities, the private sector, and government departments and

agencies, to obtain their input on the project design and maintain the project's isomorphism and objectives. Ensuring that design solutions met project needs and stakeholder expectations was crucial to the project's success.
Justification: Engaging stakeholders in the design process ensures that their needs and expectations are met, fosters support, and minimises conflicts that could arise during project execution.

Sub-theme 3.4: Cost Management. Balancing the design innovation with the costs was a challenge in maintaining affordability without compromising performance and safety. Nevertheless, the Framework offers several strategies that could be employed.

Justification: Balancing innovative design with budget constraints is essential to maintain project affordability without compromising quality or performance.

However, the integrated design workshop proved an essential and effective strategy. The LC and RIBA frameworks emphasised collaborative design and multidisciplinary coordination for integrated solutions. Crossrail can facilitate cross-functional teamwork and continually improve collaboration among designers, contractors, engineers, and stakeholders, ensuring that design solutions align with project objectives and stakeholder requirements.

Target value design and Value engineering were essential techniques for improving design solutions. By systematically assessing design alternatives and prioritising value-adding features, Crossrail could achieve cost-effective results that meet project and stakeholder requirements.

Moreover, the problem-solving techniques of the LC and RIBA PoW 2020 combined framework could assist in effectively addressing design challenges. Implementing the Lean problem-solving methods, such as root cause analysis, rapid prototyping, and value stream mapping, could help identify and mitigate design risks, improve project outcomes, and optimise designs.

Stakeholder involvement and collaboration have been paramount throughout the Concept Design stage. Crossrail could use stakeholder engagement tools such as workshops, public consultations, and feedback sessions to collect input and address the relevant concerns. Similarly, by maintaining open communication and actively involving stakeholders in the design stage, Crossrail could build trust, enhance project support, and ensure a design that meets expectations.

What-if Scenario Analysis: If the TLC Framework is applied to Crossrail for Team Integration

Given the challenges mentioned above, the TLC framework could have been applied to enhance team integration and address issues related to design complexity, technical assimilation, stakeholder engagement, and cost management. Below is a scenario analysis of how TLC principles could have supported Crossrail during its design phase.

1. **Design Coordination and Collaboration**

- **Driver**: The TLC framework's emphasis on collaborative team integration through Lean Construction (LC) techniques and RIBA PoW 2020 standards could have facilitated better coordination among diverse design disciplines. Crossrail could have used integrated design workshops, where multidisciplinary architecture, engineering, and systems integration teams worked closely to address design challenges and ensure cohesive solutions.
- **Obstacle**: Diverging priorities and disciplinary silos might have created barriers to collaboration.

Strategy: Crossrail could have adopted integrated design principles, holding regular cross-functional meetings to promote communication, identify potential conflicts early, and develop coordinated solutions. These workshops could focus on problem-solving and knowledge sharing across teams, leading to the seamless integration of design elements.

2. **Technical Integration and Cost Management**

- **Driver**: The TLC framework's focus on systems thinking could have supported Crossrail in addressing the technical integration of systems such as signalling, ventilation, and track systems. By applying Lean Construction techniques, such as value stream mapping, Crossrail could have visualised the flow of design processes and identified inefficiencies early. Target Value Design (TVD) could have helped balance technical requirements with budget constraints, ensuring cost-effective innovations.
- **Obstacle**: The complexity of technical systems and the need to balance cost with performance could have led to cost overruns and delays.

- **Strategy**: Crossrail could have employed TVD and value engineering to assess design alternatives systematically, prioritising features that added the most value while remaining within budget constraints. Lean Construction methods, such as root cause analysis, can also help identify technical integration issues early and resolve them before they escalate.

3. **Stakeholder Involvement and Engagement**
   - **Driver**: The TLC framework strongly emphasises early and continuous stakeholder engagement, which could have been critical for Crossrail to ensure that the design met the needs and expectations of diverse stakeholders. Crossrail could have organised stakeholder engagement workshops, public consultations, and feedback sessions to gather input on design proposals and identify potential concerns.
   - **Obstacle**: Diverse stakeholder interests and conflicting priorities could have created tension and challenges in reaching a consensus.
   - **Strategy**: Crossrail could have implemented structured stakeholder workshops at various stages of the design process, focusing on active listening and collaborative problem-solving. This approach would allow the project team to address concerns, align design solutions with stakeholder needs, and build trust and support for the project.
4. **Balancing Innovation with Cost Constraints**
   - **Driver**: The TLC framework's emphasis on continuous improvement through Lean techniques could have helped Crossrail optimise innovative design solutions while managing costs effectively. By applying Lean's value stream mapping and design for value principles, Crossrail could have prioritised design features that maximised value while ensuring cost-effectiveness.
   - **Obstacle**: The drive for innovation could have escalated costs if not carefully managed.
   - **Strategy**: Crossrail could have used Lean Construction principles to optimise design processes and eliminate waste, ensuring that innovative solutions did not compromise the project's budget. The project team could have conducted regular cost-benefit analyses to ensure that design innovations were aligned with the project's financial constraints.

Theme 4: Design Optimisation

Rationale: Optimising design during the developed design stage is essential to manage the complexity of design interfaces, ensure technical integration, and balance cost and quality while involving stakeholders throughout the process. For the developed design stage of the Crossrail Project, several challenges required strategic approaches to ensure the project's success. The TLC framework provides a structured framework for managing the design process, outlining key stages and deliverables. By adhering to this framework, the Crossrail project team could ensure that all design activities are aligned with project objectives and stakeholder requirements. The TLC framework emphasises the importance of stakeholder engagement throughout the design process, which is critical for addressing the complexities of design interfaces and ensuring technical integration. As noted by Davies et al. (2016), structured processes can help project teams respond effectively to emergent design challenges, thereby avoiding costly revisions later in the project lifecycle.

Sub-theme 4.1: Complex Design Coordination. The complexity of design modelling is a significant challenge because managing the complexity of design interfaces and ensuring the compatibility between different components requires special attention to detail and effective collaboration among the design disciplines. However, Crossrail's extensive infrastructure, coordinating and integrating various design elements such as architectural, structural, mechanical, and electrical systems, was crucial.
Justification: Managing the integration of various design components requires detailed coordination and collaboration among design disciplines to ensure compatibility and functionality.

Sub-theme 4.2: Technical Integration. For a seamless operation, compliance with safety standards and coordination of the design of various systems and components, including track systems, tunnelling, signalling, ventilation, and station facilities, required careful integration. Technical Integration remained critical. However, achieving technical integration while maintaining design integrity proved to be a considerable challenge during the development stage.
Justification: Ensuring the seamless operation of technical systems is critical for project success, requiring careful planning and integration during the design stage.

Sub-theme 4.3: Cost Management. Balancing design innovation with cost-effectiveness was essential to support project affordability while meeting performance requirements and regulatory standards; cost management also emerged as a significant factor. Similarly, finding the right balance between design quality and project budget required strategic decision-making and effective cost-management strategies.
Justification: Strategic cost management ensures the project remains within budget while meeting performance standards and regulatory requirements.

Sub-theme 4.4: Stakeholder Involvement. As with other themes, stakeholder involvement remained pivotal because incorporating feedback from stakeholders, including local communities, businesses, and government agencies, while maintaining design integrity and project objectives required effective communication and collaboration. They ensured that design solutions aligned with stakeholder needs and expectations were crucial to project success within the framework of Lean Construction and the RIBA Plan of Work 2020. Several strategies can be employed to ensure that design solutions align with stakeholders' needs and expectations, which are crucial for project success.
Justification*:* Continuous stakeholder engagement ensures the design aligns with their needs and expectations, fostering support and reducing the risk of later modifications.

As integrated design workshops emerged as a critical strategy, the TLC Framework emphasises collaborative design and multidisciplinary coordination to facilitate them. Crossrail could utilise cross-functional teamwork and continuous improvement to enhance collaboration among designers, contractors, engineers, and stakeholders, ensuring that design solutions meet stakeholder requirements while aligning with the project's objectives.

Target value design and Value Engineering were also essential techniques to improve design solutions. Crossrail could achieve cost-effective results by systematically evaluating design alternatives and prioritising value-added features. Furthermore, the TLC Framework problem-solving techniques could help address design challenges effectively. Implementing lean techniques such as root cause analysis, value stream mapping, and rapid prototyping helped optimise design solutions and improve project outcomes.

Interacting with and cooperating with the local community has been crucial throughout the Concept Design period. Crossrail can benefit from utilizing consulting tools such as workshops, public forums, and sessions to gather feedback. Likewise, a quality control exercise at the design stage can contribute to building trust, gaining public support, and ensuring a well-designed product through effective communication and involving stakeholders in the design revision process.

What-if Scenario Analysis: If the TLC Framework is applied to Crossrail for Design Optimisation

In addressing the challenges inherent in the Crossrail project, the TLC (Target Value Design and Lean Construction) framework could have played a pivotal role in optimising the design process. This would have helped address issues related to design complexity, technical integration, stakeholder engagement, and cost management. Below is a scenario analysis exploring how the TLC principles could have supported Crossrail during its design phase.

- **1. Design Coordination and Collaboration**
- **Driver**: The TLC framework's emphasis on collaborative team integration through Lean Construction (LC) techniques and RIBA PoW 2020 standards could have facilitated better coordination among diverse design disciplines. For Crossrail, integrated design workshops would have allowed multidisciplinary teams from architecture, engineering, and systems integration to work closely together, ensuring cohesive solutions and resolving potential conflicts early.
- **Obstacle**: Diverging priorities across disciplines and organisational silos might have hindered seamless collaboration, leading to fragmented design elements.
- **Strategy**: Crossrail could have adopted integrated design principles by holding regular cross-functional meetings and workshops. These sessions would foster communication, encourage knowledge sharing, and proactively identify conflicts, thus ensuring that all design components were aligned and compatible. Early engagement among architects, engineers, and contractors would have been critical to addressing design challenges and ensuring a coordinated approach.
- **2. Technical Integration and Cost Management**
    - **Driver**: The TLC framework's systems thinking approach could have supported Crossrail in achieving technical integration across complex systems such as signalling, ventilation, track systems, and station facilities. Lean Construction methods, such as value stream mapping, would have visualised the flow of design processes, helping to identify inefficiencies early. Target Value Design (TVD) would have also ensured that

design innovations aligned with budget constraints, optimising technical performance and cost-effectiveness.

- **Obstacle**: The complexity of technical systems and the challenge of balancing technical requirements with budget limitations might have led to potential cost overruns and delays.
- **Strategy**: Crossrail could have employed Target Value Design (TVD) and Value Engineering (VE) techniques to systematically assess design alternatives. The project could have optimised its technical solutions without exceeding financial limits by prioritising features that added the most value while staying within budget. Additionally, Lean methods like root cause analysis could have helped identify and resolve technical integration issues early, ensuring that the design stayed on track and adhered to safety and operational standards.

- **3. Stakeholder Involvement and Engagement**
  - **Driver**: The TLC framework's emphasis on early and continuous stakeholder engagement would have been crucial for Crossrail to ensure that the design met the diverse needs of stakeholders, including local communities, businesses, and government agencies. Organising stakeholder engagement workshops, public consultations, and feedback sessions would have allowed Crossrail to gather valuable input and address potential concerns about the design.
  - **Obstacle**: Conflicting stakeholder interests and differing priorities could have made it challenging to reach a consensus and align the design with the needs of all stakeholders.
  - **Strategy**: Crossrail could have implemented structured stakeholder engagement workshops at various stages of the design process, employing a collaborative, problem-solving approach. These workshops would enable the project team to actively listen to concerns, adjust designs where necessary, and build strong stakeholder relationships. This proactive engagement would also have helped ensure that the design solutions addressed the needs of local communities and government bodies, reducing the risk of costly late-stage modifications.
- **4. Balancing Innovation with Cost Constraints**
  - **Driver**: The TLC framework's focus on continuous improvement through Lean techniques would have helped Crossrail optimise innovative design solutions while maintaining strict cost management. Applying principles like design for value and value stream mapping would have allowed Crossrail to prioritise design features that offered the most outstanding value, all while staying within the project's financial limits.

- **Obstacle**: The pursuit of innovation could have escalated costs if not carefully managed, particularly in a project of Crossrail's scale.
- **Strategy**: Crossrail could have leveraged Lean Construction principles to refine design processes, eliminate waste, and optimise design solutions. The project team could have ensured that design innovations did not compromise the budget by conducting regular cost-benefit analyses. Furthermore, Value Engineering (VE) techniques would have enabled Crossrail to systematically evaluate design alternatives, ensuring the most cost-effective innovations were implemented without sacrificing quality or performance.

Theme 5: Collaborative-comprehensive design coordination and compliance

In the technical design phase, ensuring comprehensive design coordination and regulatory compliance is crucial to meeting project standards, managing costs effectively, and maintaining quality and risk management. For the technical design, which was a critical phase, we had to employ some tactical response points to make the project as successful as possible. The Crossrail project faced numerous challenges during the technical design phase, particularly in achieving comprehensive design coordination and regulatory compliance. By integrating the TLC framework with existing collaborative practices, the project team can develop effective strategies to address these challenges. For instance, fostering a culture of trust and open communication can encourage stakeholders to voice concerns early in the design process, allowing for timely adjustments and minimising costly revisions later.

