University of Pretoria

Barriers to the Implementation of Lean Construction in South Africa

by

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Declaration

I, Yvonne Leonie Jacobs, hereby confirm that the attached treatise is my own work and that any sources are adequately acknowledged in the text and listed in the bibliography.

I accept the rules of the University of Pretoria and the consequences of transgressing them.

This treatise is submitted in partial fulfilment of the requirements for the degree of PhD (Construction Management) at the University of Pretoria. It has not been submitted before for any other degree or examination at any other University.

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ABSTRACT

This study aimed to identify the barriers to the implementation of Lean construction practices faced by practitioners in the South African construction industry.

A literature review was carried out on the barriers present in the construction industry in South Africa, and elsewhere in the world. A survey was sent to practitioners in the Construction Project Management and Construction Management professions in South Africa. The data collected was used to determine if barriers found elsewhere in the world are also prevalent in the South African context. The data was also used to establish if barriers unique to the South African construction industry existed.

The most prevalent barriers elsewhere in the world were organised under five themes, namely organisational, environmental, labour/workforce, material, and exogenous barriers. Barriers under all five categories were found in the South African construction industry. Barriers unique to the South African Construction industry were identified.

These barriers include lack of skills, unrealistic CPG targets imposed on government contracts, community and business forum involvement, presence of construction mafia, lack of knowledge in management SMME's on construction projects, and client retaining authority of key responsibilities of the Principal Agent. These issues create barriers to the implementation of Lean construction practices as they hinder the flow on projects and do not contribute to the focus on value mapping and creation for the end user.

To overcome the identified barriers, institutions need to move away from the traditional transformational view of construction processes and linear view of the construction program.

This study benefits stakeholders in the South African construction industry by informing business models and current practices to be more adapted to the successful implementation of lean construction practices. The research also benefits educational institutions, built environment councils and government policymakers to inform them of the barriers which can be overcome by shifts in existing policies.

Keywords: Lean construction, barriers, South Africa, Construction Management

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ACRONYMS AND ABBREVIATIONS

BIM	Building Information Modelling
BPE	Building Performance Evaluation
CAD	Computer Aided Design
CBA	Choosing-By-Advantages
CCS	Candy Construction Software
CDE	Common Data Environments
CI	Continuous improvement
CIDB	Construction Industry Development Board
COVID	Coronavirus disease
CPD	continuous professional development
CPG	Contract Participation Goals
CPM	Critical Path Method
CWs	Causes of waste
DOR	Digital Obeya Room
EBIT	Engineering, Built Environment and Information Technology
ECSA	Engineering Council of South Africa
EOT	Extension of time
FEM	Federated Employers Mutual
GBCSA	Green Building Council South Africa
GDP	Gross Domestic Product
GFCF	Gross Fixed Capital Formation
IGLC	International Group for Lean Construction
JIT	Just-in-Time
LBMS	Location Based Management System
LC	Lean Construction
LEI	Lean Enterprise Institute
LPDS	Lean Project Delivery System
LPS	Last Planner System
LSPP	Lean Subcontracting Procurement Process
NDP	National Development Plan
NPP	New Production Philosophy
NVAA	Non-value-adding activity
PBR	Performance Based Requirements
PDCA	Plan-Do-Check-Act
PMBOK®	Project Management Body of Knowledge

POE	Post Occupancy Evaluation
PPC	Per cent Plan Complete
Pr. CM	Professional Construction Manager
Pr. CPM	Professional Construction Project Manager
QA	Quality Assurance
QFD	Quality Function Deployment
ROI	Return on Investment
RPL	Recognition of Prior Learning
SACPCMP	South African Council for the Project and Construction Management Professions
SAICE	The South African Institution of Civil Engineering
SME	Small and midsize enterprises
SMME	Small, medium and micro enterprises
TFV	Transformation, Flow, Value Generation
TQM	Total Quality Management
US	United States (of America)
VE	Value Engineering
VM	Value Management
VSM	Value Stream Mapping
WIP	Work in progress

TERMS AND DEFINITIONS

Built environment – the functional domain in which construction project managers and construction managers practice.

Centralised - concentrate the control of an activity under a single authority.

Civil engineering construction industry - an industry that is involved with the construction of both natural and physically built environments such as roads, railways, buildings, water reservoirs, airports, bridges, sewer systems, tunnels, and dams.

Construction industry - a sector of the national economy engaged in preparation of land and construction, alteration, and repair of infrastructure.

Construction Industry Development Board (South Africa) - a schedule 3a public entity established to lead construction industry stakeholders in construction development.

Construction management – the management of the physical construction processes within the built environment including the coordination, administration, and management of resources.

Construction program – the program of construction works which indicate the logic sequence and duration of all activities to be completed as part of the defined construction project.

Construction project - the organised undertaking to complete a specific set of predetermined objectives for the construction, repair, improvement, or expansion of infrastructure as described in the scope of work for the project.

Construction project management – the management of projects within the built environment from conception to completion, including management of related professional services.

Contractor – the entity entering into a contract with the client for execution of the works or part of the works.

Conversion activity - the process of converting raw materials, components, or parts into finished goods.

COP21 agreement – Also known as the Paris agreement, which aims to strengthen the global response to the threat of climate change by keeping a global temperature rise this century below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius.

Decentralised - to move the control of an activity away from a single authority to other locations, usually granting them some degree of autonomy.

Gross Fixed Capital Formation - the net increase in physical assets (investment minus disposals) within a measurement period.

Iron triangle - a metaphor pointing out that the construction project manager is asked to reach a reasonable trade-off amongst various concurrent, heterogeneous, and visible constraints. These constraints are traditionally defined as “cost”, “time” and “scope”.

Just-in-time manufacturing - a production method aimed at aligning raw-material orders from suppliers directly with production schedules, just before the material is needed.

Kanban method - a Lean method to manage and improve work across human systems by balancing demands with available capacity. This is sometimes achieved by introducing constraints into the system to balance process flow.

Last planner system - a collaborative planning process that involves trade foremen or design team leaders (the last planners) in planning in greater and greater detail as the time for the work to be done gets closer.

Muda - a Japanese word meaning wastefulness - a key concept in Lean process thinking.

New Production Philosophy - the view that the production process consists of both “flow” and “conversion” processes. (As opposed to the Traditional Production Philosophy in which the production process is viewed as a conversion process only).

Obeya Room - a Japanese word meaning “large room” which denotes a collaboration space.

Per cent plan complete - the percentage of completed planned activities (completed activities divided by number of activities)

Prefabrication - manufacturing sections of a structure or object in a factory and transporting it to the construction site for assembly.

Project – the total effort envisaged by the client, including all professional services.

Return on investment - the ratio between net profit and cost of investment resulting.

Reverse logistics - process of planning, implementing, and controlling the efficient flow of materials from the point of consumption to the point of origin for the purpose of recapturing value.

Suppliers – an entity appointed by a client to supply material and products for incorporation into the works.

Value-adding activity - any activity that adds value to the customer and meets the three criteria for a value-added activity (the step transforms the item towards completion, the step is done right the first time, the customer cares (or would pay) for the step to be done).

Waste - an act or instance of using or expending something to no purpose.

Work in progress (WIP) - raw materials, labour, and overhead costs of products still in various stages of the production process.

Works – all work carried out or planned to be carried out in accordance with the construction contract.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Following the successful implementation of Lean production principles known as the “New production Philosophy” (NPP) in the United States (US) automobile manufacturing industry, Koskela (1992) wrote a technical report detailing the application of the NPP to the construction industry.

This report compared the traditional model of construction processes with traditional manufacturing processes. In traditional manufacturing, processes were seen as “conversion type” processes, whereas in the new production philosophy, these processes were considered to consist of both “flow” and “conversion” activities. Seeing that only the result of conversion processes adds value to the product, conversion activities or processes need to be as efficient as possible while the processes identified as “flow” activities should be made as short as possible or altogether eliminated. This change in processes would increase overall efficiency.

Koskela’s argument in this seminal report (Koskela:1992) was that a similar shift in how processes are seen is necessary in the construction industry. According to the report, the industry needed to shift from its own traditional view of construction processes as conversion processes to the “conversion / flow” view was necessary. The same principles of eliminating or shortening the wasteful “flow” activities (as in the NPP) could then be applied to construction activities to increase efficiency.

These early thoughts on the application of Lean principles to construction management challenged the industry’s paradigm that time, cost and scope are at a continuous trade-off with each other.

After Lean production became widely adopted in the manufacturing sector, some of the changes implemented in the manufacturing industry made their way into how construction teams operated, and how projects were executed, and the benefits were widely documented. However, there has been little response to Lean construction implementation in the South African construction industry; an industry that forms a substantial share of the country’s gross fixed capital formation (GFCF).

The Construction Monitor: Supply and Demand focuses on the Register of Contractors in all Classes of Works public sector supply and demand at national and provincial levels and deals primarily with the General Building (GB) and Construction Engineering (CE) Construction Industry Development Board (CIDB) Classes of Works.

According to the Construction Monitor Quarterly report (CIDB, 2023:3), the South African construction sector's average contribution to GFCP was only 14.5% of the GDP.

The National Development Plan (NDP) has set a goal to increase the GFCP to 30% of the GDP by the year 2030 (NPC:2012). From these numbers, improved efficiency in the construction sector would have a substantial impact on the South African economy. On an industry level, increased efficiency and return on investment (ROI) on projects could lead to business growth despite the dire present state of the construction industry.

As Lean construction principles involve the elimination of waste (especially within processes) and the creation of continuous flow, the implantation of these principles in the South African construction industry could improve efficiency, reduce waste, and have a direct impact on ROI of construction projects.

The implementation of Lean construction practices could further help to offset the impact of the shortage of skills in the labour market by increasing overall efficiency. This is especially important in the South African context, as the country has a chronic skills constraint. The pressure of this constraint could increase inequality and provide incentives to firms to further substitute labour for capital (mechanical means). This would ultimately undermine the competitiveness of South African firms (World Bank, 2018:34). While the implementation of Lean construction contributes directly to the successful delivery of construction projects, the greater benefit is ensuring the best practices in the construction industry (Sarhan, Xia, Fawzia *et al.*, 2018). The question then, is why are South African construction companies not embracing Lean practices, but still widely operating according to the traditional view of construction as a conversion activity?

The lag in the implementation of Lean practices is not unique to the South African context. Since Koskela's (1992) ground-breaking report, a great deal of research has been conducted on the topic of Lean construction in various industries in all parts of the world. Even though the benefits of incorporating Lean construction principles have been widely published, there is still a lag in the adoption of Lean practices. Research regarding the lag in implementation in various countries was published with the acknowledgement of the existence of barriers to successful implementation. Given the low rate of implementation of Lean practices in the South African industry, it is possible that similar barriers to implementation are also present locally.

To date, limited research has been conducted about the barriers to the implementation of Lean construction practices in the South African civil engineering construction industry. Expanding the knowledge of existing barriers to Lean implementation in the South African context is important because the South African construction industry needs an overhaul from the traditional management practices.

The industry plays a pivotal role in South Africa's economic development and is also a large-scale provider of employment opportunities. The implementation of Lean construction practices could enable construction firms in the sector to be more profitable, which would lead to not only growth of the sector but also further economic development for South Africa.

1.2 PROBLEM STATEMENT, AIM AND OBJECTIVES

1.2.1 Research Problem

From the literature available on the implementation of Lean construction practices around the world, there is clear evidence that implementation of these practices leads to improved efficiency in the execution of construction projects, which in turn leads to improved performance of stakeholders in these projects. However, despite the evident benefits of Lean construction practices, companies around the world have been slow to implement them. Koskela (1993:51) noted relatively soon after the publication of this ground-breaking application of the NPP on construction that barriers to the implementation of Lean construction practices existed.

Since the publication on the general barriers to the implementation of Lean Construction practices, further research on barriers present in specific countries was published. Since 2005, research has been conducted on the barriers in the construction industry of numerous countries.

The most prevalent barriers can be organised under the themes of Organisational, Environmental, Labour / Workforce and Exogenous elements which create barriers to the implementation of Lean construction practices.

A tendency to revert to traditional construction management practices instead of implementing Lean practices is also cited as a barrier in several countries, together with the perceived failure of construction managers and other stakeholders to internalise the concepts of Lean production from the point of view of construction practices.

Little information is available on the barriers to the implementation of Lean practices in the construction industry in South Africa. One paper was presented on the drivers and barriers of Lean construction practice in South Africa (Aigbavboa *et al.*, 2016:195) in 2016, but the research, although acknowledging the existence of barriers to implementation, consisted of a small sample population within the South African construction industry. This research study will address the deficiency in the information available on barriers to Lean construction implementation affecting the South African civil engineering construction industry.

The problem statement is as follows:

What are the main barriers to the implementation of Lean construction practices in the South African construction industry?

1.2.2 Research Aim and Objectives

The aim of this study is to provide insight to a modified Lean construction model for the South African context. The insights gained from this study would inform stakeholders in the construction industry on how to adapt current business models, practices, and policies to eliminate some of the barriers in current implementation practices, leading to more efficient execution of projects.

The research objectives are to identify the barriers to the implementation of Lean construction practices present in the South African construction industry and to propose a model of Lean construction that would be more suitable in the South African context.

The research objectives can be summarised as follows:

1. To conduct a review of the existing literature on the barriers to implementation of Lean practices in the construction industry.
2. To determine which barriers are specific to the South African construction industry through questionnaires distributed to practitioners within the industry.
3. To collect data on the barriers present in the South African construction industry.
4. To analyse data collected in order to rank the barriers present in the South African context.
5. To propose guidelines of Lean construction practices that would be more suitable in the South African context.

Stakeholders in the South African construction industry would benefit from this identification as it could inform policy and business models to be adapted to overcome these barriers and enable the implementation of Lean practices. Academics interested in Lean construction would benefit from this research as it will contribute knowledge to the field of Lean construction.

1.2.3 Research Questions

The associated research questions are as follows:

1. Which barriers to the implementation of Lean construction practices have already been identified in other countries?

2. Which barriers to the implementation of Lean construction practices are prevalent in the South African construction industry?

3. Are there barriers to the implementation of Lean construction practices that are unique to the South African context?

4. How would the current forms of Lean construction practices have to be modified in the South African context to overcome the existing barriers?

1.3 DELIMITATIONS TO THE SCOPE OF THIS RESEARCH

This study is intended to investigate the barriers to the implementation of Lean construction practices in the South African construction industry.

The survey respondents will be limited to construction management professionals who have work experience in the South African construction industry. To be classified construction management professionals, respondents need to be registered with the South African Council for the Project and Construction Management Professions (SACPCMP, 2024) in either of the following two categories:

- Professional Construction Manager (Pr. CM).
- Professional Construction Project Manager (Pr. CPM).

The reason that these categories were selected is that persons registered with this body need to have a relevant qualification in a construction-related field combined with at least five years' relevant experience in construction management to be eligible to register. Further to this, individuals need to keep their registrations current and earn continuous professional development (CPD) credits over a five-year cycle to stay eligible to be registered.

The survey questionnaires will be distributed only to individuals registered in these categories with the assistance of the SACPCMP (2024).

The study is not intended to differentiate the barriers unique to a certain South African construction discipline, but rather to identify the barriers present in the construction industry in South Africa.

1.4 ASSUMPTIONS

It was assumed that individuals responding to the survey would by nature of the SACPCMP (2024) registration regulations have already had some exposure to elements of Lean construction practices during their employment.

The assumption was made that all respondents were truthful in their survey question responses. Measures were taken to assure respondents that their responses would be kept confidential to encourage honest responses.

1.5 IMPORTANCE OF THE STUDY

This study is important, as it would contribute to the knowledge base of Lean construction in the South African context. The research will be important for all stakeholders in the South African construction industry. On a practical level, it could lead to an understanding of the barriers in the way of implementing Lean construction practices and reaping the benefits of this. Further to this, policymakers would find this research helpful in that it could highlight barriers which could be lowered by modest policy changes.

This research will also be important on a theoretical level for academics and educators interested in Lean construction practices.

CHAPTER 2: RESEARCH METHODOLOGY

2.1 INTRODUCTION

In order to collect insight into the barriers to the implementation of Lean construction practices in South Africa, data on existing barriers elsewhere as well as data on elements creating barriers in the South African context were required.

The first step in this research process was to review the literature available on barriers to the implementation of Lean construction practices .

Following the literature review, data on the presence of barriers in the South African industry was collected using survey questionnaires. Data collected was coded and the results analysed to establish whether barriers unique to the South African industry were present.

This process is illustrated in Figure 2.1.

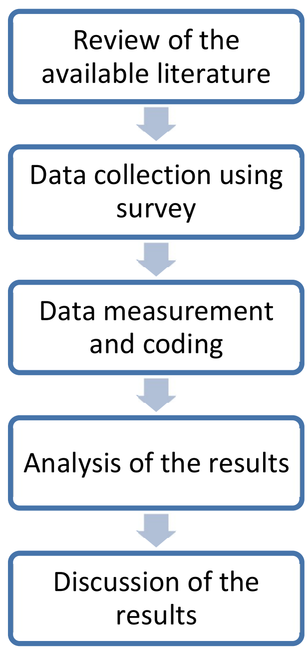

Figure 2.1 Research Process (Source: Author's own)

2.2 RESEARCH DESIGN

According to Hart (1999), the purpose of the literature review is to show command of the subject area, understanding of the problem and to justify the research topic, design and methodology. This is the aim of the literature review in this research study.

Following the literature review, a survey questionnaire was developed and sent to respondents. The objective of the questionnaire was to gather primary data on the barriers to the implementation of Lean construction practices present in the South African civil engineering construction sector. The questionnaire was in the form of a highly structured questionnaire with minimal open-ended questions to allow for quantitative analysis to be done. According to Fellows and Liu (2015), quantitative approaches relate to positivism and seek to gather factual data, to study relationships between facts and how such facts and relationships accord with theories and findings of any research executed previously. Data was collected and analysed for relationships between variables.

Bradburn *et al.* (2004) highlighted the importance of critically assessing the language used in the questions to avoid asking threatening questions where the respondent feels like there is a correct or incorrect answer. Further to this, the use of closed-ended questions might result in many people grouping responses under the “other” category which would be detrimental to the analysis of the results. The questionnaires was critically evaluated for the use of threatening or biased language. As information garnered from the literature review formed the basis for the options on most of the questions, care was taken to make sure that the review was carried out with the necessary diligence.

Pilot survey questionnaires were sent to see if any adjustment needs to be made on the response options. Questions were kept short and to the point to avoid misinterpretation by respondents.

Some open-ended questions were asked, because unique answers can come from them. According to Bradburn *et al.* (2004), researchers commonly make the mistake of paying much attention to the common answers to an open-ended question while not paying enough attention to the unique answers to these questions. In the case of this research study, the unique answers would prove valuable for future research in this area and a separate section of the results will be dedicated to this element.

2.3 METHODOLOGY

2.3.1 Introduction

The literature review was be conducted using the documents available about the implementation of Lean construction. Sources used for review were books, academic journals, reports, conference papers and news articles. According to Hart (1999:17), a high-quality literature review contains a thorough review of the relevant literature; systematically analysed and all main variables and arguments identified. This research study required a rigorous study of the available literature to ensure that the correct questions were included in the survey questionnaire.

2.3.2 Research Instrument

A survey questionnaire containing mostly closed-ended questions was developed. The answer options for the closed-ended questions were based on the results of an in-depth review of the available literature about the implementation of Lean construction practices. Care was taken to avoid loaded questions and the questionnaire was critically assessed for signs of bias. Some closed questions pertained to the respondents' agreement or disagreement with a statement. In these cases, Likert rating scale was used to present five responses ranging from "completely agree" to "completely disagree" in order to collect a more nuanced response than "yes" or "no" responses. Some open-ended questions were included in the questionnaire. The reason for the addition of some open-ended questions was to add richness to survey results that are difficult to achieve with closed-ended questions (Krosnick & Presser 2009:8). Special attention was given to the unique answers given by respondents on these types of questions, as these answers might supply significant insight on barriers exclusive to the South African construction industry as well as supplying significant starting points for future research about barriers to the implementation of Lean construction in the South African context. The questionnaire was sent to a pilot group of five respondents chosen by means of selective sampling from a known group of individuals registered with the SACPCMP (2024). From the feedback received by the pilot group respondents, the wording and structure of the questionnaire were slightly adjusted to be more user-friendly.

For the main study, a purposive sample method was selected as data needed to be collected from respondents with specific background and experience in the South African construction industry. According to Etikan *et al.* (2016:2) describe this type of sampling as the deliberate choice of a participant due to the qualities that the participant possesses.

The survey population consisted of individuals registered with the SACPCMP (2024).

The population was chosen because this study requires the feedback of individuals who have experience in working as construction project management practitioners in the South African construction industry and a purposive sample could be obtained from this population. Individuals registered with the SACPCMP (2024) as Professional Construction Managers (Pr. CM) and Professional Construction Project Managers (Pr. CPM) have already been screened and have been confirmed by the Council as possessing the necessary knowledge and experience in working as a construction management professional in the South African context.

The criteria for registration as a Pr. CM or Pr. CPM with the SACPCMP (2024) are as follows:

- An accredited honours degree in a Built Environment field of study with a minimum of four years' post-graduate relevant experience.
- An accredited B-Tech qualification in the Built Environment field of study with a minimum of five years' post-graduate relevant experience.
- An accredited National Higher Diploma in the Built Environment field of study with a minimum of six years' post-graduate relevant experience.
- An accredited National Diploma in the Built Environment field of study with a minimum of seven years' post-graduate relevant experience.

Applicants who possess the required combination of qualifications and experience, apply by sending their application forms with two project reports listing successes and failures encountered within the 10 project management areas, as listed in the Project Management Body of Knowledge Guide® (PMBOK Guide®) on their chosen project. The submissions are assessed and if the minimum score is achieved, applicants are invited to a professional interview in front of a panel of experts.

For applicants wishing to register as Pr. CM, the following skills are verified:

- Technical competency
- Competency in coordinating construction processes
- Understanding of construction contracts
- Knowledge of the SACPCMP scope of services (Work stages 1 to 6 – Project initiation to Close-out)
- General presentation and maturity as construction manager.

For applicants wishing to register as Pr. CPM, the following skills are verified:

- Technical competency
- Competency in acting as principal agent
- Competency in acting as principal consultant
- Knowledge of the SACPCMP scope of services (Work stages 1 to 6 – Project initiation to Close-out)
- General presentation and maturity as construction manager,

In cases where candidates do not possess a qualification and have more than ten years' relevant experience, the SACPCMP has a Recognition of Prior Learning route (RPL) which can be followed (SACPCMP, 2024).

Further information on the identification of work reserved for a registered Construction Project Manager and Construction Manager, the competencies that these individuals are required to have mastered to be registered, and their involvement over the six defined project stages are contained in the Appendices to further elaborate on specific demonstrated knowledge and experience that the respondents are assumed to have based on their successful professional registration status.

Using this population for the survey on barriers to the implementation of Lean construction practices in South Africa, ensured that the correct population, individuals with experience and knowledge of the project and construction management areas and scope of services were targeted. This ensured that the questionnaire was sent to the correct profile of individual with the necessary knowledge and experience of construction project management and application in the South African construction industry.

The questionnaire was sent to the council representative responsible for educational matters, who sent it to all individuals registered as Pr. CM or Pr. CPM listed on their database. It should be noted that the SACPCMP's other categories of registration such as Candidate Construction or Construction Project Managers and Construction (SACPCMP, 2024) or individuals registered in the Occupational Health and Safety categories were excluded from the request to participate in the questionnaire.

2.4 LIMITATIONS

There were three significant limitations to this study which may be addressed in future research on this subject.

The first limitation was the lack of previous research on the barriers to the implementation of Lean construction in South Africa. Limited literature on the barriers present in the South African construction industry was available. To overcome this limitation, the study was designed to investigate barriers present in other countries and establish whether these barriers were also present in the South African industry.

The second limitation was the randomness of the sample. Due to the topic of the research, participant bias might have be present as some participants might have been more interested to participate in the survey than others in the pool (Bradburn et al., 2004:157).

This bias would possibly exist in the population surveyed and the possible impact on the results was considered. The respondents might not have been a random sample, as they would possibly have responded because they had strong feelings on the subject or had experiences which might not necessarily be representative of the South African construction industry professionals' general experience.

This constraint was mitigated by also searching for registered individuals on the LinkedIn platform and asking them via direct messages to respond to the questionnaire that they received via the SACPCMP link (SACPCMP, 2024). This assisted in obtaining a wider range of respondents, and not only relying on respondents who had a special interest or specific experience that they wished to respond to by using the survey. In this process, responses from respondents who would not normally respond to a survey unprompted, were also included in the sample.

The third limitation on the study was the sample size. Because of the size of the population (3600 registered persons), there existed a risk of not receiving an adequate number of responses to represent a suitable sample size, which could be regarded as representative of the surveyed population, and from which a statistical result could be generated. The number of responses was monitored and when it was found that not enough responses were coming in, registered construction professionals were contacted via the LinkedIn platform and requested to complete the link to the survey provided by the SACPCMP. This approach was implemented successfully, and the number of responses was increased to an acceptable number to be statistically analysed.

2.5 ETHICAL CONSIDERATIONS

During this research study, care was taken to comply with legal and ethical regulations as documented in the University of Pretoria's Code of Ethics for Scholarly Activities and the Policy and Procedures for Responsible Research. Written permission was obtained before the data collection process was initiated. A copy of the ethical clearance letter can be found in Annexure A of this document.

Care was taken not to include any personal questions in the research survey questionnaire. Participants were not questioned as informants on a specific firm or institution, but rather about their personal experience and views about barriers to the implementation of Lean construction practices in the industry. The population surveyed consisted only of individuals older than 18 years and thus no additional consent was required.

Participants were recruited via email through the SACPCMP mailing list of professionally registered individuals. The questionnaire was supplied to the SACPCMP education officer according to their standard procedure for requesting participation in verified research. Their standard procedure includes verifying that ethical clearance has been obtained before they send a request to individuals on their database. No contact information was supplied to the researcher directly, and the questionnaire did not contain any request for identifiable information such as identity or telephone numbers.

To ensure that information was handled in a confidential manner, study codes instead of identifiable information were used on all data documents. All documents were encrypted and stored in a password-protected electronic file. No hard copies were produced by the researcher during the data capturing phase. Electronic data was encrypted and stored in a password-protected electronic file. The data will be stored for a period of 10 years from the date of capturing.

Care was taken to inform questionnaire respondents that their participation in the survey was voluntary. The survey was set up in such a way that the first page contained an informed consent form which requested participants to indicate that their participation is voluntary, and that they can withdraw their participation at any time during or after the study. Participants were also provided with a copy of their completed survey afterwards. Participants were not rewarded or reimbursed for participating in the survey.

Participants were asked to answer questions regarding their perceptions of the barriers present in the South African construction industry; specifically barriers hindering the implementation of Lean construction practices. The questionnaire was structured to gain data on the participants' knowledge and opinions on Lean practices, the participants' use of said practices, as well as reasons why some of the known practices are not utilised.

An assessment regarding the risks associated with this project were carried out and it was found that the project does not pose more than a minimal risk to participants. Participants were informed that no risks were identified, but also no concrete benefits of participation in the research, other than adding to the body of knowledge area of Lean construction practices implementation in the context of the South African construction industry were identified.

The study did not require any further approval of formal permissions. No confidentiality clauses were necessary. The study was assessed to not have any environmental impact.

CHAPTER 3: LITERATURE REVIEW

3.1 BACKGROUND

Lean construction is the overarching term used to refer to a project-based production philosophy as found in the construction industry.

Koskela (1992) published a seminal report in which a new production philosophy, which originated from the manufacturing industry, could be adopted for the construction industry. He stated that instead of the traditional way of modelling construction processes as conversion activities (value-adding) only, construction should instead be regarded as flow processes. Flow processes contain both conversion (value-adding) and waste (non-value-adding) activities. Examples of waste activities are waiting, storing inventory, moving material and inspection.

According to Koskela (1992:65), construction has traditionally tried to improve competitiveness by making conversion activities incrementally more efficient. However, if waste activities are also identified and eliminated as far as possible, dramatic improvements could be realised.

Koskela later refined this theory on the new production system into the "Transformation, Flow, Value Generation (TFV) theory of production". This theory identified three interdependent elements to production. These elements are as follows (Koskela *et al,* 2007):

- Transformation-oriented elements (T) (achieved by applying resources such as workers and machines)
- Materials-oriented elements (F) (flow of materials or information) through various means)
- Customer-oriented elements (V) (value generation and creation through elimination of value loss).

Abdelhamid *et al.* (2008:8) summarised the development of the TFV theory as an integration of the effective qualities of the Craft, Mass and Lean production paradigms as well as the inclusion of the value management perspective. According to these authors, this tripartite view of production has led to the birth of Lean construction as practice. An important result of the TFV theory of production is that it shifts the definition of construction management to the careful allocation of resources to transform raw materials into infrastructure while maximising the flow of materials and information, and value to the customer. Ballard and

Howell (2004:38) expanded on Koskela's work by defining the Lean construction project as "a temporary production system dedicated to the three goals of delivering the product, while maximising value and minimising waste".

Putting Lean construction theories into practice could be highly beneficial to construction companies looking for a competitive advantage and to improve their efficiency. Companies in the South African construction industry, where profit margins are already under pressure, could benefit from not only relying on improved production levels to increase performance levels. The relationship between Lean construction and company performance will be discussed in greater detail in the following subsection.

3.2 BENEFITS OF LEAN CONSTRUCTION IMPLEMENTATION

3.2.1 Implementation of lean thinking

Koskela *et al.* (2002:3) extended the TFV conceptualisation to the engineering process and stated that the conventional view of engineering design is also transformational. Koskela *et al.* (2002:3) write that in viewing the engineering tasks as transformational tasks, significant features such as the customer and time are abstracted out of the conceptualisation. Thus, if the focus is on the transformation part, process and cooperation - two significant elements within the project - are not considered. This conventional management view thus leads to engineering projects becoming inefficient and ineffective (Koskela *et al.,* 2002:3). It is important because of all the benefits that implementation of these practices have proven to show:

Koskela (1992) discusses the new production philosophy that stresses the importance of basic theories and principles related to production processes rather than new technology.

According to Koskela *et al.* (2002:8) solutions based on the "flow" method renders these processes more effective as they require a schedule prepared based on ordered tasks with the task execution being controlled by using the Last Planner System (LPS). This results in a process that is more disciplined than a process that is managed by solely using the conventional management style.

Koskela *et al.* (2002:10) concedes that efforts to make project processes more transparent and structured from a value perspective are not new. The performance approach, aimed at making the critical first phases of value generation explicit in a construction project, has been developing since the 1980s. In this sense, performance is measured as the degree to which the product matches the client's requirements for the project. This approach thus focuses on what the product is supposed to do rather than the process of getting to the product.

The value approach in the sense of actively generating value through value creation or prevention of value loss, has however not penetrated the construction industry, save for some experimental projects (Koskela *et al.,* 2002:10). From the above, it can be concluded that poor management of the value aspect of a project leads in many ways to poor performance.

Lean thinking's focus on value (both reduction in value destruction and increase of value creation). Within Lean thinking, value creation is not only cost (waste) reduction. Value is created when internal waste is reduced, but value is also created when additional features or services valued by the customer are added. Examples of these features are shorter delivery cycle or smaller delivery batches (Hines *et al.,* 2004:5).

Shaqour (2021:3) classifies the benefits of Lean construction implementation into three main groups, namely environmental, economic and social benefits to the construction project. An overview of the findings related to studies about the benefits of Lean construction classed according to these groups will follow in the following subsections.

3.2.2 Environmental benefits

Ghosh *et al.* (2014) examined the environmental benefits of the use of Lean construction and found that using Lean tools resulted in a significant decrease in material waste and production hours which in turn reduced greenhouse gas emissions, waste generation and the total overall energy use of the project observed in their case study.

Huovila and Koskela (1998:8) illustrate the TFV model's convergence to the sustainability objective of construction by illuminating the waste elimination (F) will minimise resource depletion and will generate value to the customer (V) in matching business and environmental excellence.

Lean construction tools can be beneficial to promote sustainable construction practices on both the level of project execution and the use of the product. However, Lean construction practices do not automatically mean reduced environmental impact. Lean is a systemic approach to meeting the customer's values whatever they value (Bae & Kim 2008:313). Lean can contribute to sustainability, but only when the customer values sustainability.

Therefore, the client's requirements regarding the required level of sustainability need to be included in the project requirements, as value is created in this instance if the client values sustainability.

3.2.3 Economic benefits

Lean construction implementation brings about many economic benefits, whether it is profit that increases due to improved productivity, or losses which decrease due to elimination of resource waste.

Improved process control

Lean construction practices enhance the work processes to more “sound” controlled processes which are sequenced in a manner that promotes the flow of activity and takes into consideration possible invisible sources of waste.

Improved planning

Lean construction is a useful tool to increase the reliability of planned work. The LPS, which will be elaborated on in Section 3.3, has proven to be a beneficial tool in improving workflow and reliability of planned work.

Time reduction

Lean construction practices are about transforming raw materials into a finished project while reducing waste and generating value for the customer. On a construction project, time is of the essence - both for the contractor, who has overhead costs associated with the construction activities, and for the customer, who has an opportunity cost associated with any more time than planned spent to complete the project. By having more controlled procedures in place and focusing on these three elements, variability and predictability of the process is increased.

Improved productivity

By increasing the reliability of processes and reducing waste, Lean construction practices as a result improves productivity during all phases of the project lifecycle. Increased productivity results in a lower unit cost of activities.

Improved safety

According to Bajjou *et al.* (2017a:179), the processes inherent in construction activity (fluctuating non-standard processes) increase the likelihood of accidents occurring. According to them, improving site safety performance, such as decreasing the number of accidents and incidents, is an example of waste reduction. Lean construction practices have the indirect effect of reducing safety risks and incidents created by unreliability of workflows or worker capacity being exceeded. Various researchers have mentioned the effect that a more controlled environment can have, not only on the workers' physical environment, but also on their psychological state and focus.

Amid the Coronavirus disease 2019 (COVID-19) pandemic, it was difficult to collaborate on a project when face-to-face meetings were prohibited, or the possibility fluctuated according to governmental and organisational guidelines to keep personnel safe. One of the core elements of Lean construction practices is collaboration across stakeholder teams using available technology. As such, collaboration can still take place while the health risk of face-to-face meetings or site visits are significantly reduced.

Improved quality

It is widely accepted that the quality of a construction product is the degree to which it adheres to the client's performance requirements. The notion of "Performance" will be further elaborated upon in Section 3.4. Lean construction practices are aimed at attaining the required performance levels by continuous improvement practices. Many auxiliary tools exist that can be used to enhance quality management.

Improved prediction of risk

Improved predictability of processes brought about by Lean construction practices means improved predictability of risk events. By improving predictability, the owner of the risk item can more efficiently plan for mitigation measures.

Minimisation / reduction in rework

Reduction of rework is part of the waste reduction element of Lean construction practices - the foundation of the Flow element in Koskela's TFV model. When one thinks of rework, the first theme that comes to mind is the physical demolition and rebuilding of execution phase elements that have been deemed substandard during monitoring and control activities. However, rework also encompasses any repetition of effort during all phases of the project, such as design changes required by the client and design changes due to errors made by the design team. Dave and Koskela (2009:no pagination) take the notion of rework further to include organisations generating waste by "reinventing the wheel" on every new project that they embark on. They argue that Lean construction tools can be used to improve construction companies' knowledge management practices which would enable the organisations to better capture and reuse existing knowledge.

3.2.4 Social benefits

Enhanced transparency

Brady *et al.* (2018) found that using the Lean construction management model improves transparency between the project planning, execution and control interfaces. The model's visual management tools aid in maintaining consistency between the different levels of planning so that a feasible execution stage is created and focus more on prevention than correction from a control aspect. Better transparency on a project leads to more effective communication, sound process orientation and minimisation of waste.

<u>Improved communication</u>

According to Howell (1999:no pagination) the construction project is in essence an uncertain set of workflows, and uncertainty in workflow places great demand on communication channels as stakeholders attempt to keep the work moving forward in the face of uncertainty. The Lean construction management model encourages focus on collaboration as a tool to facilitate the flow of information using digital collaboration tools such as cloud-based software. Some of the platforms make the sending of emails obsolete and removes the burden of two-way communication of information from the stakeholders, as all information is uploaded to the system and is accessible to all stakeholders. The added benefit of the ability for improved decision-making by all project stakeholders is generated by improved communication flow.

In addition to the facilitation of information sharing between stakeholders, information sharing among individuals in the same work team can also be done more efficiently. As mentioned previously, Dave and Koskela (2009:no pagination), in their linkage of Lean construction collaboration tools to improving knowledge management, have also highlighted that these tools could improve the transfer of tacit knowledge within the organisation, which could improve institutional knowledge and overall effectiveness and continuous improvement of the organisation.

<u>Continuous improvement</u>

According to Aziz and Hafez (2013:682) dramatic project level improvements could be realised if Lean construction practices are implemented correctly. If leadership commitment to Lean practices is present, a culture of continuous improvement is created and this culture, in turn, can sustain the Lean construction practices.

<u>Enhanced collaboration and reduced conflict</u>

Within the Lean construction management model, a project team needs to establish a common goal and a jointly developed project culture in order to attain the goals of Lean construction, namely, to deliver the project while maximising value and minimising waste.

Lean construction calls for collaboration at least amongst the key participants of the project. Participants of collaboration know that not everything is remedied by contract (Schöttle *et al.*, 2014:1270). On projects where collaboration between stakeholders is high, conflict is reduced, and trust is created.

<u>Customer satisfaction</u>

By implementing Lean construction practices, value is maximised for the customer and care is taken so that the activities flow in such a way that all customer requirements are met.

"Customer" in this sense does not only mean the "client" on the construction project stakeholder's team. Koskela *et al.* (2019:1384), in their discussion of total quality management, one of the tools of Lean construction practices, indicates that any work stage has a customer, the next stage (with the final stage being the delivery of the completed project to the final customer. Koskela *et al.* (2019) refer to ontological views about the work process here, where work is described as arriving at one stage, changing state, and then moving on to the next stage, until the product is achieved. In this view, if continuous improvement is applied to production, each stage works with the product of the preceding stage towards quality that the end customer can boast about.

According to Akinradewo *et al.* (2018) the implementation of Lean construction would be important to reduce waste and to enhance the overall South African construction industry's performance. The results of their study into the perceived benefits of implementing Lean construction practices in South Africa showed that the construction professionals interviewed agree that the implementation of Lean is beneficial, although it is not specified in their study why Lean construction is not systematically implemented in the South African construction industry if the professionals agree that the widely accepted benefits are also applicable in the South African context

According to Statistics South Africa's (StatsSA) GDP report for the first quarter of 2021 (StatsSA, 2021), although the construction industry only has a nominal share of 3.1% of the GDP, the industry is responsible for 7.2% of the employment share.

In September 2020, the South African government published their 25-year National Infrastructure Plan (South Africa, 2020) which details, amongst others, more than 150 infrastructure projects packaged within 18 Strategic Integrated Projects which, if rolled out as planned, will have an enormous impact on the country's economy. This plan forms a critical part of the government's plan for economic recovery and growth.

While the economic and social benefits of Lean construction implementation in the South African construction industry is clear, the benefits in terms of improved health and safety also need to be considered.

According to the South African National Institute for Occupational Health, the construction industry is usually one of the three industries with the highest risk of work-related injuries. The statistics available from the Federated Employers Mutual (FEM) Assurance Company shown in Table 3.1, reveal that an average of 2.4% of the workforce in the subsections has been affected by an injury for which the cost was claimed from FEM. Between 2013 and September 2023, 77 624 accidents were reported, of which 690 were fatal.

Table 3.1 FEM Statistics – Selected building trades subcategories (Source: FEM, 2023)

Year	Accident Frequency	Number of Employees	Number of Accidents	Fatal Accidents	Average cost per Accident	Total cost of Accidents
2013	2.75%	302 429	8 307	91	R32 689	R246 292 026
2014	2.60%	320 046	8 311	60	R27 505	R256 681 104
2015	2.61%	311 251	8 112	66	R80 808	R313 804 907
2016	2.39%	342 379	8 180	78	R58 092	R316 727 367
2017	2.43%	328 535	7 996	86	R71 259	R364 139 111
2018	2.49%	320 550	7 991	64	R34 812	R344 261 903
2019	2.52%	295 504	7 451	61	R43 470	R323 385 672
2020	2.11%	260 910	5 495	48	R86 849	R326 133 544
2021	2.41%	259 455	6 258	57	R41 768	R291 349 157
2022	2.10%	264 379	5 556	43	R61 319	R327 955 551
2023*	1.69%	235 071	3 967	36	R78 103	R326 430 236
Total	**2.40%**	**3 240 509**	**77 624**	**690**	**R616 674**	**R3 437 160 578**

***As of September 2023**

These figures only include injuries that resulted in claims by the employer to the FEM and do not include injuries not reported to the FEM, lost time injuries and other minor injuries and incidents.

In an industry that is widely accepted to be dangerous, underperforming, ineffective and unproductive, the implementation of Lean construction management practices by stakeholders operating within the industry could make a significant difference in the product that the government is aiming for. On an organisational level, the economic benefits brought about by Lean construction practices would assist in the sustainability and growth of organisations operating in the industry, which in turn leads to employment creation and skills development, a key driver of the economy.

3.3 THE FLOW CONCEPT IN LEAN CONSTRUCTION

3.3.1 Introduction

In the previous section, the overarching benefits of the proposed Lean construction model consisting of TFV, were established. In this section, the concept of “flow” within the framework of the Lean construction management model will be elaborated upon.

The “flow” concept was first proposed by Koskela (1992) in his report on the application of the New (Lean) Production Philosophy to construction. While the report included various concepts fundamental to the development of the theory of Lean construction, this section will focus on how the flow concept was developed within the Lean construction framework. The extent of this report and Koskela’s further contributions to the development of a theory of Lean construction will be discussed in detail in Chapter 4, when the theoretical framework is set out.

In introducing the “flow” concept, Koskela (1992) proposed that the traditional “activity” or “conversion” view of construction needs to be reconsidered. This view assumes that a construction project consists of a set of activities where raw material and labour are transformed into the final product. Many costing models are based on this view, where the project is divided into its elements (material and labour) and the cost of transforming these elements into the final product is calculated.

Koskela (1992) however, argued that in the conversion view, all the activities are viewed as value-adding while the non-value-adding activities are ignored. Even though the non-value-adding activities create waste, cost and time are not accounted for when using traditional models.

The concept of “waste” within the Lean construction philosophy will be further discussed in Section 3.5, but for the purpose of this introduction it is sufficient to keep in mind that Koskela identified waste activities as the non-value-adding activities, for example waiting, storing inventory, moving material and inspection.

As the waste is “invisible”, it cannot be managed and often adds to the inefficiencies and loss of production on the project. To remedy this, the traditional construction management view is that production needs to be optimised to manage that which can be managed; thus the conversion processes need to be as efficient as possible. Koskela (1992) argues that while managers should endeavour to optimise conversion activities, the simultaneous minimisation of waste activities is also required to reach optimal project performance. If the view of the construction project is changed from “activity” or “conversion” to a view of the processes as “flow” (consisting of both conversion and waste activities), managers will be able to realise dramatic improvements on projects.

Huovila and Koskela (1998:8/) describes engineering and production from the flow view as a flow of information, composed of conversion, inspection, moving and waiting. The main principles of this view of production are the elimination of waste (non-conversion activities) and time reduction of the activity. In a practical sense, the concept of flow is taking care that unnecessary actions are minimised as far as possible.

When thinking about flow processes, the flow of information from one project team member to another can form part of the value-adding activities or the waste activities depending on the efficiency of the information flow. Tribelsky and Sacks (2011) found a positive correlation between the quality of information flow at the design stage of a construction project and the effectiveness of the design documentation.

Pourzolfaghar and Ibrahim (2014:174) studied the effect of adding knowledge flow to the design workflow activities and found that specifying the required knowledge for the next activity explicitly would reduce cost and time overruns on projects. The reason for this is that the design phase, especially the concept development stage, is a tacit knowledge-dominated phase, where individuals rely on tacit knowledge to produce their specialised designs. If there are novice team members in the design team, rework might be required if the designer who passed on his portion of the work does not realise that the designer receiving the work does not have the required knowledge to continue the workflow process.

Dave and Koskela (2009:no pagination) studied the benefits of Lean construction management practices to transfer of tacit knowledge between team members. Although they mainly discussed the transfer of tacit knowledge to build up institutional knowledge, they also found that in creating a knowledge framework where the flow of knowledge is explicitly indicated, time and cost due to rework on a project can be greatly reduced.

Further to the call for information flow to be made more explicit, or at least considered when the design development is taking place, Al Hattab and Hamzeh (2017) proposed that information flow should not only be considered at task transformation level (process level), but also on a social level, where the interaction of team members and the actual exchange of information is carefully considered. Through Lean practices, team members (whether it be designers from different organisations working on a project or designers within the same organisation) can collaborate more efficiently by improving the quality and efficiency of information flows.

If one considers traditional methods of scheduling project tasks, a Gantt chart listing the work breakdown structure for each activity within the project, including an indication of the critical path comes to mind. While this type of scheduling can be used effectively to manage the projected production on site, it still assumes the traditional transformation view and ignores the non-transformation activities.

Various tools have been developed to adapt planning activities to the flow perspective (including both transformation / value-adding and waste / non-value-adding activities).

3.3.2 Flow Planning tools

Location Based Management System (LBMS)

Uusitalo *et al.* (2017:111) explain the LBMS as a management system for planning and controlling construction projects by providing continuous workflow to crews. The system comprises two elements, namely a location-based planning system and a location-based control system. The system's goal is to schedule work in such a way that crews can mobilise once and complete all work of the same type in a specific location. Continuous flow is created by aligning production rates to the time available for each activity. This system has many similarities to the critical path method (CPM), except that in the CPM there is a focus on shortening durations of activities to shorten the overall timeline, while in LBMS there is a greater focus on grouping similar tasks together as a continuous activity.

Value Stream Mapping (VSM)

Value stream mapping (VSM) is a tool that was developed to reduce non-value-adding activities on the project by identifying the value stream. This tool originated in the manufacturing sector, but many case studies have illustrated that this tool is useful in the construction sector to promote Lean construction practices by visualising the flow of work.

Desai and Shelat (2014) describe the purpose of VSM as the quantification and communication of production process characteristics such as material and information flow as well as non-value-adding activities. The process has two elements, namely "current state mapping" and "future state mapping". In the first element (current state map), the existing project processes are mapped to create a clear picture and to identify waste. This map would reveal both value-adding and non-value-adding activities in the process. In the second element (future state map), the focus is to link the value stream into a smooth flow and to eliminate waste. This would create the ideal scenario of the project execution activities where every process is connected to a customer by either continuous flow or a pull system.

Simonsson *et al.* (2012) performed two case studies on non-repetitive construction projects (bridge construction) and confirmed the potential savings that could be achieved by enabling site management staff to visualise the workflow, and as a result of this, make changes to improve flow. Various other case studies have been performed which all conclude that value stream mapping is an excellent tool to use in Lean construction management practices to improve performance.

Last Planner System (LPS)

The LPS was developed by Ballard and Howell in 1998 (Koskela 1999: 251). Ballard wanted to develop a set of tools that workers at the production level can use to proactively control work and the flow that links the work assignments together. According to Ballard (2000), the LPS refers to that individual who will be deciding what actual work will be done on site on an operational level. Last planners are thus mostly construction foremen, site managers or team leaders. At the design stage, the last planner would be the design lead.

It is important to note that LPS is a production control system supporting Lean project planning and execution. The system consists of four parts that work together with the plan getting more detailed as the work to be done gets closer. In this system, the plans and schedules are produced in collaboration with those who will do the work (or who decide what activities will be done), to reduce or eliminate constraints that pose a threat to the reliability of the schedule and lastly to continuously improve processes as the work progresses. This eliminates a situation where the work is planned out by the project's planning specialist, a detailed construction schedule produced and sent to site, and the programme being abandoned as soon as the first signs of slippage occurs.

According to the Lean Construction Institute, the Last Planner System planning cycle consists of four phases, namely the master schedule (covering the complete project), a detailed phase schedule (produced during collaborative planning sessions), a look-ahead plan (including constraint analysis), and a weekly work plan (including measured per cent plan complete (PPC)). Using this system of planning ensures that those responsible for the execution of the work are involved with the details and ensures that the more detailed planning takes place at a more appropriate time of the project (that is, closer to when the work needs to be done when most of the project variables associated with the unknowns are not present anymore at that stage).

Figure 3.1 shows a diagrammatic representation of the LPS, where the front-end planning of the project starts with the compilation of a master schedule or programme and the planning getting more detailed and shifting to the site as the planning horizon decreases.

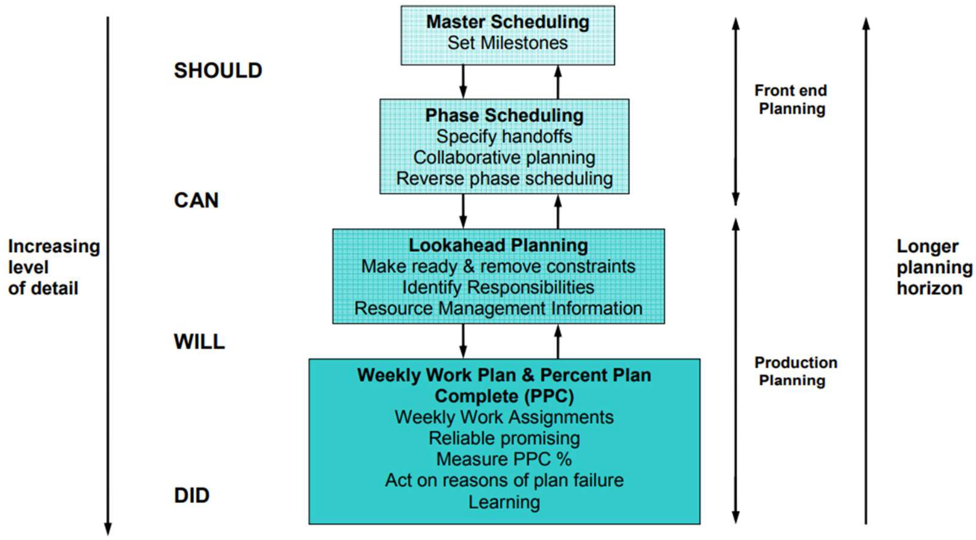

Figure 3.1 The Last Planner Planning Cycle (LCI, 2007:2)

The LPS technique is an important system that, if correctly implemented, could support the implementation of Lean construction practices on projects. Cho and Ballard (2011), in their survey of Lean projects using last planner methods, found a significant correlation between the implementation of the LPS and project performance. This system proved that it could enhance construction management practices by reducing dependencies and variations to identify and eliminate waste (non-value-adding activities) (Aziz & Hafez, 2013: 680).

There are numerous software applications and other online collaboration tools available in the market to create the planning schematics produced within the LPS. As with the compilation of the master planning schedules, the quality of the information generated by utilising the software would be on the same level as the quality of the information that was loaded. In terms of the look-ahead phases of the system, a spreadsheet program (such as Microsoft Excel) can be used with great success if the person inputting the information understands the underlying principles.