Sub-theme 5.1: Information about (PoW) Coordination. The coordination of (PoW) sources available at the project was the most pivotal problem, as Crossrail has extensive infrastructure. Thus, detailed coordination involving various engineers' disciplines, including civil, structural, mechanical, and electrical, was necessary to ensure conformity and system integration.

Justification: Detailed coordination of various engineering disciplines is necessary to ensure system integration and conformity with project requirements.

Sub-theme 5.2: Regulatory Compliance. Fulfilling regulatory requirements and obtaining the necessary certifications, permits, and licenses for the technical drawings, which also involve meeting safety, environmental, and operational standards of deep concern, are significant hurdles in the design process. Many notes and references need to be added. Compliance had to be made stringent to ensure the time was in check and to target the project's success.

Justification: Meeting regulatory standards and obtaining necessary permits is crucial to ensure the project complies with safety, environmental, and operational requirements.

Sub-theme 5.3 Cost Management. The exact and accurate apartment design, which requires expensive technical equipment, specialised materials, and expertise, among other things, presents a challenging issue. The project costs must be controlled within the allocated budget. Therefore, cutting severe costs while supporting or even bettering the quality standards was essential.
Justification: Managing costs while supporting quality and performance is crucial for project sustainability, requiring strategic cost management approaches

Sub-theme 5.4: Quality Assurance and Risk Management. Quality assurance and risk management were vital aspects of detailed design coordination. However, a comprehensive quality assurance and risk management process was required to ensure the quality and reliability of technical design, identifying and mitigating potential risks associated with construction, operations, and maintenance. Similarly, the critical priorities during design coordination were minimising risks and ensuring project resilience. Within the LC and RIBA framework 2020, several strategies could be employed to achieve these goals.
Justification: Ensuring quality and managing risks through comprehensive processes is vital to project success, minimising potential disruptions and ensuring project resilience.

Moreover, integrated design and construction teams emerged as a critical strategy. The LC and RIBA framework advocates for integrated project methods, i.e., design-build or integrated project delivery, where design and construction teams collaborate diligently from the project's initial stages. Crossrail could streamline the technical design process and improve coordination by fostering collaboration and communication among multidisciplinary teams.

However, target costing and value engineering were also essential techniques for optimising the designs. Crossrail could maximise project value without compromising quality or performance by prioritising the value-adding features and eliminating unnecessary costs. Hence, this approach ensures cost-effective outcomes aligned with the project requirements and stakeholder expectations. Moreover, the framework could utilise crucial problem-solving and continuous improvement strategies, as Lean Construction endorses these approaches, such as root cause analysis, value stream mapping, and Kaizen Events, to effectively identify and address challenges. Crossrail could implement these techniques to smooth the technical design processes, identify opportunities for improvement, and enhance project outcomes.

Similarly, risk management and contingency planning were also paramount. Crossrail could implement the LC and RIBA framework for risk analysis, mitigation, and contingency planning to identify and address potential risks associated with the technical designs. Risk Management and Contingency Planning remained paramount. Crossrail could also minimise the impact of risks on project delivery and ensure successful implementation by conducting risk assessments, developing mitigation strategies, and allocating resources effectively. (Kay, 2009).

What-if Scenario Analysis: If the TLC Framework is applied to Crossrail for Collaborative-Effective Design Coordination and Compliance

In the technical design phase, achieving comprehensive design coordination and ensuring regulatory compliance were crucial to the success of the Crossrail project. The infrastructure's complexity and the need for stringent adherence to safety, environmental, and operational standards presented significant challenges. By integrating the TLC (Target Value Design and Lean Construction) framework with existing collaborative practices, Crossrail could have effectively adopted strategies to address these challenges. Below is a scenario analysis exploring how the TLC principles could have enhanced collaborative design coordination, ensured regulatory compliance, and supported quality management in the Crossrail project.

1. Information about (PoW) Coordination

- **Driver**: Due to its extensive infrastructure, coordinating various PoWs (Plans of Work) was a pivotal challenge in the Crossrail project. Detail coordination across various engineering disciplines, including civil, structural, mechanical, and electrical, was essential to ensure system integration and conformity with project requirements. The TLC framework could have facilitated this coordination by fostering a collaborative environment where all teams worked together to streamline processes and identify issues early.
- **Obstacle**: The dispersed nature of engineering disciplines and complex interfaces can lead to misalignment between systems, resulting in integration issues or delays.
- **Strategy**: Crossrail could have leveraged integrated design workshops, where teams from different engineering disciplines collaborated from the beginning of the design phase. Using the TLC framework's emphasis on integrated project delivery (IPD), these workshops would have helped facilitate early conflict identification, coordination, and

alignment of design components. Building Information Modelling (BIM) and collaborative platforms could also have ensured real-time coordination and seamless integration between various engineering disciplines.

- **2. Regulatory Compliance**
  - **Driver**: Meeting regulatory requirements and obtaining the necessary certifications, permits, and licenses for technical drawings were crucial to the success of the Crossrail project. The TLC framework could have helped ensure compliance by providing a structured approach to managing regulatory requirements and streamlining the approval process through continuous engagement with regulatory bodies.
  - **Obstacle**: Regulatory compliance, particularly around safety, environmental, and operational standards, can be a bottleneck, delaying the approval of technical designs and increasing project costs.
  - **Strategy**: Crossrail could have used Lean Construction principles to streamline the regulatory compliance process, ensuring early identification and resolution of regulatory challenges. Through consistent communication with regulatory authorities and internal cross-functional teams, the project could have built-in regulatory reviews at each stage of the design process. Target Value Design (TVD) principles could also have been used to ensure the designs met regulatory standards while staying within budget, preventing costly revisions later.
- **3. Cost Management**
  - **Driver**: The challenge of controlling costs while ensuring high-quality designs was a critical concern for Crossrail. With the required expensive technical equipment, specialised materials, and expertise, managing costs within the allocated budget was a key factor in ensuring the project's financial success. The TLC framework's focus on value-driven decision-making would have enabled Crossrail to balance design quality with cost control effectively.
  - **Obstacle**: The high cost of technical equipment and materials, as well as the complexity of managing such a large-scale project, could lead to budget overruns if not carefully managed.
  - **Strategy**: Crossrail could have used Target Value Design (TVD) and Value Engineering (VE) techniques to prioritise the most value-adding design features while eliminating unnecessary costs. By focusing on value maximisation rather than cutting costs indiscriminately, Crossrail could have delivered an efficient, high-performance design within the allocated budget. Learning techniques such as root cause analysis

could also have helped identify areas of waste and inefficiency, enabling cost reductions without compromising quality.

- **4. Quality Assurance and Risk Management**
  - **Driver**: Ensuring quality and managing risks throughout the detailed design phase ensured project resilience and long-term success. Crossrail needed a comprehensive quality assurance and risk management process to address potential issues that could arise during construction, operations, and maintenance. The TLC framework's emphasis on continuous improvement and Lean problem-solving techniques would have helped mitigate risks and optimise design quality.
  - **Obstacle**: The complexity of the design, coupled with the associated construction risks, could have led to potential disruptions, safety concerns, or delays.
  - **Strategy**: Crossrail could have employed Lean Construction techniques, such as Kaizen Events, root cause analysis, and value stream mapping, to identify and address design issues early. Crossrail could have minimised potential disruptions by conducting detailed risk assessments at each stage of the design process and implementing mitigation strategies. Integrated project teams could also have worked closely to monitor the design's progress and ensure quality through regular inspections and feedback loops.

- **Key Strategies for Optimizing Design Coordination and Compliance**

To further optimise design coordination and regulatory compliance on the Crossrail project, the following strategies can be implemented:

  - **Integrated Design Teams**: Crossrail could have adopted an integrated design approach, where designers, engineers, contractors, and other stakeholders collaborated from the beginning of the design process. This approach, supported by the TLC framework, would foster collaboration and improve communication, ensuring that all design aspects were aligned.
  - **Lean Problem-Solving Techniques**: The TLC framework encourages the use of lean problem-solving methods, including root cause analysis, value stream mapping, and Kaizen Events. Crossrail could have used these techniques to identify potential challenges early in the design phase, streamline processes, and eliminate waste. This would have enhanced the project's overall efficiency and reduced the risk of costly changes later.

- **Target Value Design (TVD)**: By setting a target value early in the design process, Crossrail could have used TVD principles to ensure that the project met both cost and performance objectives. Regular assessments of the design's value compared to the target would have allowed for early interventions if costs exceeded projections, ensuring the project stayed on track.
- **Regulatory Engagement**: Crossrail could have implemented continuous engagement with regulatory bodies throughout the design phase. This would have ensured that all regulatory requirements were promptly met and any potential regulatory challenges were identified and addressed early. Crossrail could have also utilized lean tools to streamline the approval and certification process, thereby reducing delays and maintaining momentum for the project.
- **Risk Management and Contingency Planning**: Comprehensive risk management strategies, including contingency planning, would have been crucial for mitigating potential risks associated with the design and construction phases. Crossrail could have utilised the TLC framework to conduct regular risk assessments, develop effective mitigation strategies, and efficiently allocate resources to address unforeseen issues. This would have ensured project resilience and reduced the likelihood of disruptions during execution.

Theme 6: Efficient Execution and Safety Management

Relation: Efficient execution and safety management are pivotal in large-scale construction projects like Crossrail, where prompt delivery, adherence to safety standards, and efficient use of resources are paramount. This theme encompasses the strategic approaches necessary to overcome the challenges faced during construction, ensuring the project progresses smoothly and safely. The TLC framework offers a valuable approach to enhancing efficient execution and safety management in the Crossrail project.

Sub-theme 6.1: Logistical Challenges. The logistical challenge arose due to the coordination requirements of construction activities across multiple sites, as well as ensuring the timely delivery of materials and equipment. Moreover, innovative solutions were required to overcome the challenges of managing traffic and transportation disruptions in densely populated areas.

Justification: Managing coordination across multiple construction sites requires meticulous coordination to ensure timely delivery of materials and equipment

Sub-theme 6.2: Site Constraints and Access. As cross-rails had limited space and accessibility at construction sites, especially in urban areas, they posed significant hurdles that challenged staging construction activities, material storage, and equipment mobilisation. Creative and adaptable approaches were necessary to overcome these constraints while maintaining productivity and ensuring safety.
Justification: Limited space and accessibility pose significant challenges in urban construction.

Sub-theme 6.3: Workforce Management. Managing a large workforce that includes contractors, subcontractors, and labour unions was also a significant concern. One had to ensure good skill sets, adherence to safety and compliance protocols, and efficient labour productivity for the workforce in a multi-faceted environment. Besides, assurance of labour force spirit amid labour divergences was among the primary human resource management issues during the construction stage.
Justification: Managing a diverse and large workforce requires ensuring skill adequacy, compliance with safety protocols, and high productivity levels.

Sub-theme 6.4: Security and Risk Management. This is another critical factor in security and risk management, which involves ensuring worker safety and reducing the risk of construction-related incidents that demand robust security protocols, training programs, and risk reviews. Furthermore, implementing health and safety rules while fostering a safe culture was a significant factor in determining the classification of the construction process.
Justification: Robust security protocols and training programs are critical for ensuring worker safety and minimising construction-related risks. This sub-theme aligns with the overarching goal of managing safety and executing the project efficiently.

Sub-theme 6.5: Evaluating Work Quality. Throughout the construction process, we ensured that the quality of work adhered to the design specifications, local standards, and contract requirements. Therefore, conducting the quality control process, calling in for inspections, and identifying non-conformities were crucial to attaining the main project quality objectives.
Justification: Regular quality checks ensure the construction adheres to design specifications and standards, preventing future safety issues and ensuring efficient resource use.

Sub-theme 6.6: Scheduling, Coordination, and Disruptions. An efficient and effective job was incidentally managed, including scheduling, coordinating activities, and addressing the arising setbacks. Additionally, the participation of all stakeholders in the project and the growth of communication were necessary to ensure that the project's timelines were not compromised, and resources were allocated efficiently. Henceforth, there are several strategies could be employed within the framework of lean construction and the RIBA framework 2020 as below:

- First, engineering shared plans and cooperation at the stakeholder level will improve the construction processes without further increasing waste. Pull planning and collaborative scheduling will also help achieve the best construction efficiency and coordination.
- Besides that, the JIT delivery and lean procurement policies could give general ease to the coordination, recycle material, and use the resources better.
- Thirdly, opportunities for streamlining construction processes and enhancing project performance can be identified by fostering a culture of continuous improvement and problem-solving.
- Fourthly, implementing risk management and contingency plans can effectively and proactively address construction-related risks.
- Lastly, a safe working environment for all construction personnel can be built by prioritising safety initiatives and providing comprehensive safety training programs.

Justification: Effective scheduling and coordination prevent delays and efficiently allocate resources. Proactively addressing disruptions is key to supporting the project timeline and efficiency.