For clarity, Koskela (1999) set out the five basic principles of a successful LPS as follows:

1. Work assignments should be sound regarding their prerequisites or “The Complete Kit” (Work should not start unless all items for completion of the activity are available).
2. Work assignment realisation should be measured and monitored (Measured by PPC). The focus on work realisation reduces the risk of variability to downstream flows and tasks).

3. Investigate causes of non-realisation of work and eliminate those causes (Through this, continuous in-process improvement is done).
4. Maintain a buffer of tasks for each crew (If the assigned task is impossible to carry out, the crew can switch to the buffer task. This is instrumental to avoid lost production due to no alternative tasks available).
5. Ensure that the prerequisites of the upcoming activities (three to four weeks' look-ahead) are actively made ready in the look-ahead planning (this will create a "pull" system and ensure that the site does not stockpile too much material on site as a "buffer").

The tools discussed in this section can be used complementary to each other; the LBMS and LPS can be applied effectively in parallel to optimise project performance.

The shift in thinking about projects from a "flow" rather than "conversion" perspective enables organisations to carry out project planning while remaining flexible, as assumptions made on a longer-term horizon often turn out to differ closer to the execution time frame of any given activity.

Companies operating within the South African construction industry can benefit from embracing the flow view by adjusting planning and costing models accordingly to identify and account for non-value-adding activities, expose sources of "invisible" waste and empower their personnel to plan their work in a more flexible yet structured manner. Using the flow view and associated systems could not only increase productivity, but also reduce waste, leading to more efficient, profitable and sustainable organisations. This in turn could result in a more productive construction sector and further economic growth.

3.4 THE VALUE CONCEPT IN THE LEAN CONSTRUCTION CONTEXT

3.4.1 Introduction

As mentioned in the previous sections, Koskela (1999), when putting forward his New Production Philosophy, stated that construction needs to be viewed as consisting of both value-adding and non-value-adding activities. In this section, the concept of "value" will be further explored.

Value is an abstract concept which is generally regarded as the worth or usefulness of a product. In Lean construction, the first description in this context put forward by Koskela

(1999:15), value is associated with the extent to which the customer requirements were fulfilled.

In the Lean construction system, activities are classified either value-adding or non-value-adding (add or not-add to the fulfilment of requirements) in order to eliminate non-value-adding activities. However, in addition to trying to eliminate the non-value-adding activities, the output value could be increased through the systematic consideration of customer requirements. The customer in this case could be one of two types, either the end customer or the next activity in the process.

3.4.2 Customer Value

According to Koskela (1999:38), customer value consists of two components, product performance and freedom from defects (conformance to specification). Value must be evaluated from the perspective of the customer.

<u>Value in the design</u>

Koskela (1999:38) put forward that the design process has two customers, namely the end customer and the construction phase.

The value of the design for the end customer is determined by:

- How well the requirements (implicit and explicit) have been incorporated into the end design solution.
- The level of optimisation that was achieved.
- The impact of design errors discovered after start-up and use.

The value of the design for the construction phase is determined by:

- The degree to which constraints and requirements of construction processes have been considered.
- The impact of design errors discovered during construction.

From the above, the customer requirements must be known and effectively communicated to the design team by the client at the briefing stages of the design phase. Macmillan (2006:266) elaborates on the traditional view of value created in the built environment. In terms of his book, (return on capital) and use (measures of occupancy and profitability) value include:

- Image value - contribution of the product to prestige, vision, reputation or client's corporate identity or brand image.
- Social value - contribution of the product to reinforce social identity or civic pride, social health, goodwill, neighbourly behaviour, safety and security.
- Environmental value - contribution of the product to the protection of biodiversity, the protection of infinite resources.
- Cultural value - how the product relates to its location and context, and to broader patterns of historical development and sense of place.

It is important to note that these are nuances of the broader value concept, which is that value is created by identifying and adhering to the customer's requirements. If the end customer is not interested in adding social value with their project, the design team will destroy value by adding design features that encourage, for example, neighbourliness. This underlines the importance of a complete and detailed client brief where information on the customer's requirements must be communicated to all members of the team.

<u>Value in the construction process</u>

According to Koskela (1999:38), the value of the construction to the client is determined by:

- The degree of freedom of defects discovered during start-up and use (here the freedom of defects implies that construction was done according to the customer requirements as detailed in the design).

According to Hines *et al.* (2004:995), value creation is often seen as equal to cost reduction, and this represents a common yet crucial shortcoming of the understanding of Lean principles. Value can be created by eliminating muda (wastefulness). By reducing wasteful activities (internal waste), the cost associated with these activities is reduced. However, if additional features or services which are valued by the customer are offered, value is also increased (Hines *et al.*, 2004:995). The important point is that the value must be perceived by the customer. Green and Sergeeva (2019:637) state that there is no underlying reality of value which exists independently of narrative. It is an abstract concept which is shaped and contested continuously throughout the project lifecycle through narrative. This statement again emphasises the importance of a clear mutual understanding of the client's brief and value perception.

In the Lean construction model, customer value should be identified in order to recognise what should be produced and what should be eliminated (Jylhä & Junnila 2011:70). In the

TFV theory, the focus is on “flow” creation by eliminating non-value-adding activities from the process and ensuring that customer-defined value is created.

Value Stream Mapping

This tool was discussed in Section 3.3.2 as part of the flow planning toolkit available. This tool assists the practitioner to identify the value stream in order to reduce non-value-adding activities with the end view of increasing “flow”.

3.4.3 Value metrics and management tools

Value Engineering (VE)

According to Wandahl (2015:1028) value engineering (VE) is a management technique aimed at lowering the cost of a construction project while maintaining the technical quality and function of the product, as required by the client. In this theoretical framework, VE defines value as what the client pays for a specific “function”. In practice, by value engineering features - replacing existing design features with cheaper replacement features that satisfy the requirements - value for the client is increased.

Value Management (VM)

Value management (VM) is generally understood as the process where a project’s plan is reviewed to ascertain the value for money for the client. Wandahl (2013:1028) states that VM is a promising tool for making the client’s value system explicit early in the project life cycle, in that it has been established that a vigorous briefing process is vital for project success and elimination of many problems that originate from the inception phases of a project. In the theoretical framework, VM defines value as a tool that can be used to align stakeholders’ value systems and this system in practice is basically a set of pragmatic management tools.

Quality function deployment (QFD)

This is a structured approach to define customer requirements and translating those requirements into a functional product.

Performance based requirements tools (PBR)

Performance based requirements (PBR) are requirements that express the required outcome or results of the product without specifying the means to accomplish them. The design of an infrastructure project could be divided into specific performance requirements which could include items such as cost, capacity and durability. Some of these items might be client-specified requirements, while others are governed by legislation through building regulations' minimum standards. No specific instructions from the client are given on how these requirements should be met, but only that the product should meet them.

Post occupancy evaluation (POE)

Post occupancy evaluation refers to the process of obtaining feedback on an end product's performance in use. For example, if the product is a building, the design team would wait until 6 to 12 months after the client has taken occupation of the building, and then collect data on the building's features such as energy use and occupants' satisfaction. While of less use to the customer of the project in question than to the design team, this process plays an important role in informing future designs in the design teams' quest for continuous improvement of their design processes. If the project was not a once-off project for the customer, this process could inform the brief for subsequent similar projects.

This process is similar to the process Building Performance Evaluation (BPE).

Project stakeholders can agree on value metrics for every phase of the building process. This would ensure that the customer requirements (the customer being either the end user or next phase of the project) are top of mind at all stages. It would further ensure that any shift in requirements can be identified, documented and adjusted as necessary. For illustration purposes, Table 3.2 shows the standardised construction process of a building as put forth by Winch and Carr (2001:521), with the possible value metrics that could be used to track value.

Table 3.2 Value Metrics at each construction phase (Adapted from Winch & Carr (2001:521))

Phase	Description	Output	Value Metric
Define Need	Defining the need for the project in terms of the business strategy	Business Case	QFD. PBR
Establish Viability	Establishing the technical and financial viability of the proposed project	Decision to build	QFD. PBR
Conception	Working through alternatives (location / configuration) for the project	Decision on location & configuration	QFD. PBR
Concept Design	Defining the project	Complete definition of building	QFD. PBR
Detailed Design	Working through the detail and producing working drawings	Complete description of product	QFD
Production Planning	Planning the execution of the design (construction planning)	Construction programme and budget	QFD
Main Trades	Executing the structure	Completed structure	QFD
Finishing Trades	Fit out of structure	Completed product	QFD
Commissioning	Ensuring all systems are integrated and capable	Product ready for use	QFD
Facility Management	Managing the product in use	Realisation of business case	POE or BPE

According to the CIDB (2011:11) client value in the South African construction industry is a subjective and complex issue and they state that quality in construction is a key component in perceived value to clients. However, project stakeholders need to understand that the perceived value originates in the extent to which the project specifications have been adhered to and the brief was achieved.

Customers who believe that they have not received a value-add due to their product being designed and constructed at a higher level of quality than requested, participate in value being destroyed, as the product does not adhere to the requirements as set out at the start of the project. Instead of a “bonus” or “added value”, these excess quality features are regarded as “waste” (an element to be avoided or eliminated as far as possible) in the Lean construction context. The waste concept in this context will be discussed in more detail in the next section.

3.5 THE WASTE CONCEPT IN THE LEAN CONSTRUCTION CONTEXT

3.5.1 Introduction

Koskela (1992:17) indicated in his treatise about the application of the NPP to construction, that competitiveness can be improved by identifying and eliminating waste. Arbulu *et al.* (2003:164) describes waste as all efforts that do not add value to the final product from the point of view of the customer. Keeping in mind that in the context of Lean construction, the customer not only refers to the end customer (or “client” under the contract), but also to the next activity in the process.

In the traditional (conversion) view, waste is generally regarded as using too many resources to perform a certain function, or materials becoming unusable and having to be discarded from the construction site. In the Lean construction context however, waste has a broader meaning which includes “invisible” waste caused by the disruption of “Flow” activities. Indeed Koskela (1992:17) states that quality deviations cause waste in themselves, but also cause waste due to the interruption of flow caused by deviations. Further to this, poorly constructed requirements add to conversion time and costs, contributing to slowing down the physical flow of the project.

The next section will elaborate on the types of waste encountered in the construction process, after which the tools available to manage the different types of waste will be discussed.

Koskela (1992:17), when proposing the applicability of the new production philosophy to construction projects, defined waste as non-value-adding activities on a project. These activities refer to any activities that take time, space or additional resources but do not add value (Koskela, 1992:17). Apart from reducing the obvious non-value-adding activities, Koskela also proposed a systematic review of customer requirements, finding ways to reduce variability and cycle times, minimising the number of steps and parts required, increasing output flexibility, increase process transparency, focus on control of the complete process, build continuous improvement into the process, balance flow improvement with conversion improvement and establish benchmarks for activities.

Ohno (1988) identified the seven types of waste in production as:

- Product defects.
- Over-production of goods.
- Inventory excess.
- Unnecessary processing.
- Unnecessary movement of goods.
- Unnecessary movement of people.
- Waiting time.

This list was originally developed as part of Ohno's seminal work on the Toyota production system manual but is widely regarded as the seminal categorisation of production waste. Koskela (1992) uses this categorisation when describing non-value-adding activities in his treatise on the application of the NPP to the construction industry. The history of how Lean production systems came about and at what point construction practitioners realised the suitability of these systems to the construction industry will be discussed in Chapter 4.

Through the years, many scholars have proposed additional types of waste to this list. For the most part, the additions can be grouped into one of the seven broad types, as originally listed. For the purpose of this thesis, one additional type of waste, as added by Koskela (1992) in his seminal work, namely "making-do" will be added to the list for the purposes of introducing the concept of waste or "non-value-adding activities" under the Lean construction management system.

3.5.2 Types of Waste

Waste 1: Product Defects

This type of waste occurs when an element is deemed defective in quality or function due to not meeting the customer requirements according to the specifications. The waste occurs due to the resources that must be applied to remove the defective element, to having to discard the materials already processed - including the labour and equipment cost associated with this element. The rework due to correcting the defect (constructing or supplying the element in question again) can be categorised under Waste 4 - unnecessary processing.

Waste 2: Overproduction of Goods

This type of waste occurs when too many resources for the task at hand are produced or sourced. On a construction project, this usually leads to other sources of waste such as inventory excess on site and unnecessary movement like the need to double-handle material.

Waste 3: Inventory Excess

As mentioned, overproduction of goods could lead to inventory excess on site. Other causes of this type of waste could be poor scheduling of materials, “push” instead of “pull” scheduling and inefficient processes.

Waste 4: Unnecessary Processing

This type of waste refers to any type of over-processing during the project activities. This includes the processing required to correct defects (resulting in double-processing of the element that is defective) but can also include double-handling of materials and importantly, an element that is constructed to a higher quality than specified in the construction drawings and specifications drawn up according to the customer’s requirements.

Waste 5: Unnecessary Movement of Goods

This type of waste occurs when materials or equipment need to be moved around due to inefficient planning, excess inventory not planned for on site, or to the workspace not being planned out (double-handling of material). This waste could cause other types of waste such as waiting time and making-do situations.

Waste 6: Unnecessary Movement of People

This type of waste occurs when human resources need to be moved around due to inefficient planning of the workspace, the materials or equipment required to complete an activity not being available at the worksite or human resources getting moved to other sites due to waiting time. In a production milieu, the waste related to the unnecessary movement of people is quite evident. In the construction milieu, this type of waste is often not as evident, as site managers could choose to shift to the “making-do” scenario to keep up the appearance of daily production rates.

Waste 7: Waiting Time

Vrijhoef and Koskela (2000), in a study on the role of supply chain management in construction, found that most causes of waste in a construction project are related to the traditional myopic management of the supply chain. This system is based on the traditional "conversion" view of the process. The difficulty with the traditional system is that problems in the supply chain are only identified once the consequences are made visible, which often happens several steps downstream.

Waste 8: Making-do

Koskela (2004) added an eighth category of waste to the traditional seven types of waste, as identified by the authors of the Toyota production system. This type of waste refers to an activity that is started without all the parts needed to complete that activity being available or in the event that the activity is continued even though at least one input (any resource required in terms of machinery, materials, instructions, etc.) becomes unavailable during the process. This is a common situation where there are several uncertainties preceding a given task in the process.

Ronen (1992) explained making do, not by defining it, but explaining the opposite, the ideal situation where nothing is required (the complete kit is available). This complete kit would be complete drawings, components and information required to complete a given activity or sub activity. Koskela (2004:2) observed that in construction, the question of whether all inputs are available or not for an activity often does not have a yes/no answer, but that there might be inputs that are available, but on a sub-optimal or non-standard basis.

Making-do is often applied to prevent schedule-slippage or maintain utilisation rates measured but is in fact a penalty due to variability. Ronen (1992) refers to the "efficiency syndrome" - the urge to have resources utilised as much as possible as one of the main causes of making-do happening on an activity. Here it is clear that the process should be considered to avoid this type of "hidden" waste or efficiency fallacy.

Grosfeld-Nir and Ronen (1998) listed the consequences of making-do as increased waiting time and increased variability with the increased variability leading to increased work-in-progress or longer lead times. The increased processing time leads to a decline in overall productivity and increase in cost. Making-do also increases the complexity of the activity, which requires more complex control. If the increased complexity and subsequent control of this type of situation is ignored, the chance of a safety incident (due to working in sub-optimal or variable conditions), a poor-quality product or rework is greater.

Tribelsky and Sacks (2011:86) pointed out the following possible consequences due to the waste caused by inefficient information flow during the design process:

- Rework as a result of a design proceeding on another designer's superseded work.
- Designers shifting their attention to other projects while waiting for information and subsequently,
- waste of renewed "setup" time to familiarise themselves with what was done previously before continuing with the design process.
- Extension of overall project timelines due to a delay or repetition of design iterations.
- Over-design resulting from the desire to avoid dealing with additional or variations in design requirements that might only be forthcoming later in the project.

These consequences are good examples of "making-do" situations where designers proceed without all the information or requirements often due to pressure from customers to move the project forward, or internal stakeholders as part of the "efficiency syndrome".

In the context of the Lean construction management system, the creation of "flow" reduces variability in processes and subsequently reduces the occurrence of "making-do".

Koskela (1992 :18) listed the three root causes of waste activities as design, ignorance and the inherent nature of production. Every time a task is subdivided into sub-tasks executed by different teams or specialists, non-value-adding activities increase not only by duplication of some activities, but also by increased inspection, moving and waiting time. In this sense, the traditional hierarchical structure of organisations adds to the non-value-adding activities.

In terms of ignorance, companies often move forward with processes without considering the flow in the project, which results in non-value -adding activities being historically present in the procedures and just existing without being identified and eliminated in order to create the flow that would render the project most effective. Activities that are not measured cannot be managed. Issa and Salama (2018) identified many causes of waste and categorised them according to controllability. Improving productivity in Saudi Arabian construction projects, they found that nearly 88% of controllable causes of waste can be affected by Lean.

3.6 CONCLUSION

The inherent nature of construction is that work-in-progress must be moved, defects occur, and accidents happen. Thus, the principle of reducing non-value-adding activities cannot be applied simplistically, as activities such as health and safety procedures, not a value-adding activity, aid in eliminating waste caused by incidents on site.

Although not discussed as one of the eight types of waste in the section above, it is important to mention waste created by contractual governance. This waste was defined as “institutionalised waste” by Sarhan *et al.* (2017), who illuminated the amount of waste generated by stakeholders adhering to unfit-for-purpose contractual governance where the focus is on “win/lose” situations of transferring risks. This situation is widely accepted as the status quo in many contractual relationships. Sarhan *et al.* (2017) argue that from a Lean perspective, the traditional adversarial relationship and contractual governance methods are not conducive to creating the flow required to truly eliminate waste, but in effect, create more waste with traditional procurement arrangements.

It is widely accepted that a collaborative and transparent approach between project stakeholders is more conducive to creating the “flow” required, however, a universal application to align stakeholder interests and keep good intentions in place is yet to be found. For the time being, avoiding or at least reducing institutional waste would form part of the “big picture” thinking about the construction project by all stakeholders.

CHAPTER 4: LEAN CONSTRUCTION MODELS

4.1 INTRODUCTION

Various studies into the implementation approaches of Lean construction have been undertaken since Koskela's (1999) proposal of the applicability of Lean manufacturing processes in the construction industry. Because of the different approaches, several frameworks have been developed to explain the proposed implementation processes and concepts. Other models have been developed to rate or measure the degree to which organisations and projects have successfully implemented Lean construction management practices.

Some of the proposed models focus only on certain principles found within Lean construction, while others attempt to propose a complete framework for the implementation of Lean construction management practices. Of these, the framework developed by Bajjou and Chafi (2023) is the most recent conceptual framework which provides a generic model for the successful implementation of Lean construction. This model will be discussed in more detail in Section 4.3.2, followed by a discussion of models proposed by other researchers.

4.2 LEAN CONSTRUCTION MODELS

4.2.1 New Conceptual Lean Construction Model

Bajjou and Chafi (2023:1) developed a conceptual Lean construction model in which six key principles and eighteen subprinciples applicable to successful implementation of Lean construction were identified (see Figure 4.1). These principles are not presented in a hierarchical form, because all principles should be applied simultaneously for optimal results.

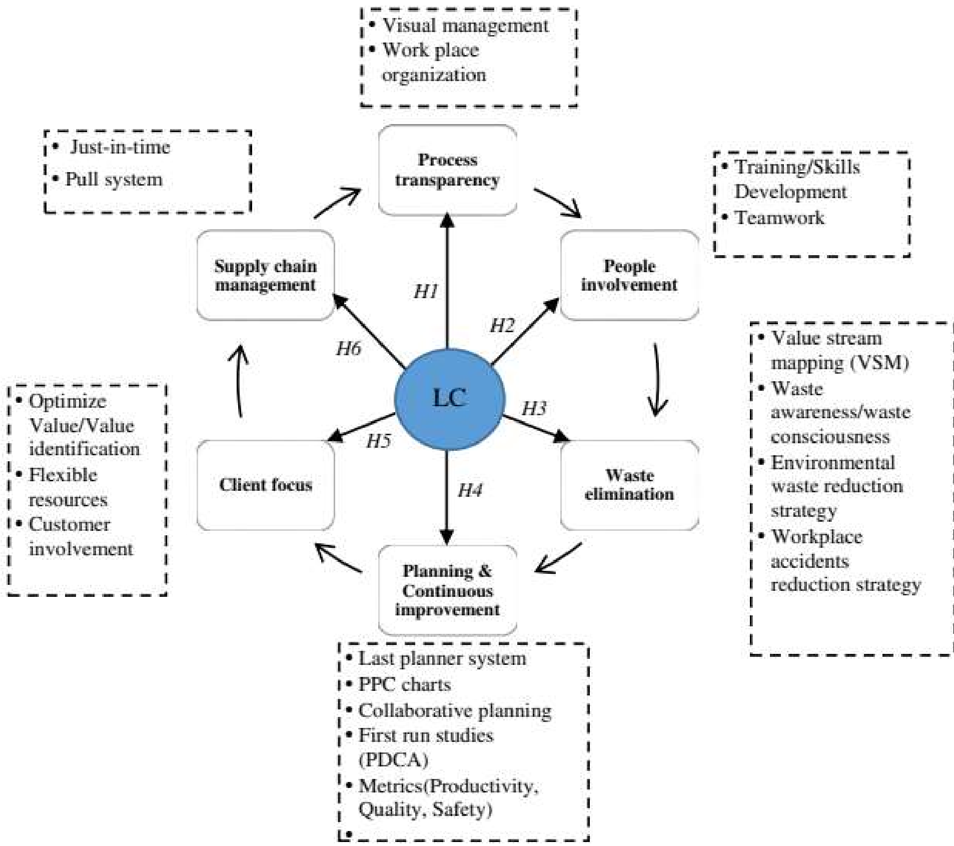

Figure 4.1 Hypothetical model of Lean construction Source: Bajjou & Chafi (2023:13)

4.2.2 Input-Output Lean construction model

Bajjou *et al.* (2019:10) identified nine elements of Lean construction principles, which are customer focus, supply, continuous improvement, waste elimination, people involvement, planning and scheduling, quality, standardisation, and transparency. The principles are divided into two main pillars, namely Management (practices which focus on system management and stakeholder interaction) and Culture and Behaviour (practices which facilitate a culture of waste elimination, continuous improvement, and optimal use of employees' skills).

The proposed model is illustrated in Figure 4.2. This model is presented in a circular form without any assignment of hierarchy in terms of importance to the different principles to effectively present the different concepts.

This model can assist practitioners in the implementation of Lean construction management practices; however, the authors point out that implementation of the practices without a proper understanding of the culture necessary to implement and sustain these efforts, will not be beneficial to an organisation.

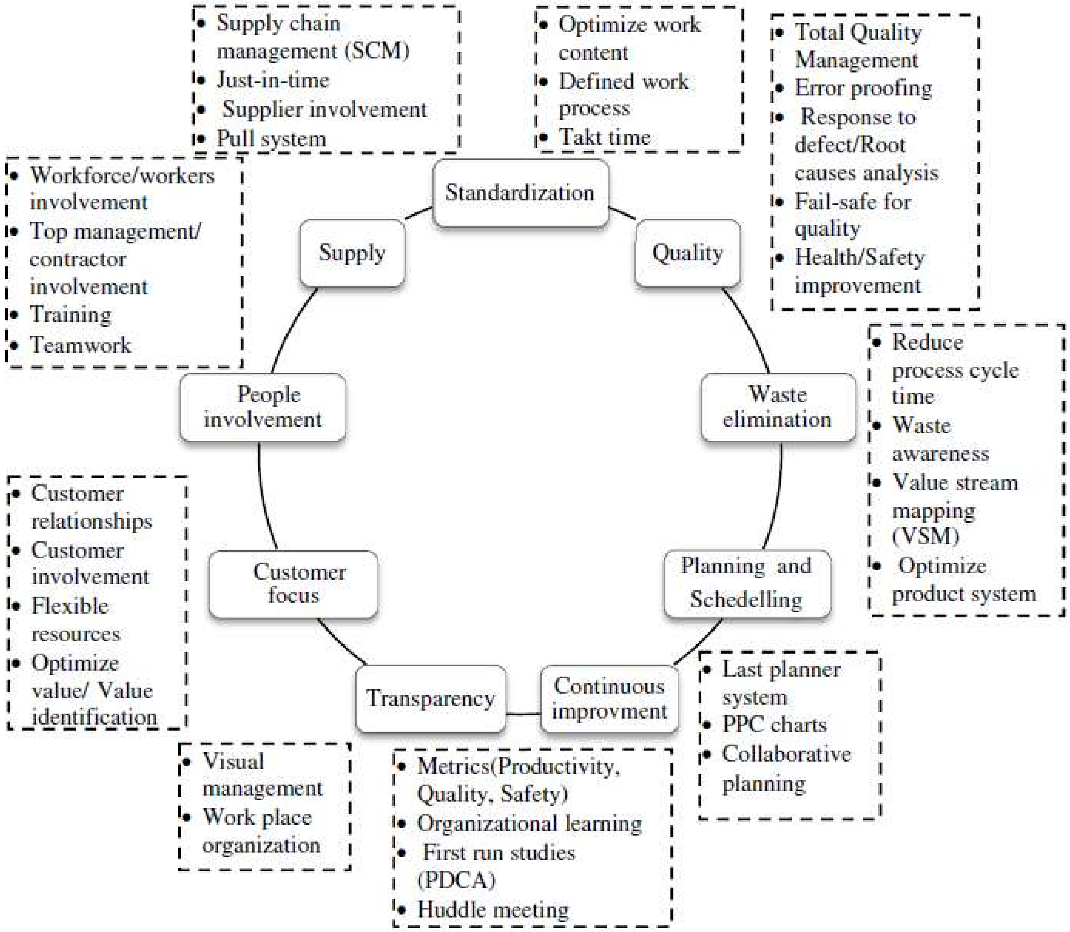

Figure 4.2 Bajjou et al.'s (2019:19) Conceptual model of Lean construction

This model was further developed to be presented in the form of an input-output model, as construction systems consist of inputs and outputs (Figure 4.3).