What-if Scenario Analysis: If the TLC Framework is Applied to Crossrail for Efficient Execution and Safety Management

Efficient execution and safety management are crucial to large-scale infrastructure projects like Crossrail, where delays, safety incidents, and inefficiencies can have significant repercussions. The TLC framework offers a practical approach to addressing the challenges encountered during construction. By adopting Lean Construction (LC) principles, Crossrail could enhance execution efficiency, mitigate risks, and ensure safety management practices throughout the project. Below is a scenario analysis that outlines how TLC principles could have been applied to address these challenges in the Crossrail project.

- **1. Logistical Challenges**
- **Driver**: One of the significant challenges in the Crossrail project was coordinating construction activities across multiple sites and delivering materials and equipment

promptly. The complexity of managing transportation disruptions in densely populated urban areas further compounded this issue. The TLC framework, focusing on efficient resource management and waste reduction, could have been employed to improve logistics planning and execution.

- **Obstacle**: Coordination difficulties between different teams and logistical delays due to congestion and space constraints in urban areas could have led to project slowdowns.
- **Strategy**: Crossrail could have implemented Lean Construction strategies like Just-in-Time (JIT) delivery to ensure materials and equipment arrived precisely when needed, minimising storage requirements and reducing waste. As encouraged by the TLC framework, collaborative scheduling and shared plans among stakeholders would have facilitated better coordination across construction sites, ensuring smooth logistics and timely project delivery. Additionally, lean procurement methods could have helped streamline the supply chain, ensuring more efficient use of resources and reducing transportation-related delays.
- **2. Site Constraints and Access**
- **Driver**: Limited space and accessibility at construction sites, particularly in urban areas, posed significant challenges for staging construction activities, material storage, and mobilising equipment. These constraints made it difficult to maintain productivity while ensuring safety during operations.
- **Obstacle**: If not properly managed, the physical constraints of urban construction sites can lead to delays, inefficiencies, and safety hazards.
- **Strategy**: Crossrail could have used the TLC framework's emphasis on problem-solving and continuous improvement to identify creative solutions to site constraints. Learning techniques like value stream mapping and root cause analysis could have helped identify site layout and logistics inefficiencies. The project could have utilised modular construction or offsite prefabrication to minimise the need for large amounts of material storage on-site. Furthermore, Lean practices such as pull planning and collaborative scheduling could have ensured more efficient use of space and resources.
- **3. Workforce Management**
- **Driver**: Managing a large workforce of contractors, subcontractors, and labour unions is complex. Ensuring the workforce had the right skills, adhered to safety protocols, and maintained high productivity levels was essential. In addition, maintaining workforce morale and addressing labour divergences was crucial to prevent disruptions and inefficiencies.

- **Obstacle**: The diversity of the workforce and the need to align various contractors and subcontractors with the project's safety and quality standards could have led to coordination issues and productivity challenges.
- **Strategy**: Crossrail could have applied Lean Construction's focus on team collaboration and continuous improvement to create an efficient workforce management strategy. This could have involved regular safety briefings, skill development training, and promoting a collaborative work environment. By integrating workforce management into Lean planning processes, the project could have ensured that all workers were aligned with the project's goals and safety protocols. Additionally, performance management techniques such as regular feedback loops and Kaizen events could have fostered a culture of continuous improvement, enhancing workforce productivity and safety compliance.
- **4. Security and Risk Management**
- **Driver**: Ensuring worker safety and minimising construction-related risks were paramount in the Crossrail project. The risk of accidents, safety incidents, and security breaches posed significant challenges to the timely completion of projects and the well-being of workers.
- **Obstacle**: Construction-related risks such as accidents, health hazards, and security threats could delay the project, increase costs, and damage the project's reputation.
- **Strategy**: The TLC framework could have supported Crossrail's risk management strategies by implementing continuous risk assessment, proactive mitigation plans, and safety audits throughout the construction phase. Lean principles, such as Kaizen and value stream mapping, could have been utilised to identify potential safety hazards early in the process and eliminate them. Crossrail could have established a safety culture by involving workers in regular safety workshops and training programs. Additionally, contingency plans and risk management strategies could have been developed to address potential safety incidents and security threats.
- **5. Checking the Work Quality**
- **Driver**: Crossrail was crucial in ensuring that work quality met design specifications, local standards, and contractual requirements. Continuous quality control and the identification of non-conformities were essential for the project's long-term success.
- **Obstacle**: Failure to monitor quality effectively could result in construction defects, safety hazards, or costly rework.

- **Strategy**: Crossrail could have used Lean Construction's quality management techniques, such as frequent inspections, real-time monitoring, and collaboration with design teams, to ensure that construction adhered to quality standards. Quality assurance processes could have been integrated into every stage of the construction process, with regular quality checks and proactive identification of issues before they became significant problems. Additionally, a robust feedback loop for quality control would have promptly addressed any deviations from the design specifications.
- **6. Scheduling, Coordination, and Disruptions**
- **Driver**: Efficient scheduling, coordination, and the ability to respond to disruptions were crucial for the timely completion of the Crossrail project. Ensuring all tasks were scheduled correctly and disruptions were managed effectively was key to maintaining progress.
- **Obstacle**: Delays, unforeseen disruptions, and inefficient scheduling could lead to resource wastage, increased costs, and missed deadlines.
- **Strategy**: Crossrail could have employed Lean Construction principles such as pull planning and collaborative scheduling to enhance coordination across all construction teams. Visual management tools, such as Kanban boards or project dashboards, would have facilitated real-time progress tracking and issue resolution. Lean procurement policies, such as JIT delivery, would have minimised delays related to material availability. Additionally, implementing risk management and contingency plans suggested by the TLC framework would have allowed Crossrail to respond quickly to disruptions, minimising their impact on the project timeline.
- **Key Strategies for Efficient Execution and Safety Management**

To optimise execution and safety management in the Crossrail project, the following strategies could have been employed within the TLC framework:

- **Collaborative Scheduling and Planning**: Crossrail could have facilitated collaborative planning sessions across all teams to ensure coordination, minimise disruptions, and streamline construction schedules. Pull planning methods could have been used to synchronise activities and ensure all stakeholders aligned on the project's timeline.
- **Continuous Improvement and Problem-Solving**: Crossrail could have created a culture of continuous improvement, where teams regularly identified opportunities to streamline construction processes and eliminate inefficiencies. Techniques such as

Kaizen events and root cause analysis could have been employed to resolve problems as soon as they arose.

- **Just-In-Time (JIT) Delivery**: By implementing JIT delivery, Crossrail could have minimised storage space requirements, reduced material handling costs, and ensured timely access to construction materials. Lean procurement policies would have supported the efficient use of resources.
- **Risk Management and Safety Culture**: Crossrail could have prioritised safety by implementing Lean risk management tools such as value stream mapping to identify potential safety risks early. The project could also have ensured that workers received regular safety training and were actively involved in promoting a safe working environment.

Theme 7: Seamless Transition and Documentation Management

Seamless transition and documentation management are crucial during a project's handover and closeout phases, as exemplified by projects such as Crossrail. This theme focuses on the strategic approaches necessary to ensure all project components are accurately documented and smoothly transitioned to operational status. The Crossrail project involved multiple stakeholders with varying interests, making it imperative to incorporate their feedback into the documentation and transition processes. Zhu et al. (2019) emphasise the importance of updating as-built information and ensuring that all relevant data are accurately captured during the handover. The Crossrail project team can better address stakeholder concerns and enhance documentation accuracy by employing the TLC framework tools, which promote active listening through regular feedback sessions and collaborative workshops.

Sub-theme 7.1: Documentation and As-Built Drawings. Proper documentation, including ensuring document completion and accuracy, as well as maintaining records of as-built drawings, manuals, warranties, and certificates, presented significant challenges. Similarly, meticulous attention to detail and coordination were required to collect, organise, and verify the documents from multiple contractors and subcontractors.
Justification: Accurate and complete documentation, including as-built drawings and manuals, is essential for future maintenance and operations.

Sub-theme 7.2: Commissioning and testing. Several hurdles were present, including completing commissioning activities, conducting system testing, and obtaining regulatory approvals for operational readiness. However, coordinating testing schedules, addressing

deficiencies, and ensuring compliance with performance standards were critical aspects of the closeout stage.
Justification*:* Thorough commissioning and testing ensure that all systems are operational and meet performance standards. Addressing deficiencies during this phase is critical for a smooth handover.

Sub-theme 7.3: Punch List Management. During final inspections, identifying and resolving punch list items, deficiencies, and outstanding issues were challenges for achieving project completion. Therefore, effective communication and stakeholder coordination were necessary to prioritise punch list items, coordinate corrective actions, and monitor progress.
Justification*:* Identifying and resolving punch list items efficiently is essential for achieving project completion.

Sub-theme 7.4: Occupancy and Transition Planning. Logistical challenges were presented, including facilitating the transition from construction to occupancy, which required the relocation of personnel, equipment, and operations. Therefore, careful planning and execution were crucial for coordinating occupancy schedules, addressing tenants' needs, and ensuring a seamless transition.
Justification: Careful planning and execution of the transition from construction to occupancy ensure minimal disruption and meet the needs of tenants and end-users

Sub-theme 7.5: Training and Handover to Operations. Ensuring the effective operations and maintenance of project assets was crucial to providing training and support to facility operators, maintenance staff, and end-users. For developing training programs, documenting operating procedures, and facilitating knowledge transfer at the closeout stage. So, within the framework of Lean Construction and the RIBA PoW 2020, several strategies could be employed, such as

- Firstly, implementing LC and RIBA PoW 2020 document control systems, workflows, and standardised templates could streamline document management, improve accuracy, and ensure the project's completion during the handover process.
- Secondly, integrating testing and commissioning teams and adopting phased testing approaches could improve issue resolution and accelerate project handover.
- Thirdly, Crossrail could minimise project delays and disruptions by prioritising and rapidly resolving punch list items through visual management systems and collaborative problem-solving.

- Fourthly, strategies such as early engagement and collaboration with end-users through mock-up exercises, user training workshops, and phased occupancy could minimise disruptions and ensure a seamless transition to operational status.
- Lastly, implementing LC and RIBA PoW 2020, such as hands-on training modules, could facilitate practical training and knowledge transfer to facility operators and maintenance staff during the handover process.

Justification: Comprehensive training and support for facility operators and maintenance staff ensure the effective operation and maintenance of project assets post-handover.

What-if Scenario Analysis: If the TLC Framework is applied to Crossrail for Seamless Transition and Documentation Management

The successful completion of large-scale infrastructure projects, such as Crossrail, requires an efficient transition from construction to operation. This involves meticulous documentation management and a smooth handover process, ensuring all relevant project data is accurately captured and operational systems are ready for use. The TLC framework, which emphasises collaboration, continuous improvement, and efficient processes, offers valuable strategies for managing this critical phase. By applying TLC principles to the Crossrail project, key challenges related to documentation, commissioning, punch list management, occupancy planning, and training can be addressed effectively, ensuring a seamless transition to operational status.

- **1. Documentation and As-Built Drawings**
- **Driver**: Accurate documentation is critical for the successful transition to operation, particularly regarding as-built drawings, manuals, warranties, and certificates. The Crossrail project faced challenges ensuring that all contractors and subcontractors provided complete and accurate documentation. This is essential for the future maintenance and operation of the system.
- **Obstacle**: Ensuring the accuracy and completeness of documentation, especially as-built drawings, can be cumbersome, mainly when multiple contractors are involved and varying documentation standards are in place.
- **Strategy**: The TLC framework could have supported Crossrail by implementing standardised document control systems and workflows, as suggested in the RIBA Plan of Work 2020 framework. By creating templates and a transparent, structured approach to documentation, the project could have ensured that all documents were accurately

completed and accessible. Learn techniques like visual management that could have been used to track document progress in real time, ensuring that all necessary paperwork was collected and verified before the handover phase.

- **2. Commissioning and Testing**
- **Driver**: Thorough commissioning and testing are essential to verify that all systems meet operational performance standards. For Crossrail, completing system testing, obtaining regulatory approvals, and coordinating these activities across multiple systems were significant challenges during the closeout phase.
- **Obstacle**: Managing the timing and coordination of commissioning activities, addressing deficiencies, and ensuring that all systems met performance standards posed significant challenges during the transition phase.
- **Strategy**: The TLC framework and the RIBA Plan of Work 2020 standards promote the integration of testing and commissioning teams. By adopting a phased testing approach, Crossrail could have accelerated the testing process and addressed any issues early on. Utilising Lean tools, such as root cause analysis, could have helped identify and resolve deficiencies quickly. Furthermore, collaborative workshops and feedback loops among the design, construction, and operational teams could have ensured that the systems met all required performance standards and regulatory approvals.
- **3. Punch List Management**
- **Driver**: During the final inspection phase, managing punch list items, deficiencies, and outstanding issues is critical for completing the project. Crossrail had to ensure punch list items were identified, prioritised, and resolved before completing the final project.
- **Obstacle**: Identifying and resolving punch list items can often be slow, leading to delays and inefficiencies during the closeout phase.
- **Strategy**: Crossrail could have employed Lean Construction principles, such as visual management systems, to track and prioritise punch list items in real-time. Using these systems, the project team could have identified deficiencies quickly and coordinated corrective actions more efficiently. Collaborative problem-solving workshops involving all relevant stakeholders could have been used to resolve outstanding issues swiftly, minimising delays and facilitating a smooth handover.
- **4. Occupancy and Transition Planning**
- **Driver**: The transition from construction to occupancy presents logistical challenges, including the relocation of personnel, equipment, and operations. Crossrail needed to

ensure that the transition to occupancy was seamless and minimally disruptive for tenants and end-users.