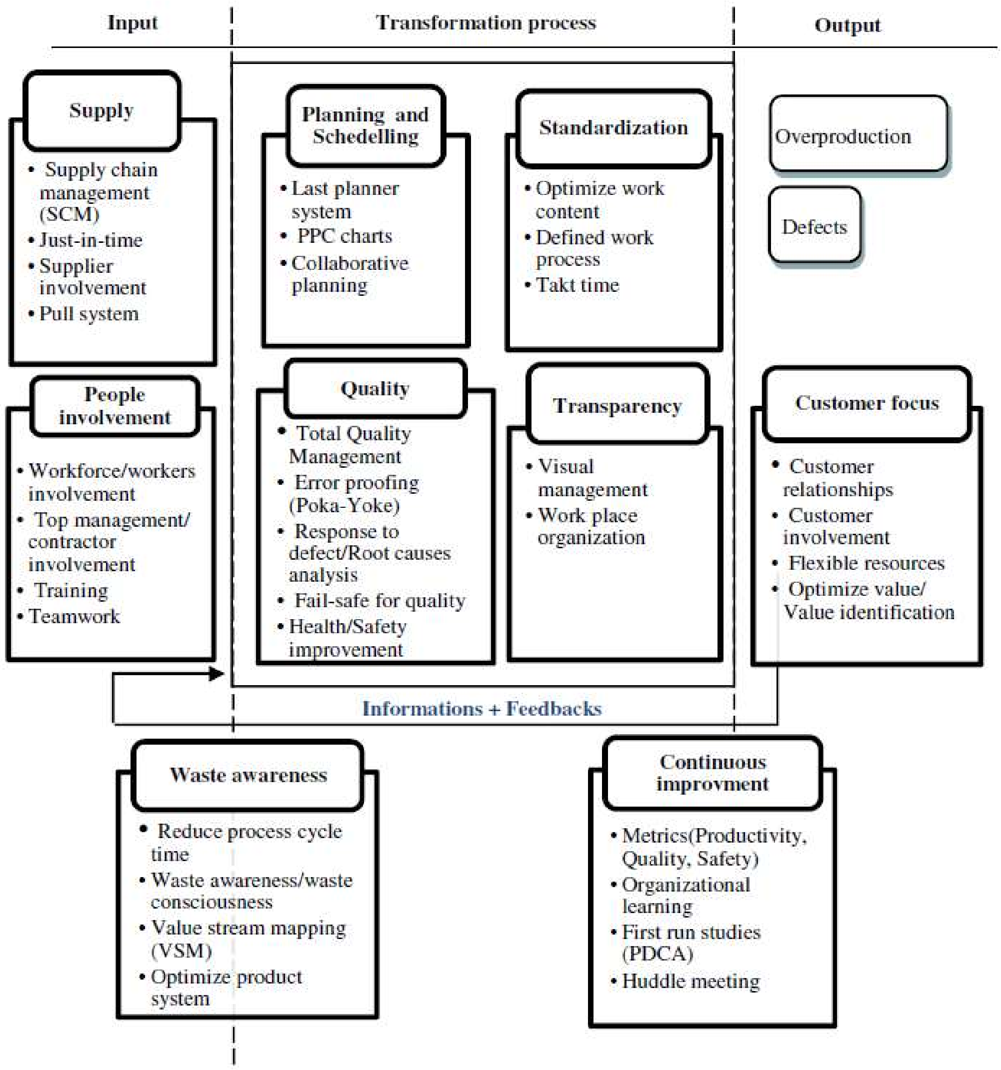

Figure 4.3 Bajjou et al.'s (2019:19) Input-output model of Lean construction

4.2.3 Lean Construction Maturity Model (LCMM)

Nesensohn (2017:359) developed a maturity model specifically aimed at measuring the state of Lean construction maturity within an organisation to support targeted interventions.

The maturity model measures Lean leadership, customer focus, way of thinking, culture and behaviour, competencies, improvement enablers, processes and tools, change, work environment, business results, and learning and competency development.

The model has divided the different Lean construction implementation elements into the following eleven key attributes, each containing "ideal statements" against which the organisation's maturity level for that statement can be attributed:

- Lean leadership
- Customer focus
- Way of thinking
- Culture and behaviour
- Competencies
- Improvements enablers
- Processes and tools
- Change
- Work environment
- Business results
- Training and competency development

The five levels of maturity within this model are defined from least mature to most mature, as Uncertain, Awakening, Systematic, Integrated and Challenging. A level of maturity is assigned to each of the "ideal statements" under a key attribute, and the lowest score for each attribute is recorded in a table to ascertain the overall maturity across attributes. This assessment also highlights strengths and weaknesses in the organisation's current level of Lean construction implementation, as this will be visible from the highest and lowest scores per key attribute.

This model enables organisations to measure the state of maturity of Lean construction. The elements of Lean construction maturity are leadership's role, the need to focus on culture and behaviour, knowledge about Lean construction and low resistance to change within an organisation. This framework is useful for organisations in the process of implementing Lean construction management in their organisations, as the method enables them to identify specific strengths and weaknesses of Lean construction approaches which will inform the planning and direction of the implementation of Lean construction programmes within the organisation.

4.2.4 BIM-Lean Approach Digital Obeya Room (DOR) Framework

Nascimento *et al.* (2017:1103) proposed a framework which integrates building information modelling (BIM) and Lean thinking to improve production planning and control. This framework focuses on defining the required workflows, analysing collected data and the visual management of construction planning and control. This framework focuses mainly on facilitating information flow and collaboration between stakeholders during the design and construction phases of a project.

Obeya rooms are useful for creating cooperative management practices. They were first introduced to better coordinate complex projects at Toyota. To implement the traditional *obeya* room concept, several sheets of paper are hung up in a meeting room. The different points of view of the project's design and business team members are described on the sheets. Thus, each team member could have easy access to information and form a better understanding of other team members' opinions about the project, in the context of visual management and continuous improvement (Nascimento *et al.,* 2017:1102).

In the framework of the digital *obeya* room (DOR), the concept of the traditional *obeya* room is implemented in a virtual space in combination with BIM. All the information is loaded into an integrated database. Afterwards, the data is analysed, consolidated in indicators, and linked to 3D visualisations (Nascimento *et al.*, 2017:1103). Since both BIM and the *obeya* room method use the plan-do-check-act (PDCA) cycle for continuous incremental improvements of work processes, it is natural to propose an integration between the two concepts to facilitate information flow during the design and construction process.

4.2.5 Lean formwork construction model

Ko and Kuo (2015:444) proposed a lean formwork construction model for building reinforced concrete structures. The reason for a proposed model for formwork construction is that traditional formwork construction processes contain many non-value-adding activities and waste that might be eliminated if another approach is used. Their model uses *Andon* concepts to establish an on-site quality control culture and *Kanban* concepts to establish flow in construction processes.

Andon is a Japanese manufacturing term originating from the word for "paper lantern" and refers to an alarm system which notifies management and workers on a production line of quality or process problems. *Kanban* refers to a bulletin board which is linked to a scheduling system which helps to inform what, when and how much to produce (Figure 4.4) (Ko & Kuo, 2015:446).

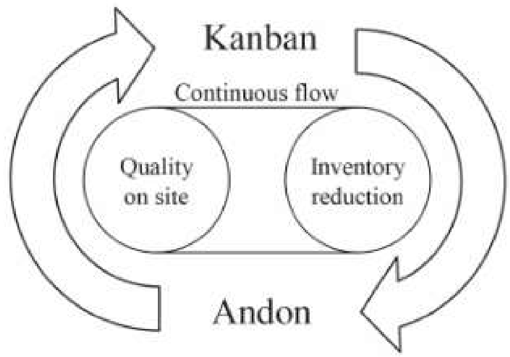

Figure 4.4 Lean formwork construction model (Source Ko & Kuo, 2015, p. 448)

This framework proposes using the *Kanban* system to optimise formwork mould inventory while creating continuous flow and allowing for continuous process control. In Ko and Kuo's (2015:450) proposed system, *Kanban* is used for delivering construction orders, thus reducing waste, reducing inventories of incomplete and unfinished formwork, and allowing accurate monitoring of inventory and production lead time. They use four *Kanbans* in their study, namely Construction *Kanban* (for delivering construction orders), Material Withdrawal *Kanban* (for retrieving parts) and Storage Yard Display *Kanban* (to display material yard information) and Signal *Kanban* (to alternate subcontractor activities).

Andon culture implementation would mean the interruption of progress of a construction activity by containing any defective products within that stage of production. The proposed method to implement a culture of *Andon* is to have a technically skilled foreman on site who can assist group leaders when a technical problem is encountered, before the defect occurs. This would mean implementing a culture where the work can be stopped to resolve a problem, instead of pushing for the work to continue and letting defective work continue to the next stage. This method seems to counteract the flow that needs to be achieved but contributes to greater overall flow because a culture of on-site (internal) quality control reduces defects later in the process, which will result in rework and thus eliminates the waste associated with these defects. Implementing a culture of *Andon* further facilitates skills development of labour on site as labourers' skills would continue to improve when a culture of learning and guidance when unsure is established.

This model has potential applications to other specialised disciplines on a construction project.

4.2.6 Safety-based model of Lean construction

Moaveni *et al.* (2019:2) proposed a Lean construction model with safety as focus within the Lean construction implementation framework. This was achieved using the Transformation-Flow-Value (TFV) framework but reviewed through the lens of safety and combined within the framework of Ballard's (2008) Lean Project Delivery System (LPDS).

The model consists of three elements, namely, Safety-based Transformation, Safety-based Flow and Safety-based Value Creation. For the Safety-based Transformation element, Moaveni *et al.* (2019:6) proposed that introducing the transformation view on LPDS, different conversion activities could be clarified at the front end of the project, facilitating transformation to be implemented in the safest possible way by adapting the design to reduce site risks and incidents, for example to adapt elements to be modular or to be prefabricated off-site. The LPDS also facilitates a clear definition of the different work packages during the full life cycle of the project, which gives stakeholders the opportunity to estimate the probable risk of accidents early in the project and adapt the design accordingly to minimise these risks.

For the Safety-based Flow element of the proposed model, the goal is to develop a reliable workflow. According to Moaveni *et al.* (2019:7) reliable workflow cannot be achieved without safe work practices. The proposal is for practitioners to estimate the optimal point in the conformance and non-conformance costs of safety by both eliminating the identified risks through inspection and detection activities, but also to mitigate risks which might lead to an accident.

In terms of the third element of this model, Safety-based Value Creation, Moaveni *et al.* (2019:8) proposes that if a client's view on safety can be changed, improvements in safety performance can be expected on a project. To this end, the value concept can be used because the main purpose is to create value for the client. Thus, the client can also drive this framework by explicit requirements in terms of safety achievements (Figure 4.5).

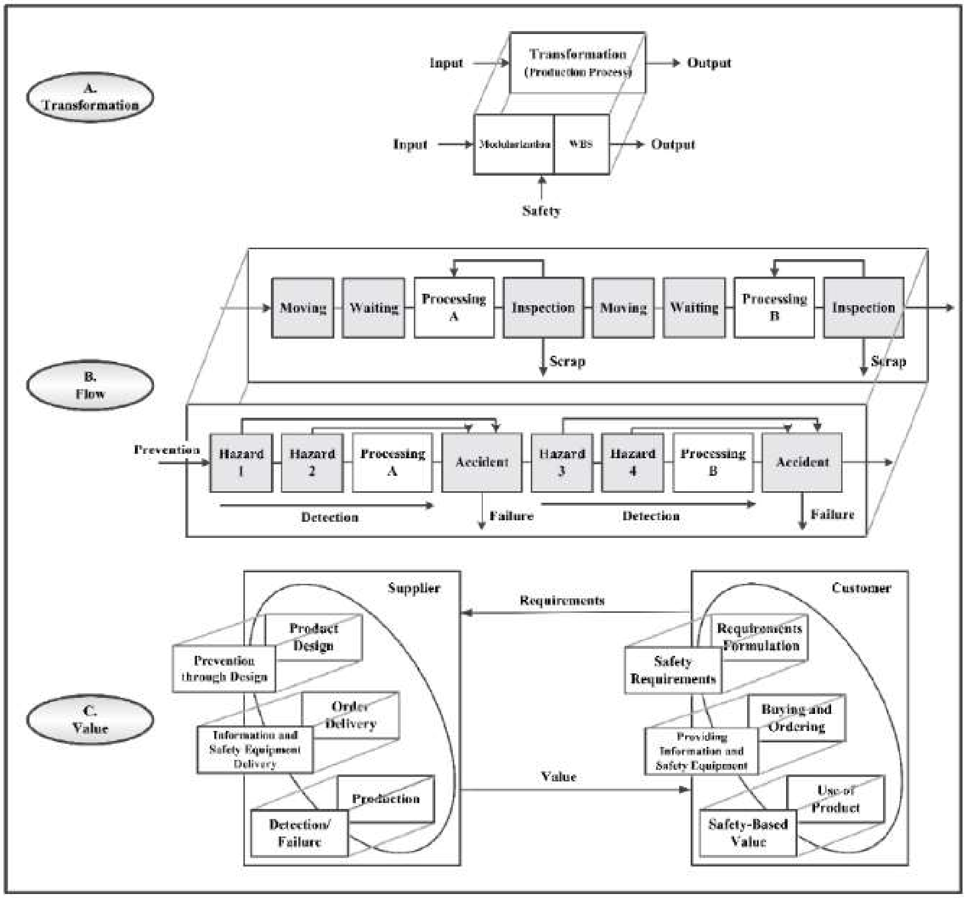

Figure 4.5 Safety-based model of Lean construction (Source: Moaveni et al., 2019:7)

4.2.7 Lean Construction Evaluation Model (LCEM)

Issa and Alqurashi (2020:341) developed a model to evaluate Causes of Waste (CWs) and Lean implementation levels in construction projects. The model consists of two elements, the first being the evaluation of waste through combining the probability of occurrence with its importance. The second element of the model is to determine the Lean effect achieved in the project by using data from waste levels, project controllability and Lean implementation levels (Issa & Alqurashi, 2020:340). This model's premise is that the Lean effect of a project can be improved by increasing the levels of controllability and Lean implementation and by decreasing waste levels. Within this model, there is an inverse relationship between waste levels and controllability.

4.2.8 Lean subcontracting procurement models

Yin *et al.* (2014:389) proposed a Lean Subcontracting Procurement Process (LSPP), which derives from Lean construction theory. The model consists of a proposed "Seven-Arrangement" operation plan combined with four types of standard operating flows.

The “Seven Arrangement” operation plan consists of factors corresponding to seven types of waste (waste from: defects, delays, overproduction, unnecessary processing, maintaining excess inventory, unnecessary transport, and unnecessary movement of people and equipment (Yin *et al.*, 2014:390). The corresponding factors of arrangement are quality, quantity, time, inventory place, task number and order, path, and location arrangement (Yin *et al.,* 2014:394).

The four types of standard operating flows refer to the information flow between four parties to the subcontracting process. In a traditional subcontracting process, the specialised subcontractor’s involvement in the procurement process will be very limited with the procurement department controlling most of the process and in most cases, procurement personnel are not held responsible for the outcome after the execution phase. In the proposed LSPP, the specialised subcontractor is regarded as a party to the process and a crucial component of the operating flow of the project. In this model, the “Seven-Arrangement” operation plan is initiated at procurement stage where detailed planning is conducted and passed onto the three other stakeholders (construction planning department, site project management and specialised subcontractor) for collaboration and input at the front end of the project, resulting in more opportunities for involvement in engineering interface, risk, and waste reduction of the overall project.

In the context of Lean, El Zind *et al.* (2023:1652) proposed a “three-layer” approach to subcontractor procurement. Their approach proposes three elements, namely realignment of the traditional steps in subcontractor procurement, the application of the “Choosing-By-Advantages” (CBA) methodology to enhance the decision-making process when selecting specialised subcontractors, and the introduction of a digital subcontractor rating programme.

Regarding the first layer of the framework, realignment of the traditional steps in subcontractor procurement, El Zind *et al.* (2023:1658) propose a completely different approach than the model proposed by Yin *et al.* (2014:390), which is implementing a pull system by which subcontract packages are sent to the specialised subcontractors only at the last possible moment. This arrangement is beneficial over the traditional process because it addresses the issue of frequent changes to the design during the execution phase, which result in rework if the subcontractor packages are awarded earlier than necessary. The drawback of this model is that any float on the procurement action is eliminated, which mitigates the risk of rework due to changes, but increases the risk of delay should the subcontractor not perform according to the agreed timelines. The second layer of the framework proposed by El Zind *et al.* (2023:1659) is to use the CBA method of decision-making using both qualitative and quantitative factors to determine the selection that would yield the most value for the client. This is different to the traditional decision-making process, which would rely on price as the main consideration of subcontractor selection. The third layer of this model is the implementation of a subcontractor rating system for subcontractor performance to be rated against various criteria from technical, commercial and time perspectives. The purpose of this layer is to create a feedback loop for continuous improvement of this procedure.

4.2.9 Rapid Lean construction-quality rating model

Hofacker *et al.* (2008:1) developed a model to assess the Leanness of a construction project. The rating tool measures six main categories of Lean, namely, client focus, waste consciousness, quality, material flow, organisation / planning / information-flow, and continuous improvement. Each category contains a list of questions which need to be answered with a rating value from zero (not applied) to six (fully applied). The results are depicted in a simple bar chart which shows the percentage of Leanness for each of the six main categories. The achieved total percentage is then calculated to classify the total Leanness of the project across the six categories according to a defined scale.

This model enables practitioners to classify their projects on a macro scale, to visualise results and to classify multiple projects in standardised classes to obtain a notion of the overall degree of Leanness of the project. The result of this tool reflects whether the organisation's project is on track with specific defined strategies on value generation and waste reduction (Hofacker *et al.*, 2008,8).

4.2.10 Lean construction framework model

Johansen and Walter (2007:19) developed a framework listing eight areas that are crucial in developing a Lean culture. These eight areas are Procurement, Management, Planning / Control, Collaboration, Behaviour, Supply, Installation, and Design.

In terms of Procurement, the framework proposes that the focus should be on process flow and suggests integrated procurement activities instead of the traditional procurement sequence to be implemented.

In the Management concept in this Lean construction framework, the focus is on improved information transparency, managing key stakeholders and initiating continuous improvement strategies. Johansen and Walter (2007:32) proposed the implementation of benchmarking and visual management processes to implement Lean construction practices under this area.

For Project planning and control in Lean construction, techniques which reduce variability and uncertainty in the construction project should be implemented. The Last Planner System is proposed as the leading concept to implement to achieve results in this area.

For Collaboration, Lean techniques such as partnering, cross-functioning, and document and information management systems can be implemented to facilitate Lean construction management practices within the project.

In terms of Behaviour, this concept denotes the requirement of employees from all levels of the organisation to participate, as well as evaluate performance within the Lean construction implementation framework.

Regarding the area of Supply within the proposed Lean construction framework, Johansen and Walter (2007:32) proposed the implementation of just-in-time (JIT) and *Kanban* techniques. Apart from these two typical Lean techniques, Value Stream Analysis can also be implemented to facilitate the timeous delivery of services and materials within a construction project.

For the Installation processes, Lean construction practitioners would need to follow the flow principles in terms of resource movement on site as well as processes themselves. To facilitate flow in installation processes, the framework proposes that strategies that minimise uncertainty in the production processes be implemented. These processes include the Continuous Flow process and the Last planner system, but also requires the implementation of a site administration tool such as the 5S system (Sort, Set in order, Shine, Standardise, Sustain).

Concerning the design aspect of a project, the framework requires approaches that reduce value destruction by eliminating inconsistent decision-making and to stimulate flow by enhancing coordination and information procedures. Johansen and Walter (2007:32) proposes the implementation of Lean techniques which focus on improving decision-making such as Concurrent Design and Set-based Design strategy. There are various tools available to facilitate these processes, such as virtual design studios and virtual reality tools.

4.2.11 Lean construction wheel

Diekmann *et al.* (2003:4) developed the "Lean Construction Wheel" (Figure 4.6) model to identify the most common Lean construction principles and best practices typically used by practitioners of Lean construction. The purpose of this model is to inform best practices, but it can also be used to evaluate an organisation's level of Lean construction implementation.

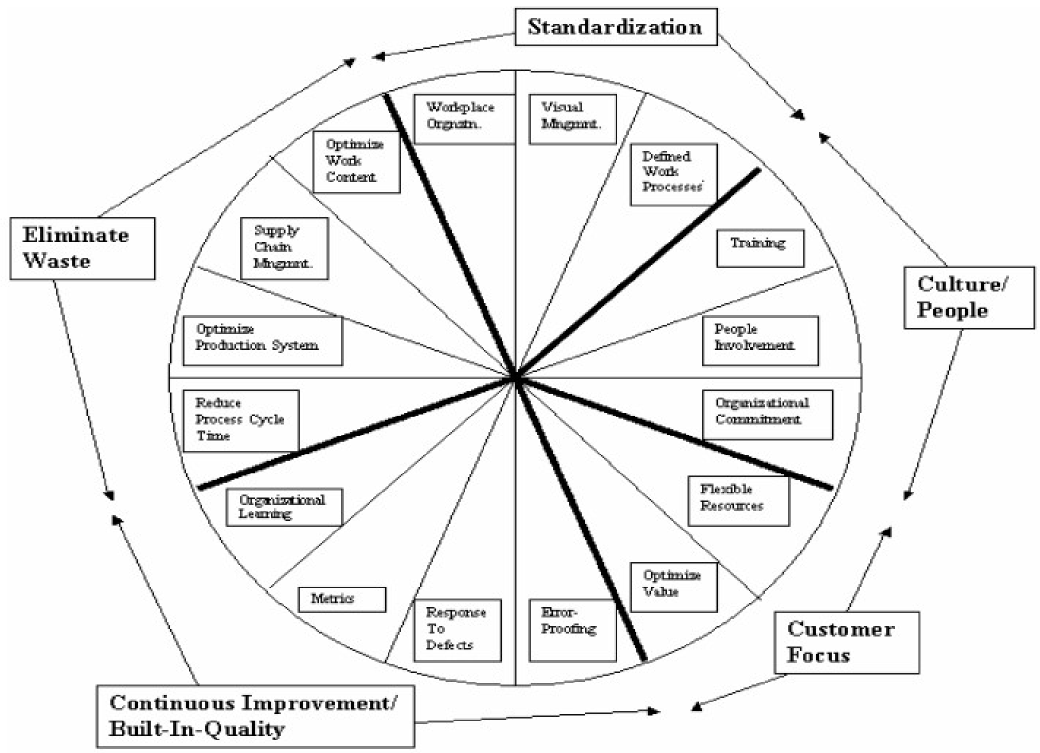

Figure 4.6 Lean Construction Wheel Model (Source: Diekmann et al., 2003:4)

The model identifies five main principles of Lean construction, namely, Standardisation, Culture / People, Continuous Improvement / Built-in Quality, Eliminate Waste, and Customer Value. Each principle is divided into sub-principles with associated questions and rating scales which can be used to measure the extent of Lean construction implementation in an organisation.

4.3 CONCLUSION

Despite the extensive theoretical frameworks and developed tools for the implementation of Lean construction management, Lean construction practices are not widely implemented, and where they are implemented, they are often not implemented to their full potential. Given the proven benefits of the implementation of Lean construction practices, barriers must exist to the implementation of Lean construction practices, which prevent efficient implementation of these practices. In Chapter 5, the available literature on the barriers to the implementation of Lean construction will be reviewed.

CHAPTER 5: BARRIERS TO THE IMPLEMENTATION OF LEAN CONSTRUCTION

5.1 INTRODUCTION

From Mossman's (2018:1249) presentation about the seeming lack of a clear definition of Lean construction, the first barrier to the introduction of Lean principles is the lack of agreement on what exactly Lean construction is. Mossman's solution to the problem of a clear, agreed definition of Lean construction is to focus on the purpose of the system more than the definition. The purpose of lean being to create more value with less resources.

However, as specified in the previous chapter, for the purpose of this research study, lean construction is "A way to design production systems to minimise waste of materials, time, and effort in order to generate the maximum possible amount of value" (Koskela *et al.*, 2002:211).

Even after extensive research conducted proving the benefits of Lean construction practices, or at the very least, implementing Lean elements into existing practices, various study findings show continuous reluctance to implement Lean practices and widespread resistance to change. Despite proven success, it is evident from this reluctance that barriers to discouraging implementation and encouraging the reluctance to change must exist.

Much research has been conducted to identify the barriers across various construction industry sectors around the world. Enshassi *et al.* (2018:123) refer to these barriers as the gap between awareness and application levels on site. Sarhan and Fox (2013:4) differentiate between barriers that prevent the diffusion and implementation of Lean construction and barriers that exist during the execution of Lean construction practices. In much of the research, these two types of barriers are similar. For the purpose of this research, the focus will be on the barriers to the implementation of Lean practices.

Koskela (1992:51) already identified barriers to the spread of his new production theory from the manufacturing industry to the construction industry in his seminal work about Lean construction application to the construction industry. According to this work, the construction industry had been slow to internalise concepts and cases presented on Lean practices at the time of publication of his new production philosophy. He speculated that a reason for this slow uptake could be that practitioners do not seem to grasp how concepts founded in the realm of production could be applicable to the construction industry where each project is seen as having its own peculiarities and the feasibility of his suggested new approach was questioned. This knowledge gap between the theory and the practical implementation of the concepts is a pervasive barrier which has over time been present throughout the spread of Lean construction practices throughout the world.

A manual content analysis was conducted on the available literature on existing barriers to the implantation of Lean construction. This analysis resulted in a list of major barriers. The major barriers identified were divided into five broad themes for discussion purposes.

These five themes are organisational, environmental, labour / workforce, material, and exogenous barriers. The barriers were organised under the respective themes as follows:

Theme 1: Organisational Barriers

- Poor change management practices.
- Acceptance of the status quo.
- Lack of resources.
- Lack of knowledge / education in Lean implementation.
- Lack of commitment to continuous improvement.
- Lack of efficient performance measurement systems.
- Lack of a knowledge management system.
- Lack of technological capabilities.
- Level of organisational maturity.

Theme 2: Environmental Barriers

- Government policies.
- Lack of green building initiatives.
- Unstable market conditions.

Theme 3: Labour / Workforce Barriers

- Employee culture and attitudinal issues.
- Fragmentation of responsibilities.
- Resistance to adapt to new technology.

Theme 4: Material Barriers

- The complexity of Lean implementation.
- Fragmented / project-based nature of the industry.
- Extensive use of subcontractors.
- Procurement practices.

Theme 5: Exogenous Barriers

- Design-related challenges.
- Traditional construction management thinking.

A discussion of the barriers under these themes will follow in the next section.

5.2 THEME 1 – ORGANISATIONAL BARRIERS

5.2.1 Poor change management practices

The implementation of Lean construction practices is the implementation of change across different departments and levels in an organisation. Treasure *et al.* (2021:163) describe the implementation of Lean construction practices as a paradigm shift for many organisations. Thus, poor change management practices can be a barrier to the successful implementation of Lean construction practices in an organisation. During research into Indian small and midsize enterprises (SMEs), Shrimali and Soni (2017:7) describe the major barriers to the implementation of Lean construction as, amongst others, resistance to change by middle management and little support by top management.

Kotter (1995) has written extensively about difficulties encountered during change implementation and the result of huge efforts are often disappointing. The essence of change management is that top management must lead change efforts by acting out the vision that is communicated to employees.

This importance of top management support, especially in the context of Lean construction implementation, was reiterated by Sarhan and Fox (2013:6) and Bayhan *et al.* (2019:6). The former wrote that top managers should allocate sufficient time and resources to create a plan and manage the changes effected by the Lean implementation process efficiently, while the latter's study found that the lack of top management support was rated as the top barrier to the implementation of Lean construction practices.

According to Aziz and Hafez (2013:682), Lean implementation starts with leadership commitment and is sustained by a culture of continuous improvement. Given that the need for top management commitment and leadership has been widely researched and proven to be critical to the implementation of major changes, why is leadership such a widespread problem during the change management process?

Kotter (1995:31), who refers to the phenomenon of an overmanaged, under-led corporate culture, explains this phenomenon as one that is usually created after an organisation experiences a certain degree of success. The growth that accompanies the success prompts top management to put systems in place to manage the rapid growth of the organisation. An unintended consequence of this “inward” focus, is that corporate behaviour becomes centralised and bureaucratic, which in turns stifles innovation and initiative. Managers, concerned with putting controls in place, are often rewarded for being cautious, and if top management consists only of cautious managers, no one will push the urgency of the implementation practices sufficiently high to create significant changes in the organisation (Kotter, 1995:46).

Thus, top management must not only be the champions of the change initiative but must also actively raise the urgency levels in order to increase the chances of success. In fact, the influence of top management during the change process will also affect other areas where barriers might be present, such as lack of employee education in Lean construction implementation, culture and human attitudinal issues.

Bayhan *et al.* (2019:3) studied enablers and barriers to Lean construction implementation and seventeen of the twenty-seven drivers of Lean implementation pertain to elements that top management could have a direct influence upon. These elements include:

- A willingness to invest in Lean practices.
- Adopting customer satisfaction as a firm policy.
- Having a clear market strategy.
- Creating awareness of Lean practices.
- Management commitment.
- Incentive mechanisms.
- Lean training.
- Supportive environment for workforce efficiency.
- Existence of certified and qualified Lean personnel.
- Efficiency of human resource management activities.
- Adopting a Lean culture.
- Lean as a firm strategy.
- Making Lean resources available in the firm.
- Making specialist Lean consultants available.
- Lean leadership.
- Employee morale.
- A long-term Lean philosophy.

5.2.2 Acceptance of the status quo

Mano *et al.* (2020:70) wrote that the general nature of the civil construction industry (locally situated operations) is one of the factors influencing the Lean journey of organisations within the construction industry. Because of their local rather than global operation, they hold a more comfortable position when compared to organisations in the automotive industry whose operations face global competition. This, in combination with poor change management practices and employees' resistance to change, could lead to a situation where the status quo practices are accepted by all stakeholders as the only practices available to the organisation. Further to this, construction practitioners often accept that the construction industry is a difficult industry with low productivity and low profit margins. Further to this, it is widely accepted by practitioners that waste is an inevitable component of any construction project.

In order to combat this situation, companies need to foster innovation, which is often difficult in an organisation where the status quo is accepted because there is no need for innovation in this type of project environment.

Ozorhon *et al.* (2013:256), in their case study about the project conditions which fosters innovation, found that innovative activities are triggered by a need such as client requirements. The next steps of the process are stakeholder (innovative ideas and practices) and financial inputs required to implement the innovative actions. Thus, the implementation of any innovative action requires many stakeholders working closely together with the necessary resources in order to achieve the desired outcomes.

Figure 5.1 depicts the phases of innovation according to Ozorhon *et al.* (2014:262) with the requirements being the trigger for innovative initiatives, and sources on innovation and financial investment as inputs to commence the process.

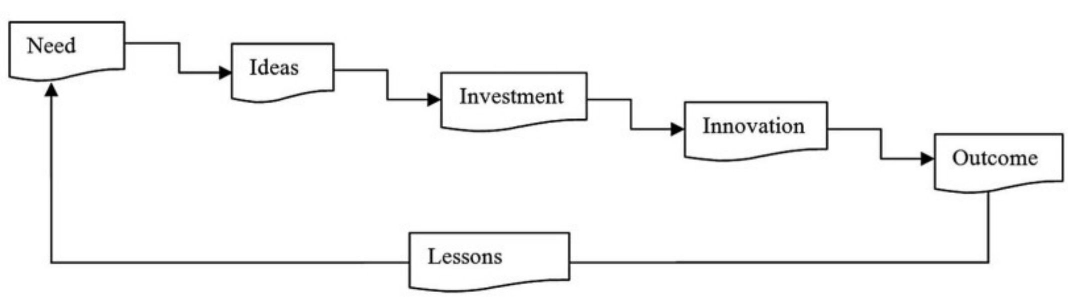

Figure 5.1 The Phases of Innovation according to Ozorhon et al. (2014:262)

The phases of this process take place over a period of time. Innovation happens after all the input, with the results following implementation of the actions. The time required to implement innovative actions can also be seen as an investment that needs to be made. Often, the direct financial return on investment cannot be established at the initial stages of implementation, and management would be reluctant to assign costs to implement a system that would not show immediate financial results. Research by Khaba and Bhar (2017:655) found that organisations not recognising the long-term financial advantages of Lean construction as a major barrier to implementation. If an organisation operates within an environment where the status quo of low productivity, high waste and low profit margins are accepted as an inherent part of the industry in which it operates, it is clear how this attitude forms a significant barrier to the implementation of Lean construction as improvement innovation.

5.2.3 Lack of resources

Sarhan and Fox (2013:6) found one of the barriers to the implementation of Lean construction to be the adherence to traditional management concepts over the implementation of more efficient Lean thinking strategies. This occurs mostly due to the organisation and management being under time and financial pressure.

Efficient implementation of Lean construction practices would require a multi-pronged approach where the initiative is implemented in specifically identified areas of the organisation. This could require additional resources, training, incentive schemes, decreased production rates while training takes place, a learning curve period where employees become familiar with working with new systems and procedures. A Lean construction specialist or consultant might also have to be employed to guide management in the implementation of these tools (Enshassi *et al.,* 2018:125).

Having a consultant specialising in Lean construction implementation as part of the team could have the added benefit of enabling knowledge transfer from the consultant to upper management about the failures or successes of programmes initiated at other organisations (Khaba & Bhar, 2017:656).

Ironically, at the point where the organisation is in peril and looking towards strategies to implement to be more efficient, the resources required to make an impact are often not available. This could result in top management trying to piece together some practices without expending additional resources which, linking back to the change management theory as developed by Kotter, will at best deliver lacklustre results. Mano *et al.* (2020:73) add another element to this barrier created by partial deployment of Lean construction practices and note that a company would often opt for partial deployment in pursuit of quick results - which in turn is one of the main causes of failure.

Enshassi *et al.* (2020:170) enforced this idea of lack of resources posing a barrier with their findings that the effective implementation of Lean tools needs sufficient funding that is efficiently and transparently distributed and is aligned with the companies' goals. Adequate funds should be made available for incentive schemes to motivate employees during the implementation process, which could be frustrating to the workers while being rolled out.

The above financial implications of Lean construction management (initial lack of productivity, cost of training, cost of tools and cost of consultants) combined with the initial lack of measurable results and existing cost constraints on projects, is a significant barrier in the implementation of Lean.

5.2.4 Lack of knowledge / education in Lean implementation

Enshassi *et al.* (2018:125) write that the most related educational barriers to the implementation of Lean construction practices are lack of knowledge, lack of understanding and awareness, and lack of experience.

According to Shaqour (2021:9), 74.4% of 162 construction companies surveyed in Egypt had implemented Lean construction practices, although 65.8% of these companies did not have knowledge of Lean principles and thus did not realise that they were implementing Lean methods. Shaqour's (2021) recommendations include efforts to deepen the knowledge of Lean methods and tools as well as educating stakeholders on the practical applications. This would deepen the culture of Lean and facilitate intentional implementation of Lean practices to add value to the construction industry.

Sarhan and Fox (2013:8) found that difficulties in understanding the concepts to be a significant barrier to the successful implementation of Lean construction. Bayhan *et al.* (2019:1) also found that a clear understanding of the requirements in Lean practices was the most significant driver in the implementation of Lean practices. This enforces the importance of stakeholders having a good understanding of the concept.

This lack of understanding results in some practitioners believing that Lean is not suitable for the construction industry, while other practitioners, who believe that it is suitable, profess to be applying Lean construction principles while they are combining traditional techniques with those that are Lean. In these situations, training of employees at all levels of the organisation becomes indispensable for the successful implementation of actual Lean construction practices. The lack of training can also be seen as a barrier to implementation where employers recognise the importance of training but are not rolling out training programmes as they appear to regard training as another party's responsibility (Enshassi *et al.,* 2020:169).

Shrimali and Soni (2017:7) lists the lack of a Lean implementation team and poor Lean training as major barriers to the implementation of Lean practices. This is mostly because guidance is necessary to employees across all levels of the organisation when Lean practices are implemented to effectively implement and understand the measures.

In addition to their findings of a clear understanding being the most significant enabler of Lean construction practices, Bayhan *et al.* (2019:8) also found that misconceptions about Lean practices are one of the barriers to the implementation of Lean construction practices. According to them, preconceived notions about exorbitant costs and difficulty in implementation might exist and might discourage organisations to start implementing Lean construction practices.

On the other hand, misconceptions about Lean construction practices could also result in many organisations that have implemented Lean by deploying one tool - not the complete system, without understanding the concept. This could be due to the tendency of those involved in Lean construction practices understanding the concepts according to their own individual needs. This misunderstanding is partly because there is no single definition for Lean construction practices. The lack of a definition of Lean construction practices forms a barrier (Mano *et al.*, 2020:70).

5.2.5 Lack of commitment to continuous improvement

The lack of commitment to continuous improvement by organisations poses a significant barrier to the implementation of Lean construction practices. This barrier is intricately linked to issues with change management processes and innovation.

5.2.6 Lack of efficient performance measurement systems

Sarhan and Fox (2013:9) lists the lack of customer-focused and process-based performance measurement systems as barriers to successful implementation of Lean construction practices. In fact, Enshassi *et al.* (2020:165) found that the lack of these types of performance management systems is one of the most significant managerial and organisational factors that hinders the implementation of Lean construction practices. Khaba and Bhar (2017:655) also included this element in their list of barriers to the implementation of Lean construction practices.

According to them, while project performance is widely measured in terms of time, cost and scope, client satisfaction is often not measured. Thus, the financial performance is known, but possible root causes of quality and productivity losses are not identified. In addition, the nature of the traditional outcomes-based performance measurement factors is such that they are measured at the end of the project. This leaves little room for corrective action. Mano *et al.* (2020:76) also found that the inability to measure the progress of a Lean project using an appropriate method could cause Lean implementation failure (where the project team loses interest or momentum due to the lack of any measured (and therefore visible) results).

5.2.7 Lack of a knowledge management system

Even if it is impossible to understand every detail of the project, it is necessary for all parties to have a holistic view of the whole. This is made possible by communication between the various parties involved, and it also requires extra effort from everyone involved to understand the changes that will affect their work with the adoption of Lean management (Mano *et al.,* 2020:71).

According to a case study conducted by Hamzeh *et al.* (2016:40) on the first implementation of Lean principles on a major construction project in Beirut, Lebanon, some major barriers were faced during implementation. The main challenges faced were resistance to change and lack of knowledge of the philosophy behind Lean construction tools. These challenges have been raised by research on the barriers to Lean implementation in other countries. Further challenges identified by Hamzeh *et al.* (2016:38) were challenges faced due to the project switching over to Lean construction principles one year into the project, which meant that the original master schedule was not developed collaboratively and there were uneven levels of involvement of engineers and foremen in the planning process. Further challenges included that failures were repeated due to slow learnings from failures. This points back to the lack of knowledge and resistance to change to the Lean construction philosophy.

5.2.8 Lack of technological capabilities

Khaba and Bhar (2017:654) found that technological capability plays a major role in implementing and sustaining Lean construction management practices in an organisation. The high cost of acquiring new technologies, training employees in these new technologies and lack of know-how to implement these new technologies are key elements in hindering the implementation of Lean construction practices. This not only relates to technological tools that increase productivity, but also technological tools that help designers analyse and increase the constructability of these designs.

5.2.9 Level of organisational maturity

Nesensohn *et al.* (2016:657) found that the level of organisational maturity can affect the organisation's ability to effectively implement Lean construction practices. More mature organisations have a common established language in terms of their Lean construction practices, while less mature organisations do not yet have clear definitions which results in practitioners having difficulty in understanding the organisation's Lean construction goals and strategies.

This barrier is closely linked to the barrier described in 5.2.4 *Lack of Knowledge / Education in Lean Implementation* as educating potential practitioners to establish a common vocabulary of Lean construction practices within the organisation requires the necessary financial resources and organisational structure which may not yet be present in a less mature organisation.

5.3 THEME 2 - ENVIRONMENTAL BARRIERS

5.3.1 Government policies

Governments are in part responsible for the success of the implementation of Lean tools (Enshassi *et al.*, 2018:130). According to them, this role is played through the enacting of policies and regulations to encourage companies to engage in the application of Lean tools. On the other hand, bureaucracy and policies can be major barriers to the implementation of Lean practices by organisations. Enshassi *et al.* (2020:169) suggested that governments can provide subsidised courses aimed at construction industry stakeholders to train them in the implementation of Lean tools. The implementation of these types of initiatives could eliminate the major barrier of lack of government support.

Bayhan *et al.* (2019:3) list some ways in which governments can support the implementation of Lean construction practices in the construction sector such as putting incentives in place, adapting regulations to enable Lean practices, and making Lean resources available. Incentives such as tax exemptions and subsidised Lean associations and projects could help organisations perform better in launching their Lean initiatives.

Even if the government in question is not actively developing policies to encourage Lean construction implementation, existing policies or bureaucracy could discourage or hinder the implementation of these practices. Bayhan *et al.* (2019:4) found that stringent government requirements and lack of informational flow in procedures, lack of understanding of Lean practices and the lack of government support for research and collaboration are all part of the category of barriers which are present from governmental agencies' side.

5.3.2 Lack of Green Building Initiatives

Khaba and Bhar (2017:654) lists the lack of green initiatives as one of the barriers to the implementation of Lean construction. According to them, there is a positive synergy between Lean construction implementation and green approaches because of the shared focus on efficient usage of resources and reduction of waste. The understanding of green initiatives as well as governments promoting these initiatives (the difficulties being similar for green as for Lean construction described in section 5.3.1), can lead to integration of these practices with Lean construction into one management approach to overcome the current limitations.

5.3.3 Unstable market conditions

Enshassi *et al.* (2020:129) found that unsteady prices of commodities can also be a barrier to the implementation of Lean construction practices. If a commodity becomes scarce or available only in limited quantities due to global events, the programme could be delayed, and the project could overrun in cost. Especially in regions with unstable security situations, when issues of border closures arise and construction markets run out of commodities, commodity prices will increase dramatically.

According to Enshassi *et al.* (2020:131) issues related to commodities' availability and price are driven by border blockades and closures. The volatile cost of commodities poses a significant threat to the success of a construction project and poses a significant barrier to the successful implementation of Lean construction practices.

5.4 THEME 3 - LABOUR / WORKFORCE BARRIERS

5.4.1 Employee culture and attitudinal issues

According to Sarhan and Fox (2013:5), Lean thinking is a new way of thinking about the construction process. Thus, radical behaviour and tradition changes are necessary to implement Lean construction practices. Bayhan *et al.* (2019:5) lists employees' resistance to Lean implementation, lack of understanding, problems with teamwork and divergent aims and stress and pressure resulting from deadlines as major workforce barriers encountered in the implementation of Lean construction practices. Employees' resistance can be due to the natural resistance to change and need to be managed as part of the change management process discussed in section 5.2.1.

Lack of understanding due to language and level of education are amongst the most important barriers in the implementation of Lean (Bayhan *et al.*, 2019:5). Lean construction implementation depends heavily on efficient collaboration and coordination between team members. A lack of teamwork and an established common goal between employees would thus pose a major barrier to the implementation of Lean practices in an organisation. Stress and pressure on employees to meet deadlines in their construction projects could have the unintended consequence of employees cutting corners or not following the prescribed practices when implementing Lean. This situation relates back to top management having to set key performance indicators in the correct way, although the implementation phase might result in processes slowing down for a time while employees become accustomed to working with new tools and the meeting of deadlines.

5.4.2 Fragmentation of responsibilities

Perez and Ghosh (2018:1119), in their case study about the implementation barriers faced on a site where the Last Planner System (LPS) was used, found that the lack of clarity about responsibilities after the initial implementation phase could lead to the failure of system implementation. There was confusion about who was responsible for maintaining the system and its positive results due to ambiguity of responsibilities. Therefore, it is necessary to take care to clearly specify who the responsible persons are for maintaining and keeping the momentum going when implementing these tools. As for many initiatives, it is recommended that “champions” are assigned at various levels of the organisation. These individuals would normally be employees who have exhibited interest and enthusiasm for the new initiative and would be responsible for leading change and maintaining and ensuring the intent of the system.

5.4.3 Resistance to adapt to new technology

Several of the tools available to implement Lean construction practices are available in the form of software packages that enable practitioners to enhance productivity of projects and constructability of designs. The role of the organisation in making the resources available to purchase these packages and train employees on the use have already been discussed in section 5.2.8. Potential resistance of employees to adapt to the new technology and use it as envisaged in the Lean management system should be anticipated and steps taken to correct this behaviour, either in the form of incentives or working the use of these tools into the long-term employee performance management system.

5.5 THEME 4 - MATERIAL BARRIERS

5.5.1 The complexity of Lean implementation

According to Bayhan *et al.* (2019:5), the complexity of Lean philosophy and the terms used in Lean construction is a major technical barrier in the implementation. Construction firms do not understand Lean construction well and do not have a common understanding of the terms and concepts used within Lean practice. In addition, if a contractor makes extensive use of subcontractors, the problem of complexity is intensified.

First, the lack of understanding and where subcontractors are used, the subcontractors might not have the knowledge. Sarhan and Fox (2013:7) makes the point that to really understand Lean construction, one must have a complete understanding of Lean production in advance before learning the concepts and being able to understand the principles of Lean construction. Practitioners often do not have the time or interest to study these concepts in depth while they are still managing projects and trying to attain financial targets. The fact that Lean tools are yet to be standardised also complicates the situation and creates hindrances for the effective implementation of lean (Khaba & Bhar, 2017:655).

5.5.2 Fragmented / project-based nature of the industry

According to Sarhan and Fox (2013:4), the fragmented nature of the construction industry hinders the incentive for project stakeholders to cooperate and learn together. Although they have different priorities, they share the goal of successfully completing the project at hand.

The adaptation of Lean practices implementation to suit the local reality of the company and projects at hand creates the barrier in that it produces unique projects with highly specific characteristics influenced by the local context, which in turn makes it difficult to carry out benchmarking with other companies in the industry that may have interest in Lean construction (Mano *et al.,* 2020:73).

5.5.3 Extensive use of subcontractors

This category is linked to the fragmented nature of the industry but is discussed separately because a differentiation needs to be made between fragmentation due to varying priorities amongst the project stakeholders and fragmentation of a project team due to the extensive use of subcontractors. Khaba and Bhar (2017:655) lists project subcontracting as one of the major barriers to the implementation of Lean construction.

The problem with subcontracting is that the subcontracting party may not share the same values as the main contracting organisation and the employer, resulting in the breakdown of collaboration amongst project stakeholders (a key element of Lean construction implementation). The lack of coordination leads to inefficient communication, which will have a detrimental impact on the project delivery and coordination system (Sarhan & Fox, 2013:4), and naturally on the success of the project.

However, the solution to this barrier is not to eliminate subcontracting from projects, as outsourcing does provide functionally specialised teams which is a core aspect of Lean (Khaba & Bhar, 2017:656). It is necessary to take note of this threat of project team harmony when subcontractors are used and invest some resources in assisting the subcontractors to comply with the Lean implementation programme or at the very least manage the collaboration between the subcontractors and their contact stakeholders in such a way as to create collaboration.

5.5.4 Procurement practices

Various barriers to the implementation of Lean construction are present when the traditional methods of procurement of material (purchase orders) as well as services (design and subcontracting) is utilised. According to Bayhan *et al.* (2019:6), the traditional insistence on mass manufacturing and bulk ordering are often compared with Lean practices and widely regarded as more attractive than Lean. The reason for this is that the price discount offered by suppliers to order early and in bulk can easily be analysed and shown as a monetary saving on the project. This traditional thinking ignores the waste implications of ordering in bulk and having all the project inventory on site very early, in the form of physical loss and tying up cash-flow or credit lines, as well as in the form of tying down the design by making it expensive for the client to make design changes after the project has commenced.

According to Sarhan and Fox (2013:5), traditional procurement methods and contracts undermine the application of Lean construction principles because of the adversarial relationship that it creates between the parties to the contract. These adversarial relationships contribute to transactional costs. Sarhan and Fox (2013:7) refers to the “conflict border” between the design and construction phase, created due to the design and implementation being treated as separate products.

In the case where design work is delegated to external designers without any follow-up or incorporation, the design becomes separated from the construction process and in the process misses the aim of Lean construction management practices of which the core is collaboration and integration (Sarhan & Fox, 2013:5). Because there is no integration, designers tend to ignore the production conditions in which their designs will be implemented which could lead to rework of the design during the construction phase and low buildability in the designs.

According to Sarhan and Fox (2013:7), there are two views regarding the way to adopt the design practices within Lean thinking principles. One view is that the design process should be changed, while the other view is that the problem lies within the context and not the process, and that a change in how projects are procured is necessary.

5.6 THEME 5 - EXOGENOUS BARRIERS

5.6.1 Design-related challenges

Enshassi *et al.* (2020:159) list design-related challenges such as incomplete designs, inaccurate designs, and lack of design constructability as barriers to the implementation of Lean construction practices. These challenges are present in the design environment, as this phase of a construction project requires efficient communication between multiple teams of varying disciplines whose processes and information inputs and outputs are intertwined. Designs lacking completeness or technical soundness, cause a breakdown of formal planning processes and systems with team members reverting to “making-do” and other procedures which are not aligned with or nearly as efficient as Lean construction practices.

According to Al Hattab and Hamzeh (2017:2), challenges during the design phase are due to the fact that traditional project management practices are concerned with the transformation process only and deliverable completion with little attention given to value generation and flow - also during the design management phase. Tribelsky and Sacks (2011:100) found that design processes can be improved by paying attention to information flow during this phase (encouraging small batch sizes, maintaining low quantities of work in progress (WIP), shortening design reviews and response cycle times, and identifying and eliminating bottlenecks).

5.6.2 Traditional construction management thinking

As seen in previous sections, Lean thinking and the implementation of Lean construction practices requires a paradigm shift within an organisation. Traditional construction management is taught as a conversion process and does not focus on non-value-adding activities present within the project processes. In their comparison between traditional and Lean construction management systems. Bajjou *et al.* (2017b:118) list further differences between the two systems under three elements, namely creating value and eliminating waste, planning and mutual coordination, and site organisation. Considering the complete shift in thinking necessary to implement changes in management practices, in conjunction with the difficulties related to change management within an organisation, it is clear that traditional construction management thinking can be a significant barrier to the implementation of Lean practices.

A further significant difference between traditional construction management and Lean practices was highlighted by Khaba and Bhar (2017:656) in their definition of value in the Lean framework. In this context, value is defined in terms of the customer's agreeable perspective without the confusion of clashing prerequisites from different stakeholders. Thus, the value proposition of a project is the extent to which the customer's needs are fulfilled. Any project component that does not add value to the customer, should not be part of the project. For example, if the customer does not value green building features, they should not be included because the designer values these features in a building. In traditional project management thinking, the contractor should build what the designer puts before them within budget, on time and according to the prescribed scope.