- **Obstacle**: Coordinating the occupancy schedule, addressing tenant needs, and managing the relocation process required careful planning and effective communication across multiple stakeholders.
- **Strategy**: The TLC framework emphasises early engagement and collaboration, which could have been key in Crossrail's occupancy and transition planning. By involving end-users early in the process, the project could have conducted mock-up exercises, user training workshops, and phased occupancy strategies. These strategies would have helped address potential disruptions, ensuring a smoother transition and better meeting the needs of all stakeholders. Collaborative planning and clear communication between contractors, facility managers, and end-users would have ensured a seamless transition and minimised operational disruptions.
- **5. Training and Handover to Operations**
- **Driver**: Ensuring the facility operates smoothly post-handover requires practical training for facility operators, maintenance staff, and end-users. Crossrail needed to ensure that all personnel were adequately trained to manage and maintain the new infrastructure.
- **Obstacle**: Ensuring proper knowledge transfer and providing adequate training to all staff can be challenging, particularly in large-scale projects with complex systems and operations.
- **Strategy**: Crossrail could have leveraged the TLC framework's focus on continuous improvement and knowledge sharing to develop comprehensive training programs. Early engagement with end-users and facility operators, as part of the RIBA PoW 2020 framework, would have helped facilitate this process. Practical training modules, hands-on workshops, and phased handovers could have been employed to ensure that staff were well-prepared for operations and maintenance. Additionally, by implementing a Lean document control system, the project team could have ensured that all operational procedures, manuals, and maintenance documentation were easily accessible and standardised.
- **Key Strategies for Seamless Transition and Documentation Management**

  To ensure a smooth transition and effective documentation management, the following strategies could have been employed within the TLC framework:

- **Standardized Documentation Systems**: As emphasised by Lean Construction and RIBA PoW 2020, the use of standardised templates, workflows, and document control systems would have ensured the accuracy and completeness of project documentation. Real-time tracking and visual management tools could have helped the project team stay on top of document completion and verification.
- **Integrated Testing and Commissioning Teams**: Crossrail could have streamlined the process and ensured that systems met performance standards without delays by employing integrated testing and commissioning teams. A phased testing approach would have allowed for quicker issue resolution and ensured all systems were operational on time.
- **Collaborative Punch List Management**: Lean principles, such as visual management and collaborative problem-solving, could have been applied to quickly prioritise and resolve punch list items, minimising delays during the closeout phase and ensuring the project was completed on schedule.
- **Early Engagement with End-Users**: Engaging end-users early through mock-ups, user training workshops, and phased occupancy would have ensured that tenants' needs were met and potential disruptions were minimised. This would have facilitated a smoother transition from construction to occupancy.
- **Comprehensive Training and Knowledge Transfer**: Crossrail could have implemented training programs that included hands-on workshops, practical training modules, and knowledge transfer systems. By ensuring that all staff were adequately trained, the project would have supported the long-term success of the infrastructure post-handover.

Theme 8: Operational Efficiency and Stakeholder Satisfaction

Relation: Effective communication is essential for ensuring all stakeholders align on operational objectives and sustainability goals. The TLC framework emphasises the importance of clear and consistent communication throughout the in-use stage. Babalola et al. (2019) highlight that effective communication strategies can significantly improve operational efficiency by ensuring all parties are informed of their responsibilities and the status of project deliverables. By implementing the TLC, the Crossrail project team can facilitate information sharing and ensure all stakeholders are engaged in the operational process.

Sub-theme 8.1: Maintenance and Facility Management. Challenges regarding resource allocation, scheduling, and prioritisation of maintenance activities were there to ensure proper maintenance and management of Crossrail infrastructure, including stations, tracks, signalling systems, and other facilities. Similarly, effective maintenance strategies and coordination were required to maintain asset performance, reliability, and safety while minimising disruptions to service.

Justification: Effective maintenance strategies and coordination are necessary to maintain asset performance and safety, minimising service disruptions.

Sub-theme 8.2: Occupant Comfort and Satisfaction. Addressing occupant comfort, satisfaction, and feedback during the in-use stage was crucial, particularly for passenger facilities such as stations and trains. Therefore, supporting a positive user experience was managing passenger flow, addressing overcrowding, providing adequate amenities, and responding to customer feedback.

Justification: Ensuring occupant comfort and satisfaction through effective facility management and addressing feedback is crucial for maintaining a positive user experience.

Sub-theme 8.3: Service Reliability and Performance. Challenges in operational planning, infrastructure maintenance, and system resilience were posed to ensure the reliability and performance of Crossrail services, including train schedules, frequency, and connectivity. However, robust operational strategies and contingency plans had to minimise service disruptions, optimise operational efficiency, and meet passenger demands.

Justification: Robust operational strategies and contingency plans are needed to ensure service reliability and meet passenger demands.

Sub-theme 8.4: Safety and Security. Maintaining safety and security standards for passengers, staff, and infrastructure during the operational stage was paramount. Proactive monitoring, incident response protocols, and stakeholder collaboration were required to implement adequate security measures, address safety hazards, and respond to emergencies.

Justification: Maintaining high safety and security standards through proactive monitoring and incident response protocols is crucial for safeguarding passengers, staff, and infrastructure.

Sub-theme 8.5: Sustainability and Environmental Management. Crossrail operations presented challenges in terms of sustainability and regulatory compliance, as they involved managing environmental impacts, energy consumption, and carbon emissions associated with the project. Similarly, comprehensive environmental management strategies and stakeholder involvement were necessary for implementing sustainable practices, including energy-efficient operations, waste reduction, and green procurement. Many strategies could be implemented within the framework of Lean Construction and the RIBA PoW 2020, such as:

- Firstly, Crossrail could identify areas for improvement and implement corrective actions to enhance service quality and user satisfaction by implementing lean performance monitoring systems and customer feedback loop strategies through continuous improvement and feedback mechanisms.
- Secondly, proactive maintenance strategies, such as predictive maintenance and condition monitoring, could optimise maintenance schedules, reduce downtime, and extend asset lifespan.
- Thirdly, Crossrail could streamline operations, improve productivity, and reduce costs while maintaining service reliability and performance by adopting operational efficiency and optimisation techniques such as value stream mapping and process optimisation.
- Fourthly, safety awareness can be promoted, accidents can be prevented, and safety regulations can be complied with by establishing a solid safety culture and providing comprehensive safety training programs for employees and contractors.
- Lastly, goals such as minimal environmental impacts, optimised resource efficiency, and sustainability can be achieved by integrating sustainability objectives into operational processes through lean environmental management systems and sustainability reporting. Therefore, Crossrail could minimise environmental impacts, optimise resource efficiency, and achieve sustainability goals by implementing LC and RIBA PoW 2020, such as sustainability checkpoint reporting.

Justification: Implementing sustainable practices and managing environmental impacts are essential for ensuring regulatory compliance and achieving long-term project success.

What-if Scenario Analysis: If the TLC Framework is applied to Crossrail for Operational Efficiency and Stakeholder Satisfaction

Ensuring operational efficiency and stakeholder satisfaction during the in-use phase of a large infrastructure project, such as Crossrail, is crucial for its long-term success. Effective communication, robust maintenance strategies, addressing occupant comfort, and implementing sustainable practices are key components of this phase. The TLC (Total Lean Construction) framework offers tools and methodologies that can significantly enhance operational processes while aligning with the needs and expectations of various stakeholders. By incorporating these strategies, Crossrail can enhance asset management, service delivery, safety, and environmental performance, thereby ensuring the satisfaction of passengers, staff, and other key stakeholders.

- **1. Maintenance and Facility Management**
- **Driver**: Maintaining infrastructure, including tracks, stations, signalling systems, and other facilities, is essential for ensuring operational efficiency. Proper resource allocation, scheduling, and prioritisation of maintenance activities are key challenges ensuring that Crossrail's infrastructure remains safe, reliable, and efficient throughout its operational life.
- **Obstacle**: Effective maintenance strategies must prevent unplanned downtime and disruptions while ensuring asset performance and reliability. Balancing service delivery with maintenance activities can be challenging, particularly when managing complex systems across a vast network.
- **Strategy**: Lean Construction principles can support Crossrail in implementing proactive maintenance strategies such as predictive maintenance and condition monitoring. By utilising lean tools like value stream mapping and continuous improvement processes, Crossrail can identify maintenance needs earlier, reduce downtime, and optimise resource allocation. Additionally, implementing Lean performance monitoring systems and customer feedback loops, as suggested in the RIBA PoW 2020 framework, would allow the team to continuously assess maintenance efficiency and user satisfaction, ensuring all facilities remain in top condition.
- **2. Occupant Comfort and Satisfaction**
- **Driver**: Ensuring passengers' comfort and satisfaction is a key operational objective for Crossrail. Managing passenger flow and overcrowding, providing adequate amenities, and responding to customer feedback are crucial for maintaining a positive user experience.
- **Obstacle**: Balancing the flow of passengers and addressing any discomforts or dissatisfaction during peak travel times, alongside responding to individual complaints, can be a resource-intensive process. Without an effective feedback mechanism, it can be challenging to identify and address the root causes of dissatisfaction.

- **Strategy**: Crossrail could adopt Lean principles to improve occupant satisfaction through continuous improvement initiatives and feedback loops. Crossrail can proactively address issues such as overcrowding and service delays by integrating passenger satisfaction metrics into regular performance assessments and using tools like root cause analysis. Implementing Lean techniques for process optimisation will allow the project to focus on creating value-added services that improve the user experience without increasing operational costs.
- **3. Service Reliability and Performance**
- **Driver**: Crossrail must ensure high service reliability and performance, including consistent train schedules, frequency, and system resilience. Service disruptions can significantly impact passengers and the broader operational efficiency of the infrastructure.
- **Obstacle**: Operational challenges, including infrastructure maintenance and system resilience, need to be addressed to optimise reliability and minimise service disruptions. Unforeseen equipment failures, extreme weather conditions, or external incidents could significantly impact service delivery.
- **Strategy**: Adopting Lean operational efficiency techniques such as value stream mapping and process optimisation would allow Crossrail to streamline operations, reduce costs, and maintain high service reliability. Additionally, using the RIBA PoW 2020 framework's contingency planning and risk management strategies would help ensure service resilience, enabling Crossrail to respond effectively to disruptions while minimising service downtime. Proactive operational planning and continuous improvement would ensure that services run smoothly, even during challenging periods.
- **4. Safety and Security**
- **Driver**: Safety and security are paramount in a public transport infrastructure like Crossrail, where passengers, staff, and infrastructure must be protected from hazards and security threats. Implementing robust safety standards, incident response protocols, and continuous monitoring is necessary to ensure the integrity of operations.
- **Obstacle**: Maintaining safety in a dynamic and complex environment, such as Crossrail, requires constant vigilance and preparedness. The challenge lies in ensuring that safety protocols are regularly updated and adhered to while also being able to respond to unforeseen incidents.

- **Strategy**: Lean Construction promotes establishing a strong safety culture, which could be integrated into the Crossrail project's daily operations. This includes offering comprehensive safety training programs for employees and contractors, as well as ensuring that risk assessments and safety audits are integrated into ongoing operational practices. Crossrail can also apply the TLC framework's emphasis on clear communication and collaboration to ensure that safety protocols are consistently updated and shared across all stakeholders, enabling timely responses to emerging risks.
- **5. Sustainability and Environmental Management**
- **Driver**: Sustainability is a crucial operational goal for Crossrail, particularly in managing environmental impacts, including energy consumption, waste reduction, and carbon emissions. This requires developing comprehensive strategies that integrate sustainability with operational efficiency.
- **Obstacle**: Navigating environmental regulations and compliance while maintaining operational efficiency presents a challenge, especially in large-scale projects that require continuous energy consumption and resource utilisation.
- **Strategy**: The TLC framework supports sustainability initiatives through Lean environmental management systems, which would help Crossrail optimise resource usage and reduce environmental impacts. Implementing sustainability checkpoints, reporting mechanisms, and energy-efficient operational strategies can ensure that the project meets its sustainability goals while adhering to regulatory requirements. Furthermore, Crossrail could collaborate closely with stakeholders to implement green procurement practices and integrate sustainable features into its everyday operations. This would align with the RIBA PoW 2020 guidelines for environmental management and sustainable development, contributing to an efficient and eco-friendly project.
- **Key Strategies for Improving Operational Efficiency and Stakeholder Satisfaction**

Crossrail can employ the following strategies to enhance operational efficiency and stakeholder satisfaction during the in-use phase:

1. **Proactive Maintenance and Performance Monitoring**: Lean techniques such as predictive maintenance, condition monitoring, and performance tracking can help optimise maintenance schedules, reduce downtime, and extend asset lifespans. This will also minimise disruptions and ensure assets continue to perform reliably.
2. **Continuous Improvement and Customer Feedback**: Crossrail could implement continuous improvement processes and feedback loops to address passenger comfort

and satisfaction. Tools such as root cause analysis and regular passenger surveys would enable the project to adjust services based on real-time feedback and proactively enhance the user experience.