Linked to the difference in definition of "customer value", Lean thinking also defines "quality management" in a different way than the traditional framework. In traditional construction management thinking, quality management is often regarded as a risk management activity and approach in a defensive manner, but Khaba and Bhar (2017:656) writes that in the Lean performance framework, the focus is on "customer satisfaction" or "customer delight" which results when the correct quality product is delivered.

There thus needs to be a shift when operating within the Lean construction management paradigm to focus on understanding the customer's needs and meeting it accordingly.

5.7 BARRIERS IN SOUTH AFRICA

It should be noted that some specific differences exist between South African construction industry and those of the rest of the world. In particular, differences in social, economic and political sectors between South Africa and other countries mentioned, needs to be taken into consideration in order to understand the unique challenges faced when lean construction practices are implemented.

Some local authorities in South Africa have implemented a policy of requiring a waste management plan from a Contractor at the permission stage of a construction project. From this perspective, the implementation of Lean tools to reduce physical waste on site could potentially not only improve efficiency and profitability for the contractor, but also assist the contractor to achieve waste reduction targets as required by the client.

The Green Building Council South Africa (GBCSA) has published a Net Zero / Net Positive certification scheme, to create a universal platform for the measurement of green building performance. This is to assist stakeholders in the construction industry to measure and report on the efficiency of their buildings. The COP21 agreement brought new focus to this aspect of the construction industry.

The GBCSA introduce a certification system for a Net Zero / Net Positive – Waste building, defined as “A Building that reduces, reuses, and recovers its waste streams to convert them to valuable resources with zero solid waste sent to landfills over the course of the year (Net Zero) or where the building can take waste from other sites and divert it for reuse, and not to landfill (Net Positive). This is applicable to both buildings in construction, and in operation (GBCSA, 2019: xiii).

From the perspective of Lean construction, the GBCSA Net Zero / Net Positive Waste certification measures can assist practitioners in the physical reduction of waste during construction, which would improve profitability and increase value if the requirement for Net Zero / Net Positive Waste is a client requirement. More detail on this certification is attached in appendix 8.

To date, little research has been conducted specifically on the barriers to the implementation of Lean construction practices in South Africa. Lean practices in South Africa were documented for the first time by Roelandt (2008:259), who documented the implementation of Lean practices in a large South African construction company in 2006.

The next published research on Lean practices in South Africa only emerged in 2014, when Emuze *et al.* (2014:223) wrote about non-value-adding activities (NVAA) in the South African infrastructure sector and recommended the implementation of Lean construction practices to eliminate NVAAs.

Aigbavboa *et al.* (2016:195) researched drivers and barriers to Lean construction in South Africa and how the barriers affect successful delivery of construction projects. Following Aigbavboa *et al.* (2016), Fitchett and Hartmann (2017) investigated the application of Lean design to space planning and construction and recommended that the focus during the design process on meeting customer requirements with the minimum amount of construction work performed. This research aligns with research conducted elsewhere in the world related to shifting to a “pull’ approach with the focus being on meeting inherent client requirements while not assuming that the requirements supplied to the design team are completely articulated by the client (thus to put more focus on the pre-design phase and to guide the client when the brief is established).

Akinradewo *et al.* (2018:1271) published research on the benefits of implementing Lean construction practices as perceived by practitioners within the Western Cape region of the South African construction industry. The research showed that practitioners perceived many benefits in the implementation of Lean construction practices, however, no mention was made of the barriers to the implementation of these practices.

In 2019, Maradzano *et al.* (2019:220) published research on the application of Lean principles in the South African construction industry by proposing a Lean construction framework for mechanical and electrical construction services, but the research does not address the possible barriers to implementation of such a framework. In the same year, Chakwizira (2019:84) researched the possibility of a Lean construction approach to solve low-income housing backlogs in South Africa. Key recommendations from this research include allowing municipalities to experiment with Lean construction approaches to facilitate refinement of South African public housing policies.

Watkins and Sunjika (2020:139) published a literature review on how the synergies between lean construction and green building can enhance sustainable development practices in South Africa. This research lists the lack of incorporating local environment constraints as a limitation and recommends further study into the barriers of implementation.

In 2022, Fitchett and Rambuwani (2022:105) and Mangaroo-Pillay and Coetzee (2022:118) published research related to Lean construction practices in South Africa. The research conducted by Fitchett and Rambuwani (2022:105) focused on understanding the types and causes of waste encountered in the South African construction industry and how the implementation of Lean practices could reduce the amount of waste on projects.

Mangaroo-Pillay and Coetzee (2022:126) published a literature review comparing the South African *Ubuntu* philosophy with the Japanese Lean philosophy and found that *Ubuntu* and Lean share many similarities, such as being people focused with foundations in respect, teamwork, leadership, collective decision-making, and continuous improvement.

5.7.2 Barriers to the implementation of Lean construction in South Africa

Roelandt (2008:266) listed “lessons learnt” during his 2006 implementation when Lean was a new concept in the South African industry. The lessons learnt centred around employing the right people who are willing to adopt the Lean approach as well as ensuring that all levels of management are committed to the implementation. This aligns with barriers related to change management and top management involvement found elsewhere in world.

Aigbavboa *et al.* (2016:200) found that there are several barriers to the successful implementation of Lean practices in South Africa. The barriers in their findings include extensive use of unskilled labour, poor communication, human attitude towards change, lack of interest from clients, lack of supply chain integration and lack of technical skills. They also mentioned perceived complexity of Lean practice implementation by stakeholders, which can be a barrier to implementation. The barrier listed as the extensive use of unskilled labour is a barrier that is not mentioned in research elsewhere in the world.

Chakwizira (2019:79), in their research on using Lean construction approaches to solve low-income housing backlogs, list change management challenges as well as low profit margins as the major barriers to the implementation of a Lean construction framework due to the lack of appetite for experimentation with new practices. These findings align with barriers elsewhere regarding poor change management, acceptance of the status quo and lack of resources.

Fitchett and Rambuwani (2022:111) researched in particular the barriers to the implementation of Lean construction practices to minimise waste and found the main barriers to be poor supervisory capacity, low levels of skills in the labour force, cultural diversity in establishing levels of quality, the late issue of information and the shortage of material. These findings align with the following barriers identified by researchers elsewhere in the world: Lack of resources, lack of an efficient performance management system and design-related challenges. The barrier listed as the low skill level of employees is a barrier that is not mentioned in research elsewhere in the world.

Mangaroo-Pillay and Coetzee (2022:131), in their research about the similarities between *Ubuntu* and Lean practices, found that a barrier to the implementation of a Lean philosophy instead of the traditional management philosophy is the requirement of organisational change. This aligns with the barrier related to poor change management practices found by researchers elsewhere in the world.

5.8 CONCLUSION

From the literature review on the barriers identified in different countries, it is evident that there is no one clear autonomous barrier which, if overcome, would enable the organisation to fully implement Lean construction practices. Rather, the literature shows a series of barriers which could be present in various combinations within an organisation or at a project level.

The following barriers already identified elsewhere in the world, were also identified in existing research on Lean construction practices within the South African construction industry:

Theme 1: Organisational Barriers

- Poor change management practices (Roelandt, 2008:266; Chakwizira, 2019:79; Mangaroo-Pillay & Coetzee, 2022:131).
- Acceptance of the status quo (Chakwizira, 2019:79).
- Lack of resources (Chakwizira, 2019:79; Fitchett & Rambuwani, 2022:111).
- Lack of efficient performance measurement systems (Fitchett & Rambuwani, 2022:111).

Theme 2: Environmental Barriers

- No identifiable research could be found on environmental barriers in the South African construction industry.

Theme 3: Labour / Workforce Barriers

- Employee culture and attitudinal issues (Aigbavboa *et al.,* 2016:200).

Theme 4: Material Barriers

- No identifiable research could be found on material barriers in the South African construction industry.

Theme 5: Exogenous Barriers

- Design-related challenges (Fitchett & Rambuwani, 2022:111).

Barriers unique to the South African Construction Industry context

From the available literature, the following two barriers to the implementation of Lean construction were identified in the South African construction industry which are not identified as significant barriers in research conducting elsewhere in the world:

- Extensive use of unskilled labour (Aigbavboa *et al.,* 2016:200).
- Low skill level of employees (Fitchett & Rambuwani, 2022:111).

CHAPTER 6: DATA COLLECTION, RESULTS AND ANALYSIS

6.1 DATA COLLECTION

The data gathering procedure consisted of a literature review as well as a questionnaire.

A desk study of the available literature on barriers to the implementation of Lean construction already identified in countries outside of South Africa was conducted.

To establish which of the barriers to Lean construction identified in other countries are also prevalent in South Africa, a survey was conducted using a questionnaire.

The questionnaire contained mainly closed-ended questions, but some questions were left open-ended to establish whether there were any barriers which are unique to the South African construction context.

The literature review of different models of Lean construction available was used to review different models and how the models need to be adapted for the South African context, given the data collected.

An electronic questionnaire (as attached in Appendix 2) was sent out to a pilot group of five participants who are registered with the SACPCMP and were selected by the researcher. The questionnaire was adapted based on informal feedback received from the pilot group. Alterations consisted mainly of shortening and clarifying questions by simplifying the language used. After the pilot phase, the questionnaire was sent out to the population sample.

To send out the questionnaire, ethical clearance was obtained from the University of Pretoria's EBIT (Engineering, Built Environment, and Information Technology) faculty's Ethical Clearance Committee, as per the procedure set out by the Committee. According to the policy, all studies that include humans or animals as participants are subject to ethics clearance before data gathering may commence. In the case of this study, human subjects participated as informants through a survey questionnaire and thus this study was subject to the requirement of ethical clearance.

An ethics application, containing all information regarding the study, supporting information such as questionnaires and study leader's approval of the research proposal, was submitted using the online platform on the University of Pretoria's website. In addition to full information regarding the student, project description, aims and objectives, and methodology information regarding the handling of participants' data was also included.

After submission, the application was routed from the student's study leader to the department's HOD and finally to the head of the ethics committee for approval. Upon approval of all parties, a letter confirming ethical clearance for the was issued to the researcher. During the research, the researcher was prompted to update the status of the study on the ethics portal, to ensure that the clearance remain valid for the duration of the study.

Next, an application was submitted to the SACPCMP to request for circulation of the survey questionnaire amongst registered Professional Construction Managers (Pr. CM) and Professional Construction Project Managers (Pr. CPM). The SACPCMP has an established standard operating procedure which includes the researcher's application form and proof of ethical clearance granted by the University of Pretoria.

Once permission was granted by the SACPCMP's education office to proceed with the data collection, the survey was sent out by the SACPCMP education officer to all individuals on their database registered in the categories of Pr. CM or Pr. CPM.

The SACPCMP confirmed that the sample size (number of persons registered in the two targeted categories) was approximately 3600. It was expected that the initial response rate would be low, and thus one week after the initial questionnaire was sent out, the SACPCMP education officer was requested to send an email reminding participants to complete the survey. After the initial two-week period (Questionnaire Phase 1), a total of 78 responses were received. Of the 78 responses, 57 responses were complete (meaning all questions were completely answered), 17 responses were incomplete (meaning at least 20 questions were completed, but not all questions were completed), 4 responses were blank (meaning the respondent accepted the informed consent but did not proceed to respond to any of the questions) and 0 respondents were excluded / disqualified (meaning that all respondents accepted the informed consent).

After capturing the data from the questionnaires received during Phase 1, it was noticed that the open-ended questions did not contain a rich variety of answers. It was also noticed that many respondents stopped completing the questionnaire upon being asked an open-ended question.

The questionnaire was subsequently shortened during Phase 1 by deleting the open-ended questions deemed to not contribute to new knowledge.

The questionnaire was sent out again using the sample population provided by the SACPCMP education office. The group of responses collected from this round of invitations to participate is referred to as Phase 2.

During Phase 2, only seven responses were initially received. The sharp decline in the response rate in comparison with Phase 1 was expected, considering that most of the respondents interested in completing the questionnaire had already done so during Phase 1. To increase the number of responses collected, the researcher used the LinkedIn professional networking application to search for persons registered with the SACPCMP in the required categories. A message was sent to the selected persons via email requesting them to complete the survey that was sent to them. A total of 150 registered persons were reached in this way.

After sending follow-up messages to respondents via this channel, a total of 58 responses were received during Phase 2. Of the 58 responses, 36 responses were complete (meaning all questions were completely answered), 11 responses were incomplete (meaning at least 20 questions were completed, but not all questions were completed), 6 responses were blank (meaning the respondent accepted the informed consent, but did not proceed to respond to any of the questions) and 5 respondents were excluded / disqualified (meaning that 5 respondents did not accept the informed consent and thus could not proceed to answer any questions).

The total response rate of the questionnaires is summarised in Table 6.1.

Table 6.1 Questionnaire response rate

Phase #	Number of responses received	Number of complete questionnaires	Number of incomplete questionnaires	Number of questionnaires left blank	Number of disqualified questionnaires
Phase 1	78	57	17	4	0
Phase 2	58	36	11	6	5
Total	136	93	28	10	5

From the responses received, the number of usable questionnaires was 121.

The date analysis was supported by a statistician from the department of Statistics at the University of Pretoria.

The data was captured by the researcher using a coded template, which was agreed with the statistician beforehand. The data was captured in such a way that the data contained in incomplete questionnaires could still be analysed. The open-ended questions were not statistically analysed but were scrutinised for any pattern and recorded as additional barriers (where applicable) or kept for a possible future area of research, if required.

6.2 RESULTS

6.2.1 Respondents' familiarity with Lean construction management systems

Respondents were asked about their familiarity with Lean construction management systems. The results are summarised in Table 6.2.

Table 6.2 Results of Question 2: To what extent are you familiar with Lean construction management systems (Questionnaire Question 2)

Response	Counts	Proportion %
Very familiar	23	19.83%
Somewhat familiar	53	45.69%
Not at all familiar	40	34.48%

The respondents who indicated that they are very familiar with Lean construction management systems have theoretical knowledge of Lean tools and have had the opportunity to implement Lean construction tools on at least one project in the past. The respondents who indicated that they are somewhat familiar with Lean construction management systems, have some theoretical knowledge of Lean construction tools but have not yet had the opportunity to implement these tools on any projects. The respondents who indicated that they are not all familiar with Lean construction management systems do not have any theoretical knowledge of Lean construction management tools and had not implemented these tools on any projects in the past.

These results are illustrated in Figure 6-1.

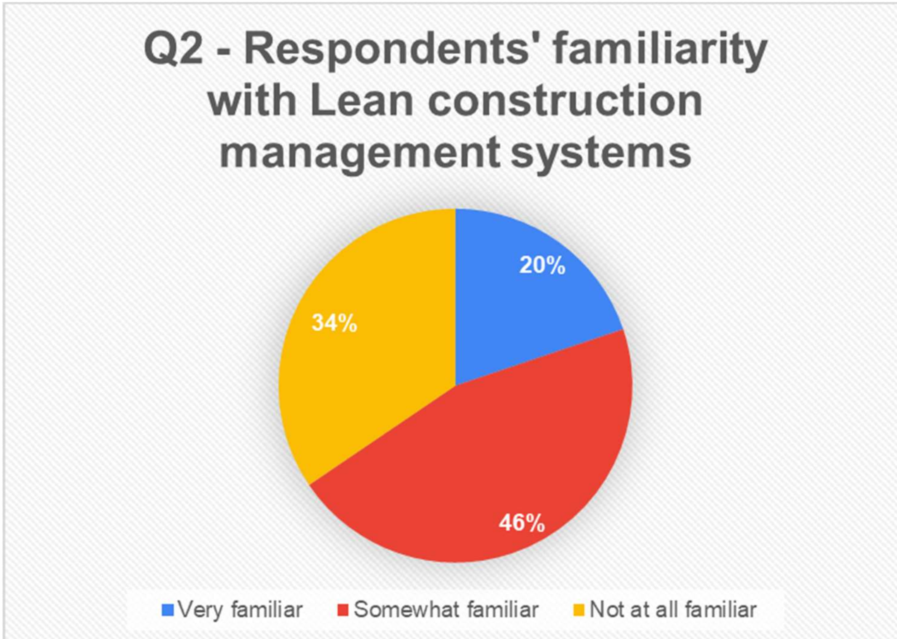

Figure 6-1 Respondents' familiarity with Lean construction management systems (Questionnaire Question 2)

6.2.2 Respondents' usage of Lean construction tools

Respondents were asked about their usage of Lean construction management tools. The results are summarised in Table 6.3.

Table 6.3 Results of Question 3: Do you use any Lean construction tools when managing construction projects? (Questionnaire Question 3)

Response	Count	Proportion %
Currently in use	22	18.64%
Previously in use	24	20.34%
Interested to start	69	58.47%
Not interested to start	3	2.54%

18.64% of respondents indicated that they use Lean construction management tools and that they are currently working on projects where Lean construction management tools are implemented. 20.34% of respondents indicated that they do not currently use Lean construction management tools, but that they have used Lean construction management tools on past projects. 58.47% of respondents indicated that they are not using Lean construction management tools, but that they would be interested in implementing these tools if given the opportunity. 2.54% of respondents indicated that they do not use Lean construction management tools and that they would not be interested in implementing these tools. These results are illustrated in Figure 6-2.

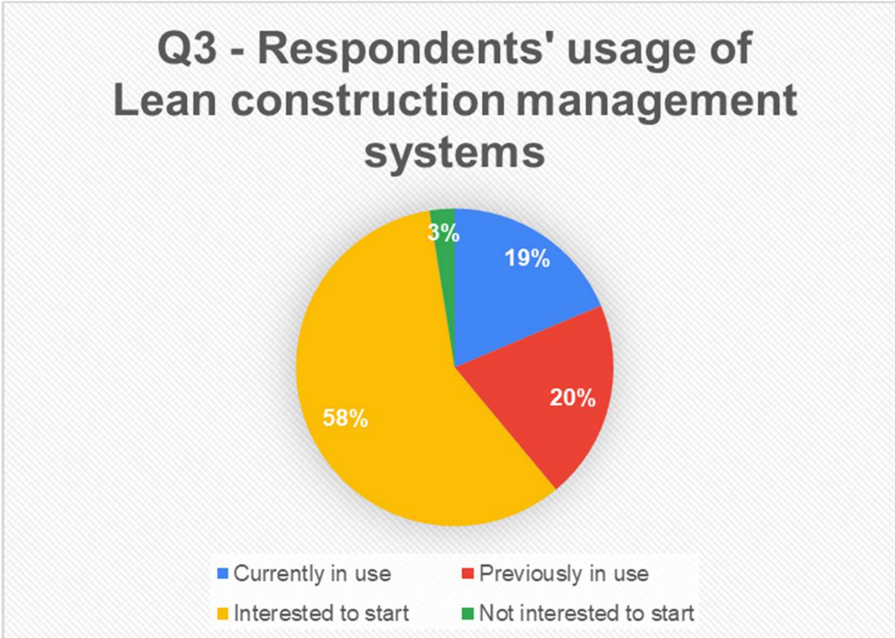

Figure 6-2 Respondents' usage of Lean construction management systems (Questionnaire Question 3)

6.2.3 Construction management tools used by Construction Management Practitioners in South Africa

Respondents were asked which general construction management tools they have used during management of their construction projects.

Table 6.4 shows the list of options presented to respondents to select from.

Table 6.4 Possible responses (Questionnaire Question 4)

Item No	Response Option	Questionnaire code
1	Last Planner System (LPS)	LPS
2	Just-in-Time (JIT)	JIT
3	Per cent Plan Complete (PPC)	PPC
4	Look-ahead Planning	LAP
5	Daily Production Reports	DPR
6	Continuous Improvement	CI
7	Prefabrication	Prefab
8	Reverse Logistics	RevLog
9	Value Engineering (VE)	VE
10	Building Information Modelling (BIM)	BIM
11	Critical Path Method	CPM
12	Location Based Management Systems (LBMS)	LBMS
13	Value Stream Mapping (VSM)	VSM
14	Performance-Based Requirements	PBR

15	Quality Function Deployment (QFD)	QFD
16	Post Occupancy Evaluation (POE)	POE
17	Total Quality Management (TQM)	TQM

The number of tools chosen by respondents is shown in Table 6.5.

Table 6.5 Number of changes selected by the respondents (Questionnaire Question 4)

Number of responses	Value
Missing	0
Minimum	1
Maximum	17
Median (IQR)	6 (4.00, 8.00)
Mean (SD)	5.81 ± 3.13
Mean (95% CI)	5.81 (95% CI: 5.16, 6.45)

The tools selected by respondents were ranked in order of most selected to least selected to determine which tools are used most often – see Table 6.6.

Table 6.6 Tools selected by respondents (Questionnaire Question 4)

Item no	Tool	Count	Rank
11	Critical Path Method	86	1
4	Look-ahead Planning	57	2
5	Daily Production Reports	57	2
9	Value Engineering	54	3
17	Total Quality Management	52	4
6	Continuous Improvement	46	5
3	Per cent Plan Complete	36	6
10	Building Information Modelling	33	7
2	Just-In-Time	29	8
14	Performance-Based Requirements	27	9
7	Prefabrication	26	10
15	Quality Function Deployment	14	11
16	Post Occupancy Evaluation	9	12
1	Last Planner System	5	13
8	Reverse Logistics	2	14
12	Location Based Management System	2	14
13	Value Stream Mapping	2	14

Respondents most often selected the Critical Path Method, Look-ahead Planning and Daily Production Reports as tools that they use on construction projects. The least selected tools were Reverse Logistics, Location Based Management System and Value Stream Mapping.

These results are illustrated in Figure 6-3.

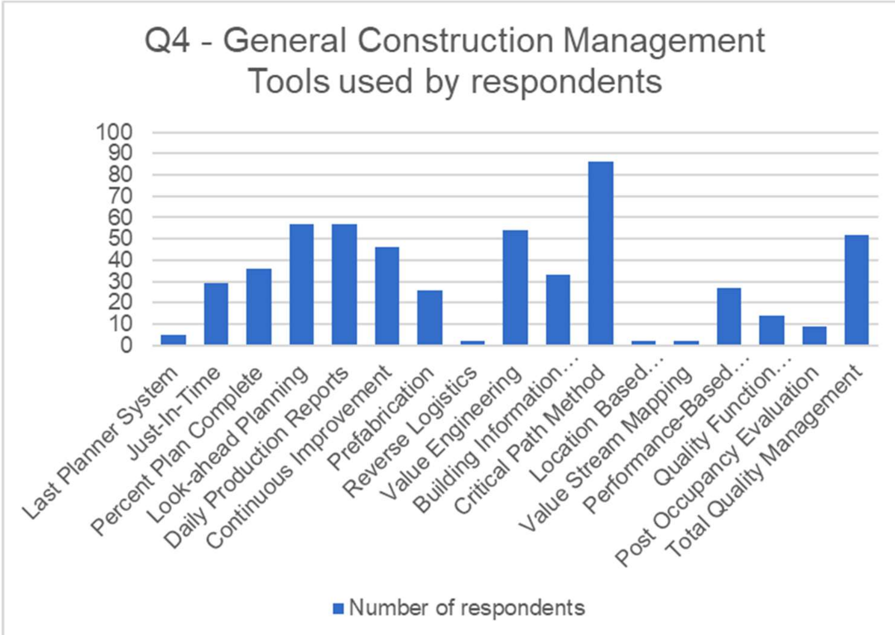

Figure 6-3 General construction management tools used by respondents (Questionnaire Question 4)

Respondents were also asked to specify any other construction management tools that they use to manage their construction projects. Three respondents indicated that they use "Candy Construction Software" (CCS), one respondent indicated that they use "Cable Management System" software, and one respondent indicated that they use a "Process Group" tool to monitor and control processes within their organisation.

6.2.4 Problems encountered by South African Construction Management Practitioners on construction projects

Respondents were asked which problems they regularly encounter on the construction projects that they manage.

Table 6.7 shows the list of possible problems was presented for respondents to choose from.

Table 6.7 Possible responses to (Questionnaire Question 6)

No	Response Option	Questionnaire code
1	Lack of skilled artisans	Skills
2	Labour issues (strikes/disputes)	Labour
3	Long organisational processes (ordering/recruitment)	OrgProc
4	Long processes due to centralised decision-making	Centra
5	Lack of top management commitment to implement management tools	TMLack
6	Lack of top management to change to more dynamic management systems	TMChange
7	Poor knowledge management practices (when staff resign, their knowledge leaves the company with them)	KMPoor
8	Poor change management practices (difficult and frustrating when new systems are being implemented)	CMPoor
9	Lack of top management support to implement new initiatives	TMSup
10	Taking initiative is discouraged and being careful is encouraged	InDiscour
11	Subcontractors not following the main contractor's management practices	Subc
12	Lack of funding for training at all levels of the organisation	TMFunds
13	Lack of an efficient performance management system	LackPM
14	Lack of the appropriate software applications to manage production	LackSoftw
15	Lack of internal information flow (between employees of the organisation)	LIFInt
16	Lack of external information flow (between different stakeholders on the project)	LIFExt
17	No culture of continuous improvement in the organisation	NoCI
18	High productivity is rewarded with a heavier workload	WL
19	Lack of proactive measures on site (staff dealing with crises on a regular basis)	crises
20	Loss of resources due to theft	theft
21	Loss of resources due to material waste and rework	waste
22	Lack of technological capabilities of staff	Techcap

The number of problems / challenges chosen by respondents was recorded – see Table 6.8.

Table 6.8 Number of challenges selected by the respondents (Questionnaire Question 6)

Number of responses	Value
Missing	0
Minimum	3
Maximum	22
Median (IQR)	9 (6.00, 14.00)
Mean (SD)	10.14 ± 4.9
Mean (95% CI)	10.14 (95% CI: 9.13, 11.15)

The problems encountered were selected by respondents and then ranked in order of most selected to least selected to determine which challenges are most prevalent – see Table 6.9.