3. **Operational Optimisation**: By adopting Lean techniques, such as value stream mapping, Crossrail can streamline its operations, reduce costs, and enhance service reliability. These approaches would help ensure operations meet passenger demands while minimising waste and delays.
4. **Safety Culture and Incident Response**: Establishing a robust safety culture and providing comprehensive safety training to staff and contractors can help ensure that safety protocols are consistently followed. As part of the Lean approach, proactive monitoring and risk assessments would allow Crossrail to mitigate potential safety hazards before they occur.
5. **Sustainability Integration**: Crossrail can achieve its sustainability goals through the Implementation of Lean environmental management systems. The project can meet regulatory compliance and contribute to a more sustainable infrastructure by tracking and optimising energy consumption, waste, and resource usage.

   Total Lean Construction (TLC) framework: Using quantitative data from the Crossrail project, we can focus on several key metrics, including cost, time, safety, and operational efficiency. The aim is to apply the TLC framework's principles, including continuous improvement, value optimisation, and waste reduction, to real-world data from the Crossrail project. We will also examine timeline analysis, which is crucial to understanding how efficiently the project progressed over time and how effectively the TLC framework addressed challenges.

5.3 Discussion and Conclusion

Expanding on the discussion and conclusion, it is crucial to examine the specific issues encountered by the Crossrail project at each stage and the tailored strategies employed to address them using the TLC Framework. This is summarised below.

5.3.1 Strategic Definition Stage

Defining project objectives that involve diverse stakeholder interests is a significant challenge. By adopting the TLC framework, Crossrail can initiate early stakeholder engagement activities, including workshops and public consultations, to overcome this challenge and ensure alignment and consensus. Similarly, risk identification and management were essential. They required thorough analysis and collaboration to address unpredicted harms and effectively allocate funding resources. Technical expertise requires careful attention to balance budgetary constraints with strategic priorities.

5.3.2 Preparation and Brief Stage

Navigating stakeholder needs and technical uncertainties posed challenges during Crossrail's preparation and briefing phase. However, by implementing the TLC framework, the project could achieve target value design and optimise resource allocation. The project prioritised risk management and contingency planning to address uncertainties effectively and minimise disruptions.

5.3.3 Concept Design Stage

Implementing the LC and RIBA PoW 2020 helps address the challenges of design coordination and technical integration during the concept design stage. Crossrail sought to enhance collaboration and optimise designs by emphasising integrated design workshops and value engineering. Additionally, applying the TLC framework enables effective resolution of design challenges, ensuring project excellence while staying within budget constraints.

5.3.4 Developed Design Stage

The challenges during the developed design stage were similar to those during the concept design stage, which required a focus on integrated design and construction teams' value engineering, optimisation, and lean problem-solving to streamline processes. Additionally, stakeholder engagement and cooperation were crucial for aligning design solutions with project objectives and addressing stakeholder concerns.

5.3.5 Technical Design Stage

Detailed design coordination, regulatory compliance, cost control, and risk management were critical during the technical design stage. Crossrail implemented integrated design and construction teams and value engineering and applied the TLC Framework, which effectively addressed these challenges while prioritising safety and quality assurance.

5.3.6 Construction Stage

The construction phase presented logistical challenges, including site limitations, workforce supervision issues, safety concerns, and the need for efficient schedule management. Crossrail could adopt the TLC framework for collaborative planning, JIT delivery, continuous improvement, and arduous risk management to ensure smooth project execution while prioritising safety, quality, and efficiency.

5.3.7 Handover and Closeout Stage

In Crossrail, the challenges involved in the handover and closeout stage were related to documentation, commissioning, occupancy planning, punch list management, and training. The adopted TLC framework could enhance documentation management, collaborative commissioning, and testing, facilitate smooth occupancy transitions, and provide comprehensive training to ensure successful project completion.

5.3.8 In-Use Stage

The TLC framework can be utilised to address challenges such as maintenance, occupant satisfaction, and safety in the final stage of the Crossrail project, referred to as the operational stage. By focusing on continuous improvement, predictive maintenance, and promoting a safety culture and sustainability, the project can deliver lasting benefits to stakeholders and the community.

As for the first method's results, it can be summarised that interviews with construction industry professionals and companies present a comprehensive overview of the industrial demographics, qualifications, experience levels, specialisations, roles, organisational size, and project sizes. The results demonstrate a diverse and dynamic environment, underscoring the multifaceted nature of work and variance of knowledge within the sample organisations. Most of the respondents possess higher qualifications. Simultaneously, many had mid-range experiences. Overall, the interview results indicate that the TLC Framework is a valuable contribution to enhancing project performance, as it is both easy to implement and understandable. However, it can be further improved, indicating a need for more in-depth research to accurately capture a broader range of experiences and develop a comprehensive, more effective framework.

However, the Crossrail project has been an example of the successful implementation of The TLC Framework. It utilises both guidelines to address multifaceted issues across various project stages. Crossrail has established itself as a global paradigm for large-scale infrastructure projects by adopting a comprehensive approach that prioritises collaboration, innovation, efficiency, and sustainability. The project emphasises the importance of strategic planning, risk management, continuous improvement, and adherence to best practices of stakeholder involvement throughout the project life cycle.

As Crossrail enters its operational phase, it serves as a testament to the transformative and effective project management techniques that deliver enduring infrastructure solutions, meeting society's needs and enhancing economic and environmental stewardship.

In conclusion, both research methods demonstrate that the TLC Framework, a combination of Lean Construction principles and the RIBA Plan of Work 2020, effectively addresses project management, quality assurance, design issues, and safety assurance and optimises the performance of construction projects. However, the Crossrail project is an on-ground and physical proof of this hypothesis and has set a benchmark for successfully delivering complex infrastructure projects.

Chapter 6 Conclusions

6.1 Introduction

This chapter outlines the steps taken to enhance the visibility of the Total Lean Construction (TLC) framework and illustrates how the framework key features and contributions are presented. The primary objective is to showcase the TLC framework innovative integration of Lean principles with the RIBA Plan of Work 2020. To achieve this, several strategies have been implemented. The chapter begins with an introduction that emphasises the framework's unique ability to address inefficiencies in construction management by embedding Lean principles across all project phases. This introduction also establishes the context for the TLC framework, demonstrating how it bridges theoretical and practical gaps identified in earlier chapters. A visual representation of the TLC framework, in the form of a flowchart or diagram, is included to depict its structure, components, and operational flow. The diagram illustrates how the framework addresses key construction challenges, including waste reduction, cost control, and stakeholder collaboration. Additionally, a dedicated subsection elaborates on the theoretical and practical novelty of the TLC framework, referencing research gaps addressed by the framework, comparing it with existing approaches, and detailing specific innovations such as integrating Lean principles with project lifecycle stages. These steps demonstrate the framework's potential for improving project outcomes and overall construction efficiency. To achieve this aim, three specific objectives were set:

6.2 Evidence for Research Objectives

This section substantiates the achievement of each research objective by linking them to the evidence presented in earlier chapters. The following outlines how the corresponding evidence supports each objective:

Objective 1: Identifying integration points between Lean Construction principles and the RIBA PoW 2020

Chapter 2**,** Sections 2.5.6 and 2.6, provides evidence for this objective**.** These sections discuss the theoretical foundations underpinning Lean Construction and the RIBA Plan of Work (PoW) 2020. A critical literature review highlights key gaps and challenges in the existing literature, which the framework aims to address by identifying integration points between these two areas. This integration is crucial for enhancing efficiency in construction projects.

Objective 2: Developing the TLC Framework to improve both process efficiency and sustainability in construction projects.

Chapter 4 provides a comprehensive overview of the development of the TLC Framework. In Sections 4.3 to 4.12, the chapter outlines the step-by-step process for integrating Lean Construction principles with the RIBA Plan of Work 2020. It outlines the methodologies applied, the integration strategies employed, and the challenges faced during the framework's development. This section provides a detailed account of how the TLC Framework was conceptualised and constructed, ensuring that the integration points identified in Objective 1 are effectively addressed.

Objective 3: Validating the TLC Framework

Chapter 5 addresses the validation of the TLC Framework, where evidence is gathered through two main methods: semi-structured interviews (Section 5.1) and a case study and what-if scenario on the Crossrail project (Section 5.2). These validation activities demonstrate the real-world applicability and potential benefits of the TLC Framework to the construction industry. The findings from these methods support the framework's robustness and potential for improving project outcomes.

Table 6.1: Summary Mapping Objectives to Corresponding Evidence

Objective	Chapter(s) & Section(s) with Evidence
Objective 1: Identifying integration points between Lean Construction principles and the RIBA PoW 2020	Chapter 2, Sections 2.8 to 2.15
Objective 2: Developing the TLC Framework	Chapter 4, Sections 4.3 to 4.12
Objective 3: Validating the TLC Framework	Chapter 5, Section 5.1 (Interviews) and Section 5.2 (Crossrail Case Study and Scenario Analysis)

Table 6.1 maps each objective to the respective chapters and sections where the evidence is discussed. This ensures transparency and strengthens the linkage between the research objectives and the supporting evidence.

6.3 Discussion

The application of Lean Construction principles often faces various obstacles, including financial, administrative, and local authority issues, among others. However, the author has considered all these aspects while developing the TLC framework. The newly developed framework is initiated by combining Lean construction principles with the RIBA Plan of Work 2020 to measure and control the cost, time, quality, and sustainability of any construction project. It fully integrates the RIBA work plan with the principles of Lean philosophy. A comprehensive framework has been developed that is both practicable and adaptable, encompassing all project sizes. LC and RIBA PoW 2020 are frameworks for project management practices and encompass the steps for sustainable construction and encouraging a green environment. By adopting this proposed framework, the construction industry can also reduce its environmental impact, a global concern. Therefore, the significance of LC and RIBA PoW 2020 extends beyond any specific region, spreading globally.

The present research study examined the Lean construction techniques currently employed in the construction industry and the principles of implementing Lean Construction, explicitly addressing issues related to LC techniques for project planning, project changes, risk management, and waste management (as discussed in Chapter 2 of the literature review). Then, new tools and techniques were developed to overcome the problems and manage construction projects effectively and efficiently. The prevailing approach adopted in the research presented herein was the requirement for a combined framework using LC and RIBA for construction project management. The TLC Framework has developed this research thesis, allowing for the incorporation of cost control and measurement, timeliness, quality, and sustainability in construction projects. It was supported by the accessibility of paper articles, books, and other available research for LC and RIBA PoW 2020, as well as case study materials. Then, these sources (previous research and case study) were used to test the measurement models, which include Lean Construction implementation tools, techniques and methods, and models; experimental studies to grasp the lean construction initiatives for developed and developing states; and evaluating the case study to validate the implementation of the developed framework (referred to Chapter 5). To evaluate the proposed TLC Framework, data were collected through interviews with specific professionals and respondents. The second method of validation, documentary analysis and observations, was also conducted. Lastly, the TLC proposed Framework, and the data results were evaluated and discussed briefly (referenced in Chapter 5).

This PhD research originated from the RIBA PoW 2020 as a suitable construction project management process relevant to building and infrastructure and applies to residential buildings as observed through the case study. This study has assessed the fact that the LC process is a fundamental method and how it offers significant potential for enhancing project management in the construction industry. The framework has been developed to overcome the barriers to implementing effective project management practices, including time management, total quality management, cost management, and sustainability management. Furthermore, it enables the identification of the necessary steps at both the strategic and execution levels to ensure that all hurdles are addressed and dealt with effectively, thereby achieving the goal of measuring and controlling cost, quality, and sustainability in construction projects. The research gap associated with the various techniques in construction management has accelerated the need to develop a comprehensive and usable framework, as currently, no system leverages the synergistic benefits of Lean Construction and RIBA PoW 2020. Chapter 3 (Research Methodology) outlines the roadmap for developing the research and addressing the gaps in the current state of knowledge. Using the methodology outlined in Chapter 3, an urgent need has arisen to develop a usable combined framework, as an updated version of RIBA PoW 2020 is now available. Chapter 4 builds upon this perception through the results obtained for each key stage, as stated in the preceding sections. Here, the development of a new construction framework and the foremost results obtained by the questionnaire are presented. Moreover, to the author's knowledge, no other study has evaluated these issues or addressed the integrated framework model presented in this study. However, this research thesis has focused on the new visions and understandings of the implementation framework development, which can be incessantly applied in the construction industry for project management.

6.4 Conclusions

No doubt, numerous techniques have been developed and applied as control methods, including control techniques and project control software, yet many construction projects have been observed that have not yet achieved their cost and time goals. However, using the developed framework in this research, the inhibiting factors and the measure in practice for mitigation can be recognised and eliminated. The mitigating measures can be categorised as preventive, predictive, corrective, and organisational, forming a checklist of good practices. Moreover, Kerzner (2003) states that the primary objective of project control in a construction project or industry is to complete the project on time, within budget, and following other identified objectives. That is why it is a complicated task for a project manager to complete any project within budget and on time while achieving the other set goals, as it requires continuous monitoring of progress, plan evaluation, and corrective actions wherever and whenever required.

A literature review, interview, and case study gathered further evidence to validate these factors. Later, this data was used to tie together the research with the facts that happened on-site. The Crossrail Railway project in London has been studied as a case study to achieve the research goal. This project is a prime example of effectively implementing Lean Construction and RIBA PoW 2020, serving as a benchmark to study the actual challenges faced by a construction project at various stages of the project life cycle. All the responses to interview questions, available literature, and the adopted case study have shown similar concerns that are problematic characteristics of a project, namely, time and cost overrun, quality check and assurance problems, conflicts, lack of coordination, lack of safety, unreliable programme, and disagreement between stakeholders such as client, subcontractor, and main contractor.

This fact motivated me to conduct this research, as the case study demonstrated the main techniques of lean construction and its benefits in construction projects. Similarly, the interviews were conducted with the most relevant individuals, including certified engineers, contractors, designers, labourers, and supervisors. Additionally, the available literature reports and documents enabled a detailed evaluation of the developed TLC framework, illustrating actual construction projects through case studies. Rather than focusing solely on real-world implementation, scenario analysis was employed to explore the expected benefits and impacts of the TLC framework. This approach enabled the prediction of how the framework could address critical challenges, including time management, cost control, and achieving other project objectives. By simulating various project conditions and outcomes, the scenario analysis provided valuable insights into the potential effectiveness of the TLC framework in improving project performance. The key findings derived from this analysis, as outlined in Chapter 5, include: (1) Improved site management was observed through enhancements to construction planning and control practices, as well as improved coordination. (2) Lean Construction principles were evaluated to develop a new lean assessment system and achieve quantifiable results. (3) The development and implementation of LC and RIBA PoW 2020, along with key performance indicators (KPIs) and performance indicators (PIs), led to successful performance improvement. (4) The development of control and measurement through TLC enabled improved quality, performance, cost, and time, demonstrating the framework's potential for all construction industry projects. (5) Recognition of stakeholder involvement was achieved, demonstrating the benefits of the developed framework. Chapter 4 presents a Total Lean Construction (TLC) framework that incorporates lean construction principles and enablers. This achieves a more consistent approach to benefiting from lean construction to its fullest, adapting the lean principle with enablers within the developed framework.

Control and measurement methods have been developed to manage costs, control overruns, and ensure time, quality, and sustainability. These are also represented in this chapter. The innovative construction in this research study was based on enablers that can help improve project performance and achieve project objectives. Moreover, this study also discussed the adaptation and consideration of main enablers, as well as the development process of the framework. Section 4.12 presents the TLC framework. Chapter 4 discusses the tools and techniques of Lean construction, including the Last Planner, survey analysis, a project performance matrix, and frameworks for addressing cost and time issues. Based on the analysis of interviews (conducted with a sample size of 25, with 19 participants accepted, as presented in Chapter 5), the first section of the chapter included the interview analysis, and the second section presented the case study analysis, which validated the TLC framework.

The critical role of management and stakeholders, whether internal or external, should not be underestimated. Recognising project scope and objectives is critical in the management of construction projects. For this purpose, clear communication between stakeholders and departments is crucial; failing to do so can lead to serious coordination issues among design, execution, and management teams. That is why the programme submitted to the client during the project execution, covering various stages, serves as a preface to the executed and completed activities on site, followed by a theoretical future, which can be optimistically completed on time and within budget. However, the developed framework and proposed practice recommended are a high-quality process for improving the reliability of the plan and, if applied, would surely result in efficient control and management of all activities and projects in general. However, time control was applied on an experience-based basis through simple visual observation of what had been completed and what was lagging. According to this study and the available literature, one of the most effective control methods for on-site production is cost control, which is typically managed using specialised software. Moreover, it is arguable that the deep concern and severe attention to managing finances at the site are related to the organisational culture; for example, production control or project performance is more than a mere comparison of completed and expected completion costs of activities. Similarly, in construction projects, managing and controlling participation is essential in all phases of the project life cycle. In general, the work herein suggests that from the stage of conceptualisation to operation, the main factors that make a project successful are the involvement of stakeholders at every stage and their feedback on the project. The client and the authorities should be involved from the initial stages to avoid any hurdles that could hinder the timely and within-budget completion of project goals and objectives.

However, as mentioned in most construction project cases (Chapter 2), project teams often overlook the concepts of value addition and activity flow. It has been observed in the literature and presented in this research thesis that productivity is affected by programme delays. Although the definition of a successful project varies from project to project, successful completion typically demands continuous improvement, collaboration, stakeholder involvement, and effective risk management. For this purpose, if partnering management is encouraged over contractual management, it would be beneficial because each partner will be the stakeholder responsible for the successful completion of the project. Secondly, the conventional and basic theory of project management should be amended to one that encourages the construction of a system as a flow of numerous transformations, resulting in a dynamic and complex system. Meanwhile, in projects where this theory has been established, the adoption of Lean Construction has had a significant impact. Chapter 4 represents the study's outcomes by initially summarising the research and then noting the findings. Afterwards, an integrated framework based on the qualitative study findings is presented, which can serve as guidelines for organisations to utilise Lean Construction techniques and achieve excellence in time, cost, quality, sustainability, and safety management at construction sites. Later, in Chapter 5, after developing the framework, the research transfers to the validation step from the practitioners' point of view. However, the developed TLC framework can align with the project steps and manage overlapping activities based on the type of project. This would increase the project's flexibility, and all issues can also be resolved and reduced using the framework developed and proposed in this thesis.

However, the prior discussion about the key impacts of lean construction techniques, the responsibility of lean construction practices in organisations, the challenges of implementing lean construction techniques, and the results of adopting lean construction have been ranked to compare the variables. This ranking will enable organisations to prioritise their concerns in the decision-making process. The results obtained in this study show a strong positive correlation between factors that inhibit time control and those that inhibit cost control. Moreover, the results are like those of Chang (2002), who stated that categorising the causes of overruns by cost and schedule is not straightforward. Similarly, sustainability and quality assurance are two key project objectives that can be achieved through continuous improvement, requiring input from stakeholders. In the meantime, the RIBA PoW 2020 of Work 2020 recommends evaluating and providing feedback during the post-occupancy phase to identify lessons for future improvement. However, it also considers efficacy as a measure of timeliness, cost variation, and the quantity of finished works as part of Lean Construction implementation. However, it is observed that the reasons behind cost overruns are usually the same as those behind time extensions. This research has focused on reducing inhibiting factors and improving construction performance by integrating the principles of Lean Construction and RIBA PoW 2020. Lean Production has been providing distinct benefits in production by analysing production as both flow and conversion. Therefore, improving flows in construction is the primary objective of Lean Construction, which involves reducing flow activities and effectively creating conversions in the manufacturing sector.

The developed TLC framework provides insight into the concept that everyone should understand their role and the involvement of stakeholders from the strategic definition stage. It is crucial to define the project and its scope, objectives, and goals in the interest of all stakeholders to avoid conflicts and improve coordination. It can also be argued that if stakeholders participate in a project from its inception, achieving its goals will be easier and more streamlined. At the same time, efficiency can be increased through effective risk management, which requires adequate risk assessment from the strategic definition stage through to the in-use stage. An appropriate mitigation plan must be developed and implemented to prevent any hazards at the site, within the budget, and within the specified time horizon. Similarly, at the design stage, it is essential to have all stakeholders on board, including local authorities, designers, and executioners; meanwhile, coordinating all departments involved in the design process is crucial. For this purpose, BIM has proven to be a successful tool; however, it is essential to ensure that all utilities and design departments agree on the final design. It can minimise design changes and reduce the frequency of cost and time overruns. However, at the technical design stage, risk management, value engineering, and lean problem-solving have been observed to be effective in addressing the issues of regulatory compliance, cost control, and detailed design coordination while prioritising safety and quality assurance for the project.

During the construction phase, challenges such as coordination, site restrictions, workforce supervision, safety and schedule management were observed to be solved by collaborative planning, Kaizen, JIT delivery, and strict risk management. These are critical strategies that can ensure the smooth execution of projects without compromising efficiency, quality, and safety. Moreover, during the post-construction or handover and closeout stage, the main problems arise with documentation, commissioning, and occupancy planning, which can be mitigated by adopting lean documentation management, coordinating commissioning, and conducting thorough testing. At the same time, punch list resolution has facilitated smooth occupancy transitions and provided brief training to ensure the project's successful completion. Similarly, for the operational phase, maintenance, occupant satisfaction, service reliability, safety, and sustainability management issues have been addressed through continuous improvement, predictive maintenance, operational optimisation, and the promotion of a safety culture.

Moreover, considering the project's sustainability, there is a deep relation between waste and value. During construction, a substantial amount of waste is generated, posing a challenge to achieving the sustainability goals of any construction project. To achieve complete improvement in lean production, the fundamental procedures should be adopted and understood, including identifying waste streams and then removing them. In this case, waste reduction is driven by improvements focused on eliminating non-value-adding and non-flow activities, thereby making conversion or value-adding activities more efficient.

Through the developed TLC framework in this research work, Lean Construction has presented a new, highly organised method for construction projects. For example, pre-cast concrete structure elements, steel structures, structural insulated panels, movable walls, and raised access floors are substitutes for improvements and waste reduction that are produced off-site, resulting in lower costs and reduced space requirements. Similarly, Lean Construction has imposed numerous positive environmental impacts which should be considered. If the comprehensive plan is disrupted, it will halt the entire project, or it may lead to numerous problems for the subsequent stages of the project life cycle, ultimately increasing the project cost. Moreover, unpredictable delays in logistics, such as material, will cause severe losses in terms of time overrun, extra labour costs, and delayed production. So, the adverse effects of Lean should also be considered. This study focuses on effective coordination that can either bring smoothness or introduce difficulty into the construction process. For example, an unexpected variation in material demand or design, based on the site's specific circumstances, may lead to severe loss and failure of a construction project if not communicated in a timely manner.

While considering the method of interviewing practitioners, it was noted that some were unfamiliar with the LC and RIBA PoW 2020 and its implementation in the construction industry. Those who were aware appreciated the adaptation of TLC frameworks. The results obtained from the interview were positively correlated with the implementation of the LC and RIBA PoW 2020 in construction projects. The participants represented a diverse range of organisations, varying in size, type, and culture. Besides this fact, they all agreed that the TLC framework is easy to understand and implement. It is a practical strategic framework that has driven improved results in the construction sector.

The Crossrail project, however, is the most precise illustration of utilising the TLC framework to fully implement project objectives and minimise roadblocks and barriers that could result in delays and overruns. It used both standards to solve complex problems at various project phases. Crossrail has become a global model for large-scale infrastructure projects by adopting a comprehensive strategy that emphasises efficiency, creativity, sustainability, and teamwork. The project strongly emphasises the value of risk management, strategic planning, ongoing development, and adherence to industry best practices for stakeholder participation across the project life cycle. As Crossrail enters its operational phase, it has demonstrated the transformational potential of effective project management practices in delivering long-lasting infrastructure solutions that support environmental stewardship, strengthen the economy, and meet societal standards. In summary, the two research approaches demonstrate that the LC and RIBA PoW 2020, which combines the concepts of the Lean Construction methodology with the RIBA PoW 2020 framework, helps address issues related to project management, quality control, design flaws, security assurance, and the optimal performance of construction projects. Nonetheless, the Crossrail project has established a standard for completing complex infrastructure projects, as it is a real-world project and tangible evidence of this theory.

Lastly, the primary objective of the integrated LC and RIBA PoW 2020 framework in this research work is to provide a streamlined construction process that offers sustainable, high-quality, cost-effective, and time-efficient outcomes while eliminating waste and non-value-adding activities to enhance the overall construction performance. Therefore, measuring and controlling the time, cost, quality, and sustainability have been proposed and integrated into RIBA PoW 2020 to enable the developed framework to perform comprehensively. Modelling in this research thesis for the developed framework was conducted by incorporating the RIBA PoW 2020 framework to develop measures to mitigate the inhibiting factors and measure performance using time matrix, cost matrix, waste matrix, and performance improvement. Based on the qualitative study findings of this research thesis, an integrated framework could serve as a guideline for contracting and construction organisations to utilise LC techniques, thereby achieving improved processes and results on project sites. Moreover, the research work was conducted on the available literature. The framework was then validated through a case study and interviews with practitioners and professionals to obtain empirical results.

This research study concluded that no single system could encompass all aspects of good project performance in the construction industry. The primary reason for this is that construction projects are inherently complex. Every project differs from others in terms of scope, objectives, stakeholder interest, and expected outcomes. Therefore, managing time, waste, cost, quality, and sustainability-related issues on-site properly, collectively, and effectively is a significant challenge. Hence, a new direction led by the combination of LC and RIBA PoW 2020 has been advocated in this study. The subsequently developed framework will overcome the barriers to implementing the best practices in Waste management, time management, cost management, quality management and sustainability management. This framework recognises the actions that must be undertaken at both- high strategic and site levels to ensure that all the resistances are countered and dealt with. The research validated the framework from the practitioner's viewpoint as it developed this integrated framework. It concluded that it could coordinate the project life cycle, manage activity overlaps, and enhance project flexibility based on project type. Overall, the key issues and problems of the project can be addressed, and their profound impacts can be mitigated by utilising the proposed and developed framework in this research.