Table 6.9 Problems regularly encountered selected by respondents (Questionnaire Question 6)

Item no	Tool	Count	Rank
2	Labour issues (strikes / disputes)	74	1
1	Lack of skilled artisans	66	2
11	Subcontractors not following the MC's management	61	3
7	Poor knowledge management practices	55	4
3	Long organisational processes	54	5
4	Long processes due to centralised decision-making	51	6
20	Loss of resources due to theft	48	7
21	Loss of resources due to waste and rework	47	8
22	Lack of technical capabilities of staff	44	9
19	Lack of proactive measures on site	43	10
8	Poor change management practices	36	11
13	Lack of efficient performance management system	36	11
17	No culture of continuous improvement	37	12
9	Lack of top management support	36	13
12	Lack of funding for training	35	14
18	High productivity rewarded with heavier workload	35	14
5	Lack of top management commitment to implement management tools	34	15
14	Lack of appropriate software applications	30	16
15	Lack of internal information flow	30	16
6	Lack of top management to change to more dynamic management systems	27	17
16	Lack of external information flow	26	18
10	Taking initiative is discouraged and being careful is encouraged	20	19

The challenges selected by most respondents were labour issues (strikes and disputes), lack of skilled artisans, and subcontractors not adhering to the main contractor's management practices. The challenges least selected as regularly encountered were lack of top management to change to more dynamic management systems, lack of external information flow, and taking initiative being discouraged.
These results are illustrated in Figure 6-4.

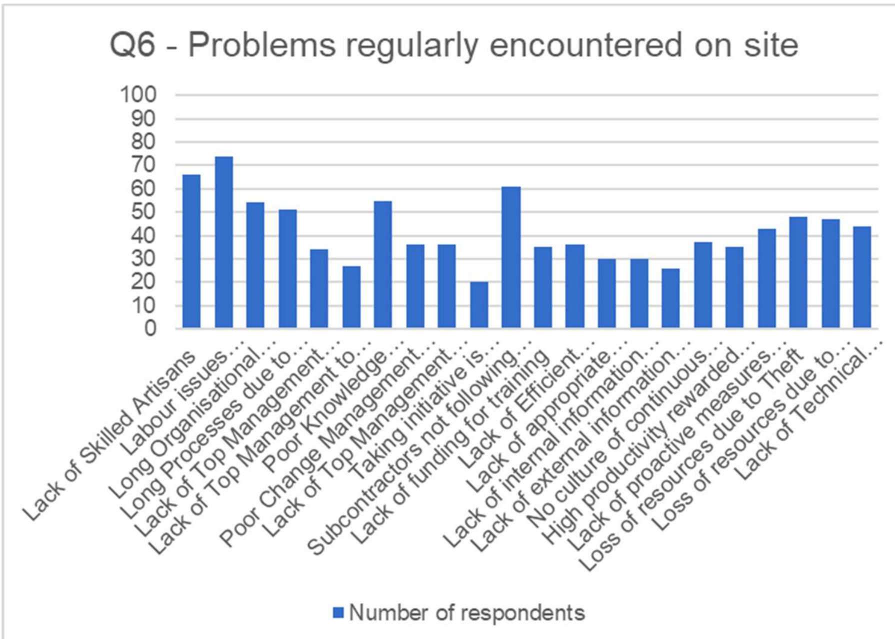

Figure 6-4 Problems regularly encountered on site (Questionnaire Question 6)

Respondents were given the choice to select "other" and specify other problems regularly encountered on their sites, which were not listed in the multiple choices presented. Seven respondents included this choice amongst their lists and specified the following issues that they regularly encounter on site:

- Poor knowledge of site personnel of standard forms and contracts, parties' rights, and obligations.
- Constant work stoppages due to "business forums".
- Client constraining the project managers by retaining authority (In public sector projects).
- Constant work stoppages due to community involvement.
- Lack of full commitment of senior staff due to being appointed on fixed term contracts.
- Lack of knowledge in dealing with small, medium and micro enterprises (SMMEs).

- Management, health and safety and quality processes not duly executed and merely a paper exercise to comply with company policies.

Each respondent was further asked to indicate the problems most often encountered from their list of selected choices in Question 6 – see Table 6.10.

Table 6.10 Problems most often encountered from respondents' selection (Questionnaire Question 8)

Item no	Tool	Count	Rank
2	Labour issues (strikes / disputes)	53	1
1	Lack of skilled artisans	50	2
3	Long organisational processes	23	3
11	Subcontractors not following the MC's management	18	4
7	Poor knowledge management practices	16	5
4	Long processes due to centralised decision-making	15	6
20	Loss of resources due to theft	13	7
5	Lack of top management commitment to implement management tools	11	8
13	Lack of efficient performance management system	10	9
21	Loss of resources due to waste and rework	9	10
19	Lack of proactive measures on site	8	11
22	Lack of technical capabilities of staff	8	11
8	Poor change management practices	7	12
15	Lack of internal information flow	7	12
17	No culture of continuous improvement	7	12
6	Lack of top management to change to more dynamic management systems	5	13
16	Lack of external information flow	5	13
9	Lack of top management support	4	14
10	Taking initiative is discouraged and being careful is encouraged	4	14
12	Lack of funding for training	4	14
18	High productivity rewarded with heavier workload	4	14
14	Lack of appropriate software applications	3	15

Respondents selected labour issues (strikes and disputes), lack of skilled artisans and long organisational processes as the three challenges encountered most often on construction projects. Respondents selected lack of funding for training, high productivity rewarded with heavier workload, and lack of appropriate software applications the least amongst their choice of regular problems encountered.

These results are illustrated in Figure 6-5.

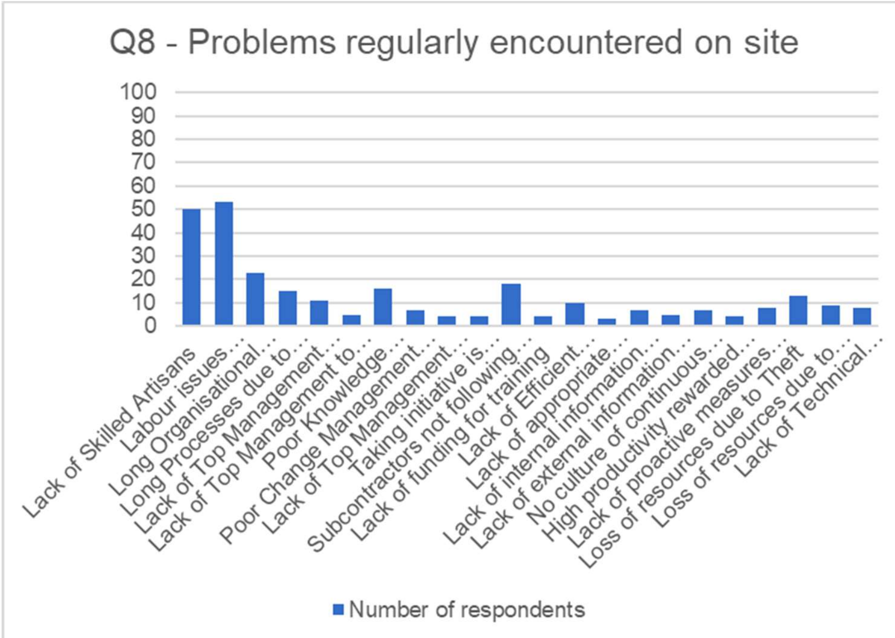

Figure 6-5 Problems encountered most often from respondents' selection (Questionnaire Question 8)

Respondents were asked what, in their opinion, was the main cause of their three most-encountered issues on a construction project. Respondents supplied 119 responses which were categorically organised. The ten categories which contained elements raised by two or more respondents are listed in Table 6.11.

Table 6.11 Respondents' opinions on main causes of problems encountered (Questionnaire Question 9)

Item no	Category	Count	Rank
1	Lack of training facilities to train and accredit South African artisans	19	1
2	Requirement to use local subcontractors even though no skilled subcontractors available	9	2
3	Problems with client not adhering to their contract obligations, making decisions without assessing the impact on the project	8	3
4	Interference of business forums and construction mafia	7	4
5	Community involvement causing work stoppages	6	5
6	Bureaucracy ("red tape") causing delays	6	5
7	Unrealistic demands of labour unions	4	6
8	Lack of retention of skilled staff once trained	2	7
9	Lack of succession planning	2	7
10	Willingness of staff to implement new management systems	2	7

These results are illustrated in Figure 6-6.

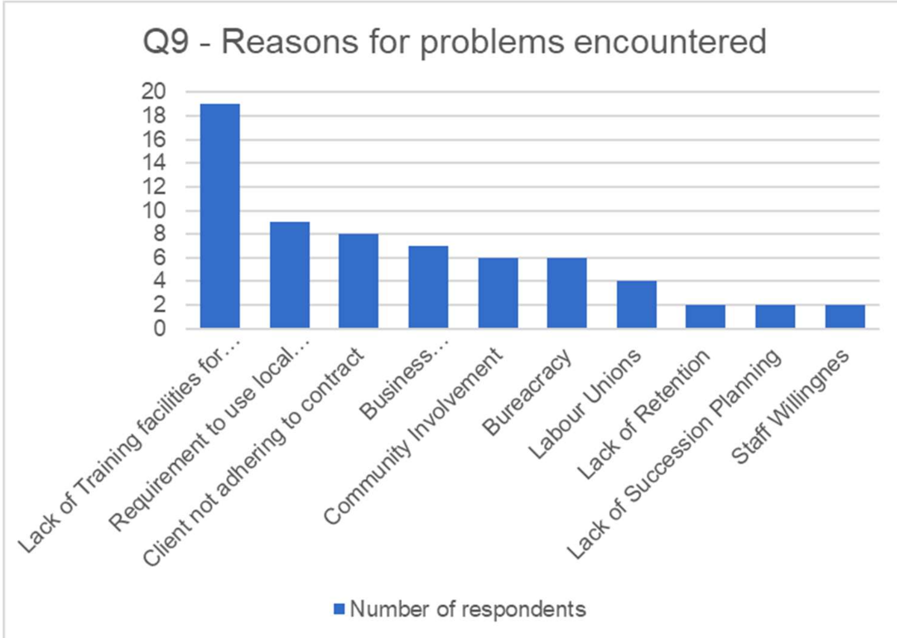

Figure 6-6 Respondents' opinions on main causes of problems encountered (Questionnaire Question 9)

6.2.5 External problems / challenges encountered by Construction Management Practitioners in South Africa during management of construction projects

Respondents were asked about external factors encountered which could cause problems / challenges in construction projects.

Table 6.12 shows the list of external factors that were presented for respondents to select from.

Table 6.12 Possible responses to (Questionnaire Question 10)

No	Response Option	Questionnaire code
1	Government policies or bureaucracy	Gov
2	Long lead times from tender to project award	LeadT
3	Unstable material prices	Prices
4	Unstable construction market conditions	MCon
5	Fragmented nature of the construction project (client / contractor / consultant having different interests)	Fragm
6	Lack of information sharing between project stakeholders	LackIS
7	Low profit margins	LofProfit
8	Corruption (fraud / bribery)	Corruption
9	Lack of client funding to complete the project	Lackfunding
10	Inaccurate designs having to change while construction is underway	Inndesign
11	Contractual issues due to client / consultant / contractor not performing their duties	Contract
12	Delays due to disputes and claims	Disputes
13	Client changing the design while construction is underway (due to client requirements changing)	ReqChange

The number of factors chosen by respondents was recorded – see Table 6.13.

Table 6.13 Number of external factors selected by respondents (Questionnaire Question 10)

Number of responses	Value
Missing	0
Minimum	3
Maximum	13
Median (IQR)	6.00 (5.00, 9.00)
Mean (SD)	6.88 ± 2.63
Mean (95% CI)	6.88 (95% CI: 6.34, 7.42)

On average, respondents selected six factors.

The factors selected by respondents were then ranked in order of most selected to least selected to determine which factors are encountered most often – see Table 6.14.

Table 6.14 External factors selected by respondents (Questionnaire Q10)

Item no	Category	Count	Rank
2	Long lead times from tender to project award	74	1
1	Government policies or bureaucracy	61	2
11	Contractual issues due to client / consultant / contractor not performing their duties	61	2
10	Inaccurate designs having to change while construction is underway	55	3
8	Corruption (fraud / bribery)	51	4
13	Client changing the design while construction is underway (due to client requirements changing)	50	5
7	Low profit margins	47	6
12	Delays due to disputes and claims	47	6
4	Unstable construction market conditions	45	7
3	Unstable material prices	43	8
5	Fragmented nature of the construction project (client/ contractor / consultant having different interests)	42	9
6	Lack of information sharing between project stakeholders	33	10
9	Lack of client funding to complete the project	24	11

Most respondents selected long lead times from tender to project award, government policies or bureaucracy and contractual issues due to client / contractor / consultant not performing their duties.

These results are illustrated in Figure 6-7.

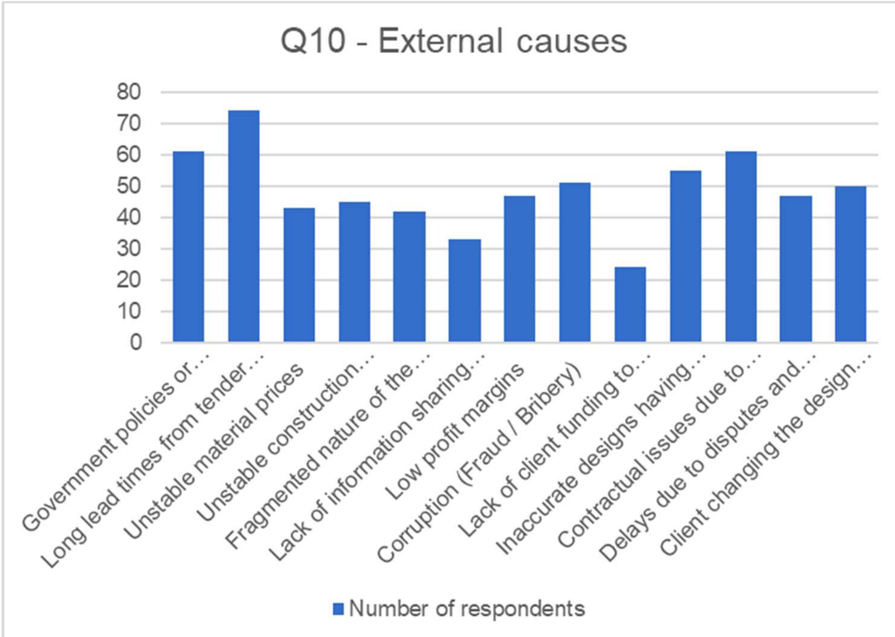

Figure 6-7 External causes of problems encountered (Questionnaire Question 10)

Respondents were asked, in their opinion, where the root of most construction project problems / challenges lay.

Table 6.15 shows the options that were given for respondents to select from.

Table 6.15 Possible responses to Questionnaire Question 14

No	Response Option	Questionnaire code
1	External (due to the behaviour of stakeholders in the project who are not part of my organisation)	External
2	Internal (due to the behaviour of individuals / systems within the organisation that I work for / project that I manage)	Internal
3	Structural (due to industry practices / governmental policies)	Structural

The responses were as shown in Table 6.16.

Table 6.16 Source of challenges selected by respondents (Questionnaire Question 14)

Response	Count	Proportion %
External	38	40.86%
Internal	25	26.88%
Structural	30	32.26%

40.68% of respondents indicated that the root of most construction management – related problems is external (due to the behaviour of project stakeholders who are not part of the respondent's organisation). 32.26% of respondents indicated that the root of these problems is structural (due to industry practices / governmental policies). 26.88% of respondents indicated that these problems are internal (due to behaviour of individuals / systems within the organisation that they work for / project that they manage).

These results are illustrated in Figure 6-8.

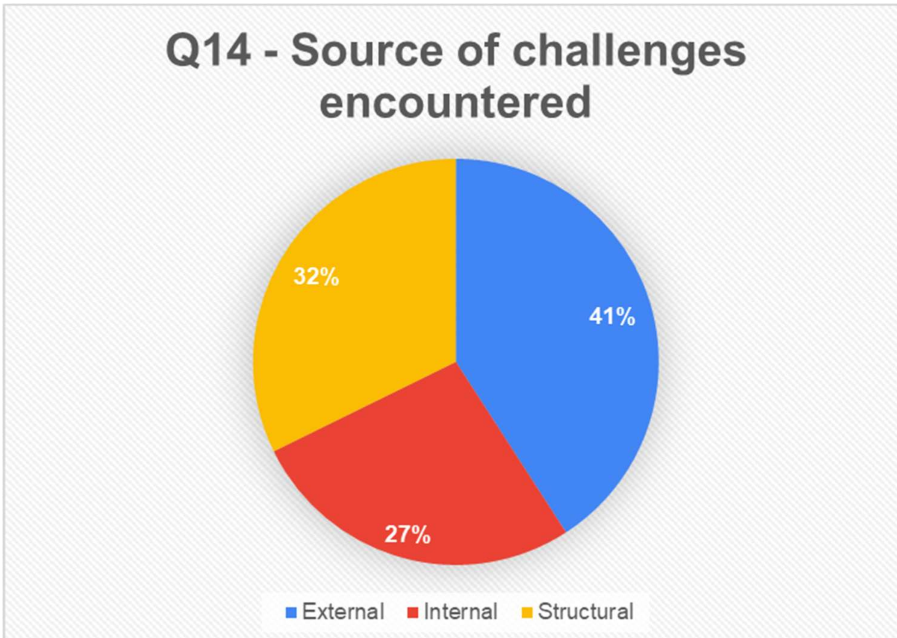

Figure 6-8 Source of challenges selected by respondents (Questionnaire Question 14)

6.2.6 Perceived problems experienced by Construction Management Practitioners in South Africa post the COVID-19 pandemic

Respondents were asked whether problems affecting projects, as listed in the questionnaire, (Question 12) have decreased, increased, or remained the same after the COVID-19 pandemic. The results were as follows:

Table 6.17 shows the responses.

Table 6.17 Perceived increase of encountered problems after the Covid19 pandemic (Questionnaire Question 15)

Response	Count	Proportion %
Less	2	2.15%
More	56	60.22%
Same	35	37.63%

Most respondents (60.22%) stated that problems have increased, 37.63% indicated problems have remained the same and 2.15% indicated that problems have decreased. These results are illustrated in Figure 6-9.

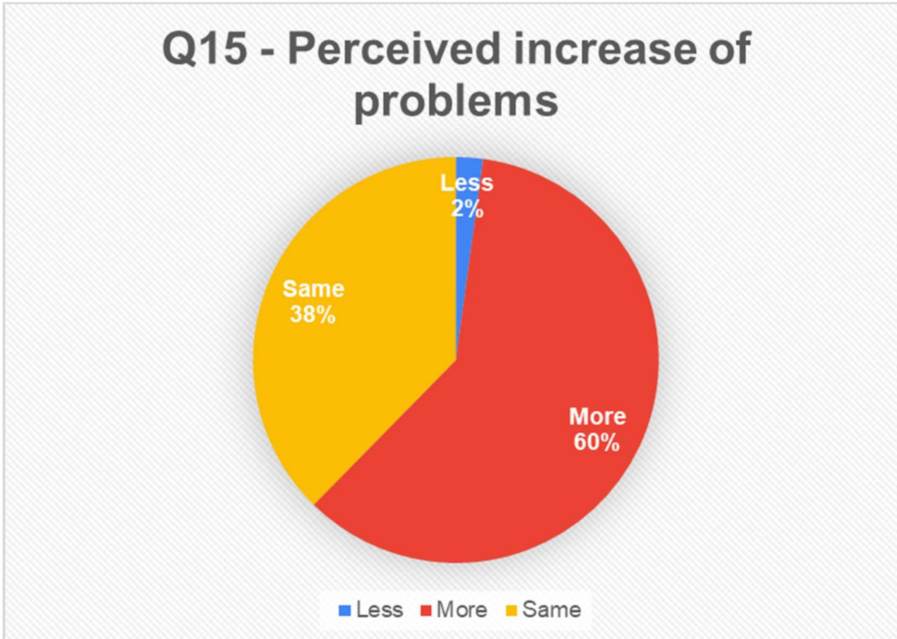

Figure 6-9 Perceived increase of encountered problems after the Covid19 pandemic (Questionnaire Question 15)

6.2.7 Waste as inevitable element of a South African construction project

Respondents were asked the extent to which they agreed that waste is an unavoidable element of construction projects. The results are summarised in Table 6.18.

Table 6.18 Extent of respondents' agreement that waste is an unavoidable element of a construction project (Questionnaire Question 16)

Response	Count	Proportion %
Completely agree	16	17.2%
Somewhat agree	36	38.71%
Neither agree nor disagree	4	4.3%
Somewhat disagree	23	24.73%
Completely disagree	14	15.05%

17.2% of respondents completely agreed that waste is inevitable. 38.71% of respondents somewhat agreed that waste is inevitable in construction projects. 4.3% of respondents neither agreed nor disagreed with the statement. 24.73% of respondents somewhat disagreed with the statement, while 15.05% completely disagreed with the statement.

These results are illustrated in Figure 6-10.

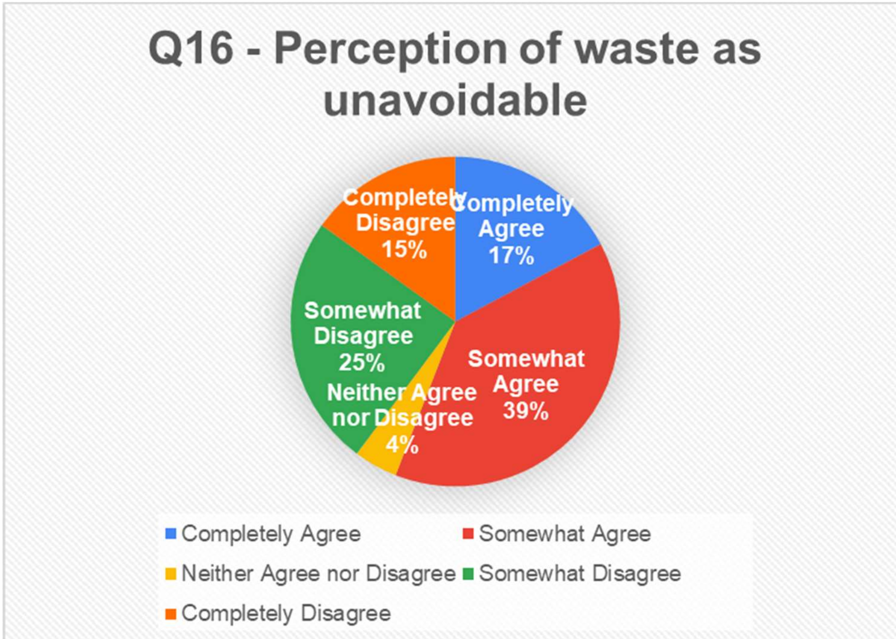

Figure 6-10 Respondents' perception of waste as unavoidable element of a construction project (Questionnaire Question 16)

6.2.8 Number of waste elements encountered on South Africa construction projects

Respondents were asked which types of waste they most often encounter during the execution of their construction projects.

Table 6.19 presents the list of possible types of waste was presented to respondents to select from (questionnaire code in brackets).

Table 6.19 Types of Waste listed for selection by respondents (Questionnaire Question 17)

No	Type of waste	Questionnaire code
1	Demolition of defective workmanship	DefW
2	Rejection of defective products / materials	Product
3	Double handling of material	DHand
4	Waiting for resources due to logistical issues	logistical
5	Unnecessary movement of goods or people	Unneccesarynmove
6	Waiting for decisions to be made by external stakeholders	Waitdec
7	Waiting for information (drawings, RFI responses, instructions, etc.)	Waitinf
8	Excess inventory not used on the project	Excesinv
9	Making do with resources available on site	Making-do
10	Theft / shrinkage	Theft
11	Production halt due to safety incidents	Safety
12	Production halt due to environmental approvals / Incidents	Env
1	Demolition of defective workmanship	DefW
2	Rejection of defective products / materials	Product
3	Double handling of material	DHand
4	Waiting for resources due to logistical issues	logistical
5	Unnecessary movement of goods or people	Unneccesarynmove
6	Waiting for decisions to be made by external stakeholders	Waitdec

The number of types of waste selected by respondents were recorded, as shown in Table 6.20.

Table 6.20 Number of types of waste selected by the respondent (Questionnaire Question 17)

Number of responses	Value
Missing	1
Minimum	3
Maximum	12
Median (IQR)	5.00 (3.00, 6.00)
Mean (SD)	5.28 ± 2.37
Mean (95% CI)	5.28 (95% CI: 4.79, 5.77)

Respondents selected on average five types of waste from the list presented. The respondent who selected the least number of types of waste from the list, selected three different types, while the respondent who selected the greatest number of types of waste from the list, selected all twelve types presented.

6.2.9 Types of waste most encountered on South African construction projects

The selected types of waste were ordered from most selected to least selected, as per Table 6.21.

Table 6.21 Types of waste most encountered (Questionnaire Question 17)

Item no	Category	Count	Rank
1	Demolition of defective workmanship	60	1
6	Waiting for decisions to be made by external stakeholders	58	2
3	Double handling of material	57	3
7	Waiting for information (drawings, RFI responses, instructions, etc.)	57	3
10	Theft / shrinkage	53	4
4	Waiting for resources due to logistical issues	40	5
2	Rejection of defective products / materials	39	6
9	Making do with resources available on site	30	7
11	Production halt due to safety incidents	25	8
5	Unnecessary movement of goods or people	23	9
8	Excess Inventory not used on the project	22	10
12	Production halt due to environmental approvals / incidents	22	10

The five most selected types of waste were demolition of defective workmanship, waiting for decisions to be made by external stakeholders, double handling of material, waiting for information (drawings, RFI responses, instructions etc.) and theft.