6.5 Contributions to Knowledge

This research makes several original contributions to the body of knowledge in construction management, particularly within the context of Lean Construction and project lifecycle planning:

1. **Novel Framework**: The Total Lean Construction (TLC) Framework presents a unique integration of Lean Construction principles with the RIBA Plan of Work 2020. While previous research has explored lean tools or architectural workflows independently, this study offers the first comprehensive synthesis of both. The framework provides a scalable, stage-by-stage roadmap that aligns lean methods with each RIBA phase from strategic definition to in-use addressing efficiency, sustainability, and value creation in parallel. This represents a significant advancement in lean implementation theory and fills a recognised gap in the literature (Salem et al., 2006; Chen et al., 2019).
2. **Empirical Validation**: The research provides empirical evidence supporting the practicality and industry relevance of the TLC Framework. Through expert interviews and the Crossrail case study, the study validates the framework's potential to reduce waste, enhance collaboration, improve cost and time outcomes, and promote sustainability in real-world construction projects.

6.6 Research Limitations

This PhD research has some limitations described below:

(1) The lack of relevant literature poses a significant challenge to this research study.

(2) The intended target population for interviews was initially set at 25 individuals. However, due to challenges from a lack of accessibility or awareness within the target demographic, only nineteen individuals were successfully interviewed to validate the proposed framework.

(3) The scholarship funding for this research project ended in June 2023, and the author has faced financial difficulties.

6.7 Recommendations for Future Research

While this study has established the potential benefits of the TLC framework, further research is necessary to explore its broader applicability and refine its integration with Lean Construction principles. The following areas are proposed for future research, with a focus on how they can be approached and why they are important for advancing the field:

1. **Further Validation of the TLC Framework Across Distinct Types and Sizes of Construction Projects**
    - **What can be done**: Conduct additional studies that apply the TLC framework to various construction projects, varying in scale, type (e.g., residential, commercial, infrastructure), and geographical location.
    - **How**: Utilise quantitative and qualitative methods, including case studies, interviews with project stakeholders, and performance data analysis, to evaluate the framework's performance under various project conditions.
    - **Why**: Validating the framework across different types of projects will help identify its strengths and limitations, enabling improvements and broader adoption in various sectors of the construction industry.
2. **Exploration of Additional Lean Construction Techniques and Their Integration into the Framework**
    - **What can be done**: Investigate other Lean Construction techniques not currently integrated into the TLC framework, such as Last Planner System, Value Stream Mapping, or Kaizen.
    - **How**: Conduct a literature review and case studies on projects where these techniques have been successfully implemented, followed by experimentation to integrate them into the TLC framework.
    - **Why**: Expanding the TLC framework to incorporate additional Lean techniques could enhance its adaptability and effectiveness in a broader range of project environments, thereby improving overall performance.
3. **Longitudinal Studies to Assess the Long-Term Impact of the TLC Framework on Project Outcomes**
    - **What can be done**: Conduct longitudinal studies that track the long-term effects of implementing the TLC framework on project outcomes such as cost savings, time efficiency, stakeholder satisfaction, and quality improvement.
    - **How**: Collect data from projects implementing the TLC framework over multiple years, utilising direct observations and secondary data (e.g., project reports, KPIs, performance metrics).
    - **Why**: Long-term studies will provide valuable insights into the sustained impact of the TLC framework, including its potential to create lasting improvements in project delivery and its broader influence on industry practices.

4. **Development of Training Programs and Tools to Facilitate the Implementation of the TLC Framework in Construction Projects**

- **What can be done**: Design and develop specialised training programs, workshops, and digital tools to help project managers, contractors, and other stakeholders effectively implement the TLC framework.
- **How**: Collaborate with industry professionals to create hands-on training modules, webinars, and online resources focusing on practical implementation and overcoming challenges when adopting the framework.
- **Why**: Training programs and tools are essential for ensuring stakeholders understand how to apply the TLC framework in practice, ultimately promoting smoother integration and more effective outcomes.

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Appendix 1: Ethics Application Form

This form was submitted and approved for research ethics application for this PhD research.

1. Title of the investigation
A Total Lean Construction Framework
Please state the title on the PIS and Consent Form, if different:

2. Chief Investigator (must be at least a Grade 7 member of staff or equivalent)
Name: Andrew Agapiou ☐ Professor ☐ ☒ Reader ☐ Senior Lecturer ☐ ☐ Lecturer Senior Teaching Fellow Teaching Fellow Department: Architecture Telephone: +44 (0)141 548 3067 E-mail: andrew.agapiou@strath.ac.uk

3. Other Strathclyde investigator(s)
Name: Mohamed Atweijeer Status (e.g. lecturer, post-/undergraduate): (e.g. lecturer, post-/undergraduate): Postgraduate PhD Researcher Department: Architecture Telephone: 00447841770355 E-mail: mohamed.a-tweijeer@strath.ac.uk

4. non-Strathclyde collaborating investigator(s) (where applicable)
Name: N/A Status (e.g. lecturer, post-/undergraduate): N/A Department/Institution: N/A If student(s), name of supervisor: N/A Telephone: N/A E-mail: N/A Please provide details for all investigators involved in the study: N/A

5. Overseas Supervisor(s) (where applicable)
Name(s): N/A Status: N/A Department/Institution: N/A Telephone: N/A

Email: N/A I can confirm that the local supervisor has obtained a copy of the Code of Practice:☐ ☐ Yes No Please provide details for all supervisors involved in the study: N/A

6. Location of the investigation
At what place(s) will the investigation be conducted The study will be conducted with academics and professionals working in the construction industry in the public and private sectors in the UK
If this is not on the University of Strathclyde premises, how have you satisfied that adequate Health and Safety arrangements are in place to prevent injury or harm?

7. Duration of the investigation
Duration(years/months): 60 Days Start date (expected): 12 / 08 / 2023. Completion date (expected): 12 / 10 / 2023.

8. Sponsor

Please note that this is not the funder; for a definition and the sponsor's key responsibilities, refer to Section C and Annexes 1 and 3 of the Code of Practice.

Will the sponsor be the University of Strathclyde?

Yes ☒ No ☐ If not, please specify who is the sponsor: N/A.

9. Funding body or proposed funding body (if applicable)
Name of funding body: Libyan Ministry of Higher Education, Missions Sector represented by the Academic Attaché of the Libyan Embassy in London ☐ Status of proposal – if seeking funding (please ☐ click appropriate box): In preparation ☐ Submitted Accepted Date of submission of proposal: N/A Date of start of funding: N/A

10. Ethical issues
Describe the main ethical issues and how you propose to address them: The investigation involves human participation, but no personal or sensitive information will be requested. The identity of all participants will be kept anonymous.

11. Objectives of investigation (including the academic rationale and justification for the investigation): Please use plain English.
In the construction industry, lean construction has gained significant attention among practitioners seeking to reduce waste, increase cost efficiency, and meet client needs. Related research has focused on examining how the principles and techniques of lean construction can be systematically integrated into construction project delivery across work stages. The academic rationale for this study is based on a review of relevant literature, which summarises the conclusions from the review, identifies gaps in knowledge, and highlights inconclusive or contradictory findings. The justification for this research is that there are barriers facing the complete implantation of lean construction in the construction

industry, and the integration framework with the RIBA plan of work (2020) might help to solve these barriers.

12. Participants
Please detail the nature of the participants: Academics and professionals Summarise the number and age (range) of each group of participants: Number: 20-30 Age (range) 30-60 Please detail any inclusion/exclusion criteria and any further screening procedures to be used: N/A

13. Nature of the participants Investigations governed by the Code of Practice involving any participants listed in B1(b) must be submitted to the University Ethics Committee (UEC) rather than DEC/SEC for approval.
Do any participants fall into a category listed in Section B1(b) (participant considerations) applicable to this investigation? ☐ Yes ☒ No If yes, please provide details of which category (and submit this application to the UEC): N/A.

14. Method of recruitment

Describe the recruitment method (see Section B4 of the Code of Practice), providing information on any payments, expenses or other incentives.

Participants who express interest in participating in the interviews will be contacted via email and provided with a sample recruitment/advertisement email. The email will explain the purpose of the study, the interview process, and the incentives or payments (if any) for participation.

The online interviews will be recorded after the participant approves. However, detailed notes will be taken during the interviews, and the transcripts will be securely stored. The University's guidelines on data management and storage will manage the data.

A sample recruitment/advertisement email is provided below:

I am conducting a research study on **A Total Lean Construction Framework**

This study's purpose is to validate the framework. Your participation will help us gain insights into the challenges and opportunities of implementing this framework in the construction industry.

If you are interested in participating in an interview, please reply to this email, and I will contact you via email to schedule a convenient time. The interview will take 45-60 minutes to complete.

Thank you for considering this invitation. If you have any questions or concerns, please do not hesitate to contact me.

One website might use it to find experts and academics in the construction sector for interviews. Find the website below:

Academics and professionals will be interviewed via telephone, Skype, and Zoom, as well as face-to-face.

15. Participant consent

Please state the groups from whom consent/assent will be sought (refer to the Guidance Document). The PIS and Consent Form(s) should be attached to this application form.

In terms of interview consent, interviewees will receive a consent form via email to sign before the interview.

16. Methodology Investigations governed by the Code of Practice involving any project listed in B1(a) must be submitted to the University Ethics Committee rather than DEC/SEC for approval. The interviews will be recorded to ensure accurate data analysis and reference purposes. However, ensuring the confidentiality and privacy of the participants' information is crucial. The participant will be informed about the recording and obtain their consent beforehand. This will be done by including a consent statement at the beginning of the interview and explaining how the recordings will be used and stored. The recordings will be securely stored on password-protected devices.
Are any categories mentioned in the Code of Practice Section B1(a) (project considerations) applicable in this investigation?☐ Yes ☒ No If ‘yes’, please provide details: N/A.
Describe the research methodology and procedure, providing a timeline of activities where possible. Please use plain English. This research aims to use interviews with academics and professionals. To validate the developed framework.
What specific techniques will be employed, and what exactly is asked of the participants? Please identify any non-validated scale or measure and include any scale and measure charts in an appendix to this application. Please include questionnaires, interview schedules or any other non-standardised data collection method as appendices to this application. The interview samples form is attached to this form.
Where an independent reviewer is not used, the UEC, DEC or SEC reserves the right to scrutinise the methodology. Has this methodology been subject to independent scrutiny? ☐ ☒ Yes No If yes, please provide the name and contact details of the independent reviewer: N/A

17. Previous experience of the investigator(s) with the procedures involved. Experience should demonstrate an ability to conduct the proposed research in accordance with the written methodology.
The PhD Candidate Mohamed Atweijeer has successful experience in conducting a survey in Libya as a part of his master’s degree research.

18. Data collection, storage, and security
How and where is data managed? Please specify whether it will be fully anonymous (i.e. the identity unknown even to the researchers) or pseudo-anonymised (i.e. the raw data is anonymised and given a code name, with the key for code names being stored in a separate location from the raw data) - if neither please justify.
The data will be collected online and/or via telephone for the surveys and interviews that will be anonymous. Explain how and where it will be stored, who has access to it, how long it will be stored and whether it will be securely destroyed after use:
All the data will be kept and saved on the researcher's university drive, and it will be backed up and saved on the OneDrive account from the university. The data does not have any personal information that requires it to be destroyed after use.

Will anyone other than the named investigators have access to the data? Yes ☐ No ☒

If 'yes', please explain:

19. Potential risks or hazards
Briefly describe the potential Occupational Health and Safety (OHS) hazards and risks associated with the investigation: The interviews will be conducted via internet with academics and professionals working in construction industry in public and private sector in the UK. There are no potential risks or hazards. for participants, as participants will not provide any information that may identify themselves.
Please attach a completed erisk Assessment for the research. Further Guidance on Risk Assessment and Form can be obtained on Occupational Health, Safety and Wellbeing's webpages

20. What method will you use to communicate the outcomes and any additional relevant details of the study to the participants?

The transcription process will be done manually or with the help of transcription software. Manual transcription will be used by listening to the interview recordings and transcribing them verbatim. Transcribers can type out the transcript using word processing software, ensuring proper formatting and labelling. However, Transcription software might also be used to automate the transcription process. This software is listed below: Transcriptor is transcription software that uses speech recognition technology to convert audio into text. Ols also uses speech recognition technology to convert audio into text. Temi.com: This automated transcription software uses artificial intelligence to transcribe audio and video files into text. Data Handling: Once the interview transcripts are obtained, the data will be managed securely and confidentially. Sharing the Study's Outcome with Participants will be under request.

21. How will the study's outcomes be disseminated (e.g. will you seek to publish the results and, if relevant, how will you protect the identities of your participants in said dissemination)?
The research outcomes will be a core part of the PhD thesis by Mohamed Atweijeer and a journal article with his supervisors. As participants will not provide any information that may identify them, there are no potential risks to their participation.

Checklist	**Enclosed**	**N/A**
Participant Information Sheet(s)	☒	☐
Consent Form(s)	☒	☐
Sample questionnaire(s)	☐	☐
Sample interview format(s)	☒	☐
Sample advertisement(s)	☐	☒
OHS Risk Assessment (S20)	☒	
Any other documents (please specify below)	☐	☒
	☐	☒
	☐	☒
	☐	☐
	☐	☐

22. Chief Investigator and Head of Department Declaration

Please note that unsigned applications are not accepted, and both signatures are required.

I have read the University's Code of Practice on Investigations Involving Human Beings and have completed this application accordingly. By signing below, I acknowledge that I am aware of and accept my responsibilities as Chief Investigator under Clauses 3.11 – 3.13 of the Research Governance Framework and that this investigation cannot proceed until all required approvals have been obtained.

Signature of Chief Investigator 

Please also type your name here: Andrew Agapiou.

I confirm I have read this application; I am happy that the study is consistent with departmental strategy, that the staff and/or students involved have the appropriate expertise to undertake the study and that adequate arrangements are in place to supervise any students that might be acting as investigators, that the study has access to the resources needed to conduct the proposed research successfully, and that there are no other departmental-specific issues relating to the study of which I am aware.

Signature of Head of Department

Please also type your name here : Prof. Tim Sharpe

Date: / / 8/8/23

23. Only for University sponsored projects under the remit of the DEC/SEC, with no external funding and no NHS involvement

Head of Department statement on Sponsorship

This application requires the University to sponsor the investigation. The Head of the Department does this for all DEC applications except those that are externally funded and those connected to the NHS (those exceptions should be submitted to RandKES). I am aware of the implications of university sponsorship of the investigation and have assessed this investigation concerning sponsorship and management risk. As this investigation is within the remit of the DEC and has no external funding and no NHS involvement, I agree on behalf of the University that the University is the appropriate sponsor of the investigation and that the investigation poses no management risks. If not applicable, tick here.☐

Signature of Head of Department

Please also type your name here : Prof. Tim Sharpe.

Date: / / 8/8/23

For applications to the University Ethics Committee, the completed form should be sent to ethics@strath.ac.uk with the relevant electronic signatures.

24. Insurance
The questionnaire below must be completed and included in your submission to the UEC/DEC/SEC:

Is the proposed research an investigation or a series of investigations conducted on any person for a Medicinal Purpose? Medicinal Purpose means: • treating or preventing disease or diagnosing disease or • ascertaining the existence, degree of, or extent of a physiological condition or • assisting with or altering in any way the process of conception or • investigating or participating in methods of contraception or • inducing anaesthesia or • otherwise preventing or interfering with the regular operation of a physiological function or • altering the administration of prescribed medication.	Yes / No N/A

If "**Yes**", please go to **Section A (Clinical Trials)** – all questions must be completed.

If "**No**", please go to **Section B (Public Liability)** – all questions must be completed.

Section A (Clinical Trials)

Does the proposed research involve subjects who are either: i. under the age of 5 years at the time of the trial. ii. known to be pregnant at the time of the trial.	Yes / No

*If "**Yes**", the UEC should refer to Finance.*

Is the proposed research limited to: iii. Questionnaires, interviews, psychological activity including CBT. iv. Venepuncture (withdrawal of blood). Muscle biopsy. Measurements or monitoring of physiological processes, including scanning. vii. Collections of body secretions by non-invasive methods.	Yes / No

viii. Intake of foods or nutrients or diet variation (excluding drug administration).	

If" No", the UEC should refer to Finance

Will the proposed research take place within the UK?	Yes / No Yes

*If "**No**", the UEC should refer to Finance*

Title of Research		
Chief Investigator		
Sponsoring Organisation	University of Strathclyde	
Does the proposed research involve:		
a) investigating or participating in methods of contraception?		No
b) Can you assist with or alter the process of conception?		No
c) the use of drugs?		No
d) What is the use of surgery (other than biopsy)?		No
e) genetic engineering?		No
f) participants under 5 years of age (other than activities I-vi above)?		No
g) participants known to be pregnant (other than activities I-vi above)?		No
h) Is the pharmaceutical product/appliance designed or manufactured by the institution?		No
i) work outside the United Kingdom?		No

If you **say "YES" to any question A**, please complete the **Employee Activity Form** (attached). If **you say "YES" to any of the questions a-I** and this is a follow-on phase, please provide details of SUSARs on a separate sheet.

*If "**Yes**" to any of the questions a-I, then the UEC/DEC/SEC should refer to Finance (insuranceservices@strath.ac.uk).*

Section B (Public Liability)	
Does the proposed research involve:	
a) Aircraft or any aerial device	No
b) Hovercraft or any water borne craft	No
c) Ionising radiation	No
d) Asbestos	No
e) Participantsunder 5 years of age	No
f) Participantsknown to be pregnant	No
g) Pharmaceutical product/appliance designed or manufactured by the institution?	No
h) Work outside the United Kingdom?	No

*If **"YES"** to any of the questions, the UEC/DEC/SEC should refer to Finance (insurance-services@strath.ac.uk).*

For NHS applications only - Employee Activity Form

Has NHS Indemnity been provided?	N/A
Are Medical Practitioners involved in the project?	N/A
If YES, will Medical Practitioners be covered by the MDU or another body?	N/A

This section aims to identify the staff involved, their employment contract and the extent of their involvement in the research (in some cases, it may be more appropriate to refer to a group of persons rather than individuals).

Chief Investigator		
Name	**Employer**	**NHS Honorary Contract?**

		Yes / No
Others		
Name	**Employer**	**NHS Honorary Contract?**
		Yes / No
		Yes / No
		Yes / No
		Yes / No

Please provide any further relevant information here:

Appendix 2: Participant Information Sheet

[FOR USE WITH STANDARD PRIVACY NOTICE FOR RESEARCH PARTICIPANTS]

Name of Department: Architecture

Title of the Study: A Total Lean Construction Framework

Introduction

You are kindly invited to participate in research conducted by **Mohamed Atweijeer**, PhD Candidate at the University of Strathclyde. It is essential to comprehensively understand the main reason for conducting the current research before deciding whether you will participate. Please take the time to read the following information about the study. **The interviews will be recorded to ensure accurate data analysis and reference purposes.**

What is the purpose of this research?

This research aims to validate an integration framework between Lean construction and "RIBA PoW 2020." This framework can potentially help construction project managers improve their construction management performance.

Do you have to take part?

Participation in this study is entirely voluntary, and you can withdraw without giving a reason. As you will not provide any information that may identify you, there are no potential risks from your participation.

What will you do in the project?

These interviews will be conducted, and your answers will provide information about your Lean construction experience. Your responses will be used in this research to validate the framework that will assist Lean integration with "RIBA PoW 2020". The interview will take 45-60 minutes to complete.

Why have you been invited to take part?

You have been invited to participate in this research because you are currently working in UK universities or the construction industry. Your experience is significant in improving the performance of construction management.

Who will have access to the information? Only the investigators will have access to the information collected during the research.

Where will the information be stored, and how long will it be kept?

The information will be kept on the University cloud during the whole period of the research.

What happens next?

If you want to learn more about the research or have any questions, please contact the researcher. Please note that you will be asked to consent before starting the interview whether or not you are agreeable to participate. Thank you for your attention and time spent reading this information sheet.

If you would like to receive feedback and know more about the completed research outcomes, please email me your contact details.

Researchers contact details:

Name: Mohamed Atweijeer, PhD Candidate

Phone No: +44 (0)7841770355

Email: mohamed.atweijeer@strath.ac.uk

Address: Department of Architecture, School of Engineering, University of Strathclyde, James Weir Building, Glasgow, G1 1XJ, UK

Appendix 3: Consent Form

Name of department: Architecture

Title of the study: A Total Lean Construction Framework

- I confirm that I have read and understood the Participant Information Sheet for the above project, and the researcher has answered any queries to my satisfaction.
- I confirm that I have read and understood the Privacy Notice for Participants in Research Projects and understand how my personal information will be used and what will happen to it (i.e. how it will be stored and for how long).
- I understand that my participation is voluntary and that I can withdraw from the project at any time, up to completion, without giving a reason or consequences.
- I understand that I can request the withdrawal from the study of some personal information and that researchers will comply with my request whenever possible. This includes the following personal data: audio recordings of interviews identifying me and my personal information from transcripts.
- I understand that anonymised data (i.e. data that do not identify me personally) cannot be withdrawn once included in the study.
- I understand that any information recorded in the research will remain confidential, and no information identifying me will be made publicly available. ▪ I consent to being a participant in the project.
- I consent to being audio recorded as part of the project.
- I consent to remain anonymous in the final research papers.

(PRINT NAME)	
Signature of Participant:	Date:

Appendix 4: Semi-Structured Interview Questions

The Validation of a Total Lean Construction Framework

This interview is part of PhD research aimed at validating the TLC Framework. The primary goal of this research is to develop and validate a comprehensive framework that integrates Lean Construction (LC) principles and techniques with the RIBA Plan of Work (PoW) 2020. The main objective is to facilitate the adoption of lean construction principles in construction project delivery. Three specific research objectives have been identified:

(1) ***To Identify and Map Integration Points:*** Conduct a critical literature review highlighting the necessity and relevance of integrating Lean Construction principles with the RIBA PoW 2020. Identify and map the integration points between Lean Construction principles and the RIBA stages by analysing both Lean Construction techniques and the RIBA Plan of Work

(2) ***To Develop the TLC Framework:*** The Total Lean Construction TLC Framework overlays lean construction principles onto the RIBA PoW 2020. This framework will aim to improve efficiency across the project life cycle.

(3) ***To Validate the TLC framework*****:** Assess the effectiveness of the TLC framework through empirical research, including interviews with industry professionals and a particular case study. This validation process will ensure that the framework is practical, effective, and aligns with the goals of improving construction processes and efficiency.

This research employs various carefully chosen methods to fulfil its objectives, including a literature review, framework development, interviews, and case studies. The findings from this research will contribute to the body of knowledge in construction project management and support the practical implementation of lean construction principles. Consequently, the following interview questions are structured into three main parts, including twenty-two questions:

Part A: Designed to gather general information. (*5 questions*).

Part B: Investigate the participants' knowledge of lean construction and the RIBA work plan. (*2 questions*).

Part C focuses on validating the TLC Framework. Levels **and** validating the framework according to the predefined criteria, including value, contents, design, applicability, effectiveness, and suitability. (*15 questions*)

Part A: General information

(Please tick [✓] the appropriate response)

Q1 What is your academic or professional qualification?

- Diploma
- Bachelor
- Master
- Doctorate
- Other (Please specify) ___________

Q2 How many years of experience do you have in the construction industry?

- Less than 5
- 5-10
- 11-15
- 16-20
- More than 20
- Other (Please specify) _________

Q3 What is your current professional position?

- Project manager
- Site manager
- Training project manager
- Site supervisor
- Civil engineer
- Other (Please specify) _________

Q4 Please indicate the number of employees in your organisation.

- Less than 10
- 10 – 50
- 50 -250
- More than 250
- Other (Please specify) _________

Q5 What size of projects does your company mainly engage in?

- Less than £2 million
- £2 – 10 million
- £10 - 50 million
- More than £50 million

Part B: Knowledge of Lean construction and "RIBA PoW 2020".

Q6 Are you aware of the principles and techniques of lean construction (LC)?

Q7 Are you aware of the RIBA plan of work 2020 principles and techniques?

Part C: TLC Framework

Q 8 Can you describe your experience with Lean Construction and RIBA PoW 2020?

Q9 How do you think the TLC Framework can enhance the performance of construction project management?

Q10 In your opinion, what are the significant risks of time and cost overruns in construction projects, and how can the TLC Framework help mitigate these risks?

Q11 How do you think the TLC Framework can be used to facilitate the adoption of lean construction principles in construction project delivery?

Q 12 Can you provide examples of how the TLC Framework can be used to measure task performance?

Q13 How do you think the TLC Framework can be improved to address the challenges faced in construction project management?

Q14 How do you think the TLC Framework can be applied to achieve sustainable delivery of construction projects?

Q15 In your opinion, what ethical considerations need to be considered when implementing the TLC Framework?

Q16 How do you think the TLC Framework can be adapted to meet the specific needs of different construction projects?

Q17 What are the potential limitations of the TLC framework, and how can these limitations be addressed?

Q18 Is the framework easy to understand and use?

Q19 Are the framework components well defined?

Q20 Is the framework well designed?

Q21 Does the framework demonstrate an effective procedure for integrating lean construction and the RIBA PoW 2020?

Q22 Could you please provide any necessary recommendations to improve the proposed TLC framework?

Thank you for taking the time to participate in this interview and share your valuable insights. We appreciate your contribution.

Name: Mohamed Atweijeer, PhD Candidate
Phone No: +44 (0)7841770355
Email: mohamed.atweijeer@strath.ac.uk
Address: Department of Architecture, School of Engineering, University of Strathclyde, James Weir Building, Glasgow, G1 1XJ, UK