These results are illustrated in Figure 6-11.

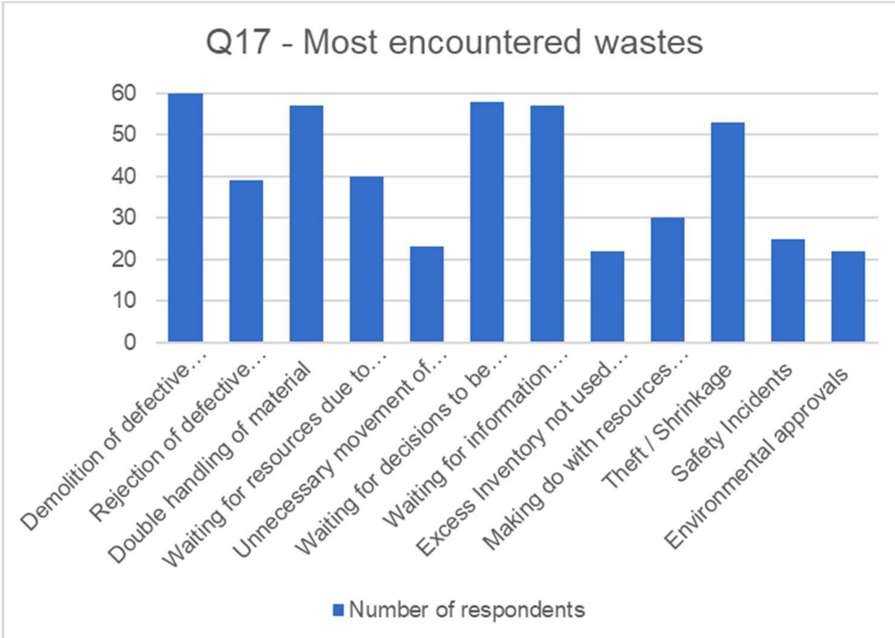

Figure 6-11 Types of waste most encountered (Questionnaire Question 17)

6.2.10 Three types of waste most often encountered on South African construction projects

Respondents were asked to select from their own base selection in 6.2.3, the three types of waste that they encounter most often on their construction projects. The results were as shown in Table 6.22.

Table 6.22 Most prevalent types of waste encountered (Questionnaire Q19)

Item no	Category	Count	Rank
1	Demolition of defective workmanship	46	1
7	Waiting for information (drawings, RFI responses, instructions, etc.)	40	2
3	Double handling of material	38	3
10	Theft / shrinkage	35	4
6	Waiting for decisions to be made by external stakeholders	34	5
2	Rejection of defective products / materials	23	6
4	Waiting for resources due to logistical issues	16	7
9	Making do with resources available on site	13	8
11	Safety incidents	13	8
5	Unnecessary movement of goods or people	12	9
8	Excess inventory not used on the project	8	10
12	Environmental approvals	5	11

The three types of waste most often selected by respondents were defective workmanship, waiting for information (drawings, RFI responses, instructions, etc.) and double handling.

These results are illustrated in Figure 6-12.

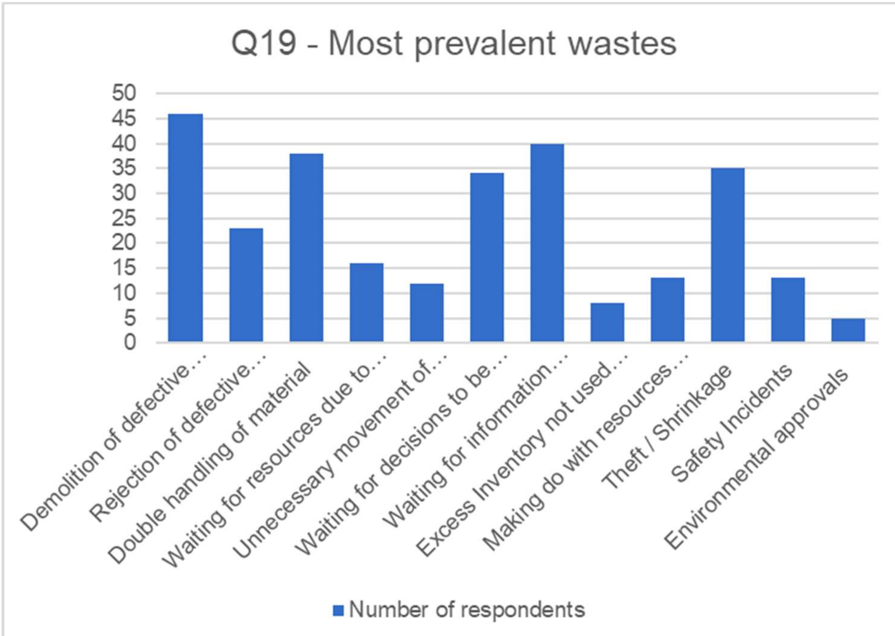

Figure 6-12 Most prevalent types of waste selected (Questionnaire Question 19)

6.2.11 Types of waste that have become more noticeable on South African construction projects after the COVID-19 pandemic

Respondents were asked which types of waste have noticeably increased on South African construction sites after the COVID-19 pandemic. The results are listed in Table 6.23.

Table 6.23 Types of waste which have noticeably increased after the COVID-19 pandemic (Questionnaire Question 21)

Item no	Category	Count	Rank
4	Waiting for resources due to logistical issues	40	1
6	Waiting for decisions to be made by external stakeholders	34	2
10	Theft / shrinkage	31	3
7	Waiting for information (drawings, RFI responses, Instructions, etc.)	28	4
5	Unnecessary movement of goods or people	23	5
11	Safety incidents	19	6
3	Double handling of material	18	7
1	Demolition of defective workmanship	17	8
9	Making do with resources available on site	15	9
2	Rejection of defective products / materials	11	10
8	Excess inventory not used on the project	7	11
12	Environmental approvals	5	12

Respondents most often selected waiting for resources due to logistical issues, waiting for decisions to be made by external stakeholders, theft, and waiting for information (drawings, RFI responses, instructions, etc.) as the four types of waste which have noticeably increased after the COVID-19 pandemic.

These results are illustrated in Figure 6-13.

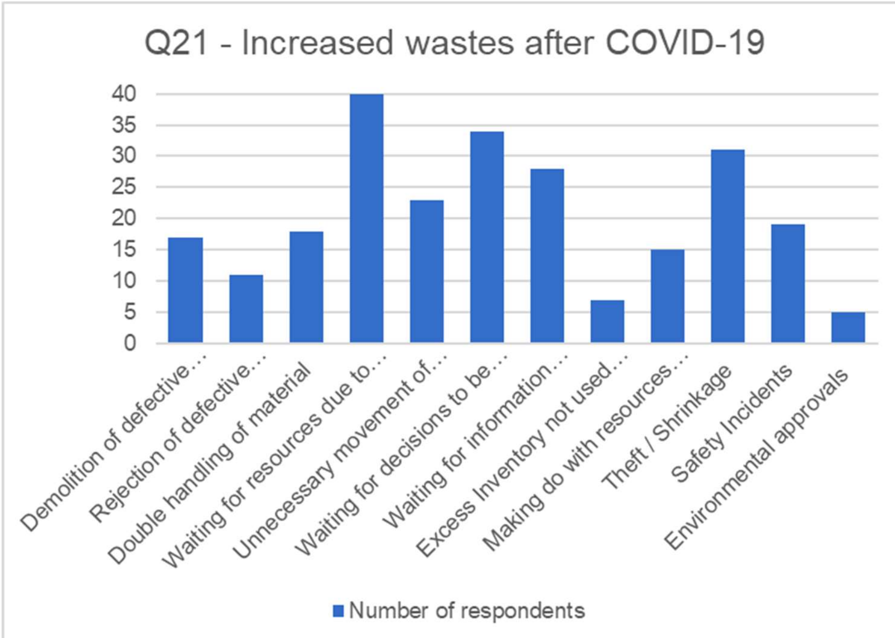

Figure 6-13 Types of waste which have noticeably increased after the COVID-19 pandemic (Questionnaire Question 21)

6.2.12 Effect of COVID-19 on construction management practices in South Africa

Respondents were asked whether the COVID-19 pandemic has affected the way they manage their construction projects.

Table 6.24 shows the options that were given for respondents to select from:

Table 6.24 Possible responses to Questionnaire Question 27

No	Response Option	Questionnaire code
1	Yes, I am using different management methods as a direct result of the COVID-19 pandemic	Yes, direct
2	Yes, I am using different managing methods, but it is not a direct result of the COVID-19 pandemic	Yes, not direct
3	No, I am using the same methods as before the pandemic, but looking into alternative methods	No, alt
4	No, I am using the same methods as before the pandemic and do not plan to incorporate alternative methods	No

The results were as shown in Table 6.25.

Table 6.25 COVID-19 effect on construction project management methods (Questionnaire Q27)

No	Response	Count	Proportion %
1	Yes, Direct	31	33.33%
2	Yes, Not direct	17	18.28%
3	No, Looking into alternatives	31	33.33%
4	No, no plans for alternatives	14	15.05%

33.33% of respondents indicated that they are using different management methods as a direct result of the COVID-19 pandemic. 33.33% of respondents indicated that they are using the same methods as before the pandemic but are looking into alternative methods. 18.25% of respondents indicated that they are using different methods, but not as a direct result of the pandemic. 15.05% of respondents indicated that they are using the same methods as before the pandemic and do not plan to incorporate alternative methods.

The results are depicted in Figure 6-14.

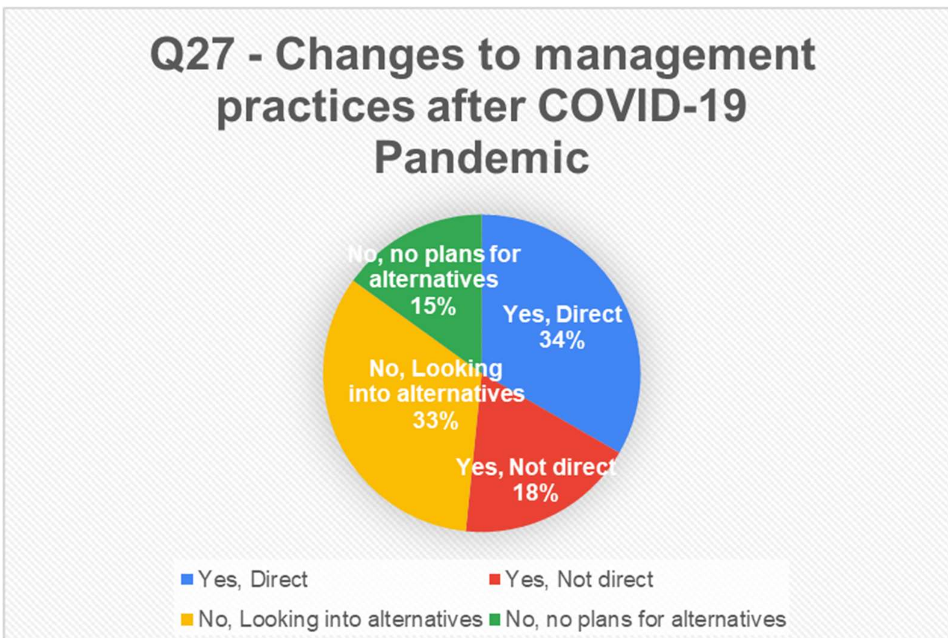

Figure 6-14 Effect of COVID-19 pandemic on changes to construction management practices (Questionnaire Question 27)

6.2.13 South African Construction Management Practitioners' access to financial resources to implement changes to construction management practices

Respondents were asked to state whether they have access to the required financial resources to implement changes to their construction management practices.

The results were as shown in Table 6.26.

Table 6.26 Respondents' indication of lack of access to financial resources to implement changes to construction management practices (Questionnaire Question 22)

Response	Count	Proportion %
Completely agree	20	21.51%
Somewhat agree	33	35.48%
Neither agree nor disagree	20	21.51%
Somewhat disagree	13	13.98%
Completely disagree	7	7.53%

21.51% of respondents completely agreed that they do not have access to financial resources required. 35.48% of respondents somewhat agreed, 21.51% neither agreed or disagreed, 13.98% somewhat disagreed, and 7.53% completely disagreed that they do not have access to the required resources to manage their construction projects.

The results are depicted in Figure 6-15.

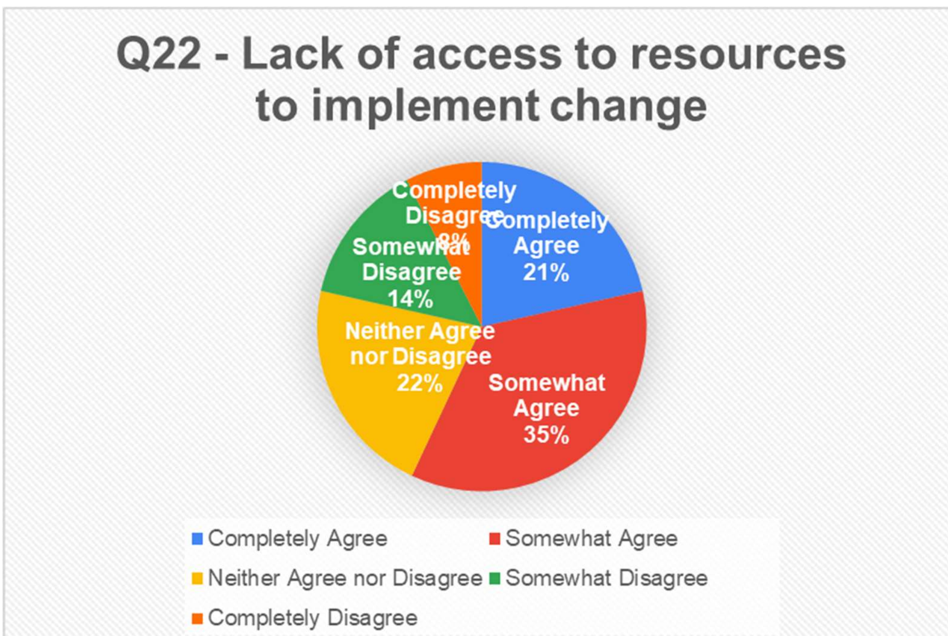

Figure 6-15 Respondents' indication of lack of access to financial resources to implement changes to construction management practices (Questionnaire Question 22)

6.2.14 South African Construction Management Practitioners' appetite for change in construction methods if lack of financial resources is not a constraint

Respondents were asked to state whether they would make any changes to their methods if they had access to the financial resources required to implement changes to their current construction management practices.

Table 6.27 presents the options that were given for respondents to select from.

Table 6.27 Possible responses to Questionnaire Question 23

No	Response Option	Questionnaire code
1	Make major / substantial changes to my current way of working	Major
2	Make minor / slight changes to my current way of working	Slight
3	Make no changes to my current way of working	No change

The results were as shown in Table 6.28.

Table 6.28 Extent of change implemented by respondents if financial resources were available (Questionnaire Question 23)

	Response	Count	Proportion %
1	Major change	50	53.76%
2	Slight change	37	39.78%
3	No change	1	1.08%

The results are depicted in Figure 6-16.

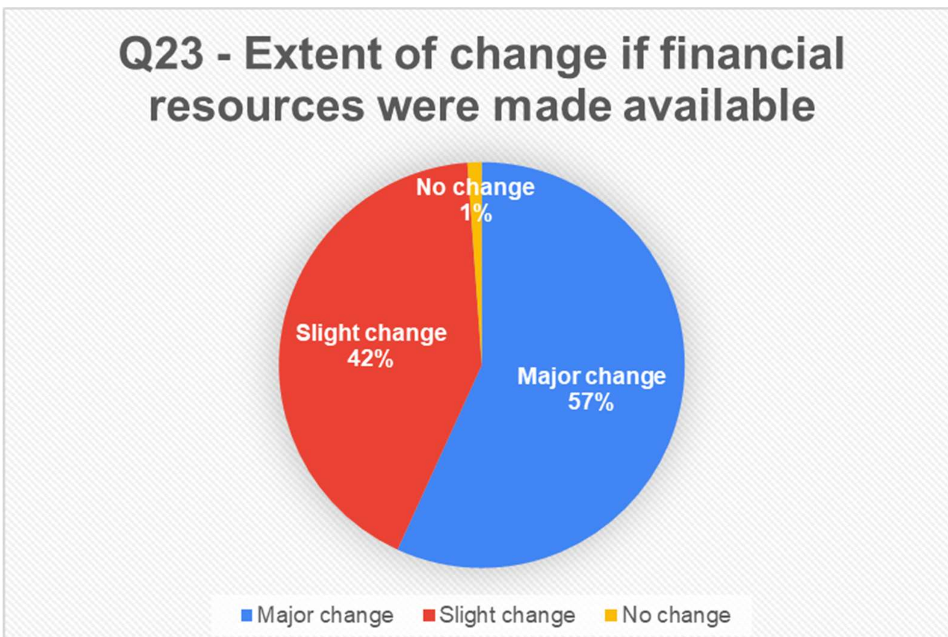

Figure 6-16 Results of Question 23: If I had access to the financial resources required to implement changes to my current construction management practices, I would: (Questionnaire Q23)

6.2.15 Types of changes in construction management practices that Construction Management Practitioners in South Africa would make if resources were available

Respondents were asked which types of change they would make if they were given the resources required to make them. Table 6.29 shows the list of options that was presented to choose from.

Table 6.29 Possible responses to Questionnaire Question 24

No	Response Option	Questionnaire code
1	Train unskilled labourers	unsk
2	Purchase construction software applications or licenses	software
3	Appoint additional site supervisory personnel	supervision
4	Upgrade office IT infrastructure	IT
5	Upskill site management	upskill
6	Safety and environmental training	OHStraining
7	Quality training and accreditation (for example ISO accreditation)	ISO
8	Acquire support with contractual issues (such as appointment of a construction law consultant to assist with claims and disputes)	Contract
9	In-house team building events / workshops	Teambuildin
10	Host site team building events (where all site stakeholders participate)	siteteam
11	Acquire governance and risk management tools or consultants	riskman
12	Acquire productivity data collection tools on sites	datacolle
13	Train employees in efficient communication	comms
14	Train site management in soft skills (to improve collaboration and conflict management between stakeholders on site)	softskills
15	Acquire waste prevention systems	Wasteprev

The number of changes selected were recorded and are shown in Table 6.30.

Table 6.30 Number of changes selected by the respondent at (Questionnaire Question 24)

Number of responses	Value
Missing	1
Minimum	3
Maximum	15
Median (IQR)	5.00 (4.00, 8.00)
Mean (SD)	6.52 ± 3.38
Mean (95% CI)	6.52 (95% CI: 5.82, 7.22)

The changes selected by respondents were ranked in order of most selected to least selected and the results were as shown in Table 6.31.

Table 6.31 Changes that respondents would make if the funds were made available to do this (Questionnaire Question 24)

Item no	Category	Count	Rank
5	Upskill site management	68	1
1	Train unskilled labourers	61	2
3	Appoint additional site supervisory personnel	52	3
13	Train employees in efficient communication	51	4
14	Train site management in soft skills (to improve collaboration and conflict management between stakeholders on site)	48	5
7	Quality training and accreditation (for example ISO accreditation)	47	6
2	Purchase construction software applications or licenses	39	7
9	In-house team building events / workshops	35	8
15	Acquire waste prevention systems	34	9
6	Safety and environmental training	32	10
8	Acquire support with contractual issues (such as appointment of a construction law consultant to assist with claims and disputes)	32	10
4	Upgrade office IT infrastructure	31	11
10	Host site team building events (where all site stakeholders participate)	27	12
12	Acquire productivity data collection tools on sites	24	13
11	Acquire governance and risk management tools or consultants	19	14

The changes most selected by respondents were upskill of site management, training of unskilled workers and adding more supervisory resources to the construction project. These results are illustrated in Figure 6-17.

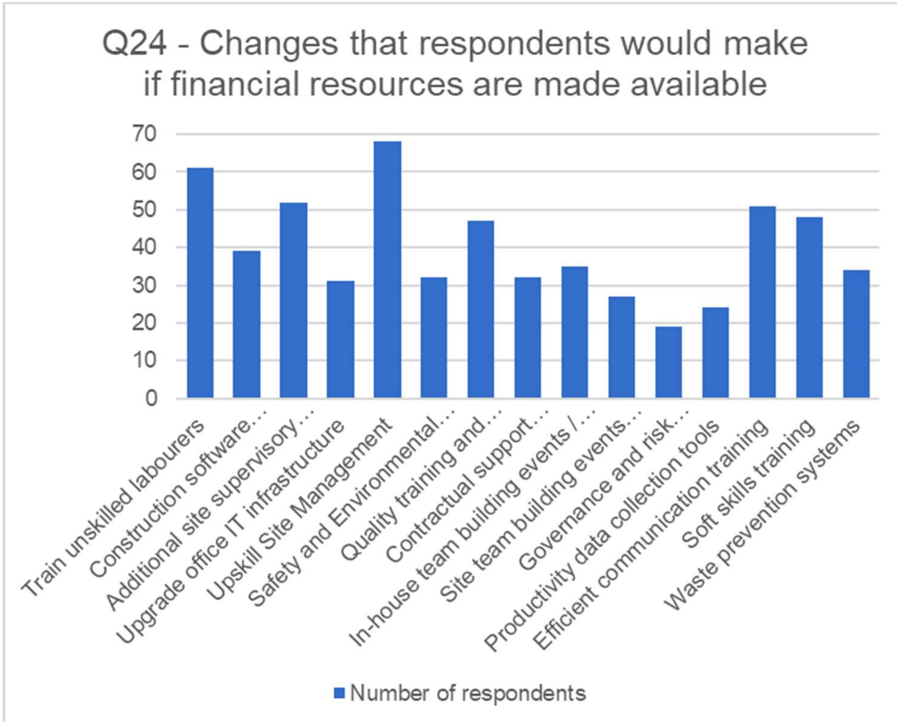

Figure 6-17 Changes that respondents would make if the funds were made available to do this (Questionnaire Question 24)

Respondents were further asked to choose from their selected list, the three most important changes that they would make, and the results were as shown in Table 6.32.

Table 6.32 Most important changes that respondents would make if the funds were made available (Questionnaire Question 26)

Item no	Category	Count	Rank
1	Train unskilled labourers	48	1
5	Upskill site management	47	2
3	Appoint additional site supervisory personnel	35	3
13	Train employees in efficient communication	25	4
2	Purchase construction software applications or licenses	24	5
7	Quality training and accreditation (for example ISO accreditation)	21	6
14	Train site management in soft skills (to improve collaboration and conflict management between stakeholders on site)	19	7
15	Acquire waste prevention systems	14	8
8	Acquire support with contractual issues (such as appointment of a construction law consultant to assist with claims and disputes)	13	9
6	Safety and environmental training	12	10
4	Upgrade office IT infrastructure	10	11
9	In-house team building events / workshops	10	11
10	Host site team building events (where all site stakeholders participate)	9	12
12	Acquire productivity data collection tools on sites	7	13
11	Acquire governance and risk management tools or consultants	4	14

The results were training of unskilled labourers, upskilling of site management, and adding more supervisory resources to the site.

These results are illustrated in Figure 6-18.

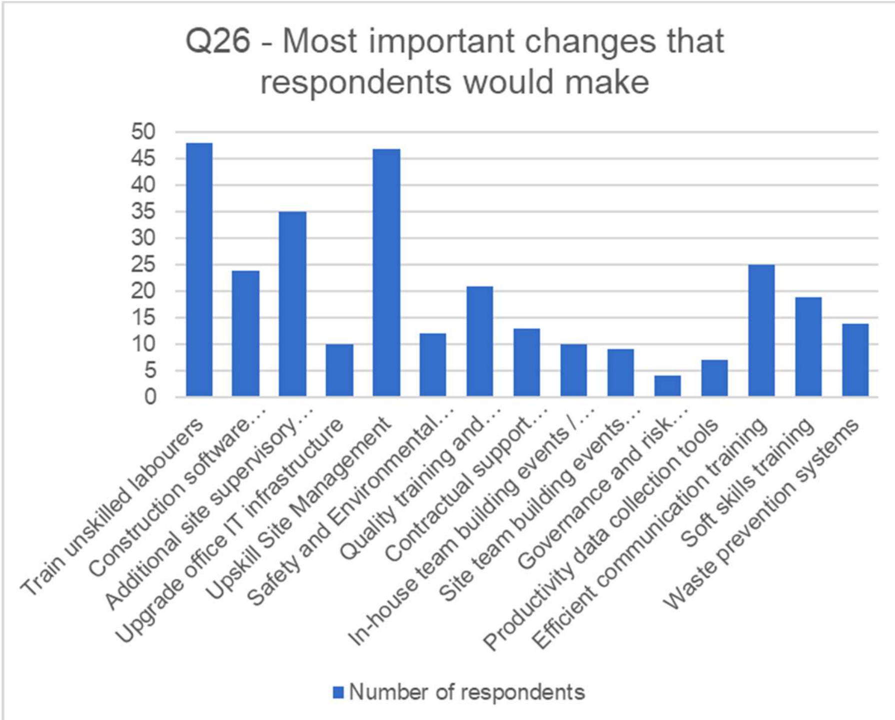

Figure 6-18 Most important changes that respondents would make if the funds were made available (Questionnaire Question 26)

6.3 DATA ANALYSIS

6.3.1 Introduction

The objectives of this research study were to determine which barriers to the implementation of Lean construction already identified elsewhere, are also prevalent in the South African construction industry. Further to this, the objective was to find out if any barriers exist which are unique to the South African construction industry. Lastly, the objective was to propose an adapted model of Lean construction that might be more successful in the South African context.

6.3.2 Prevalence of barriers to the implementation of Lean construction in the South African construction industry

The barriers already identified in other countries were studied, and the most prevalent barriers already identified elsewhere were discussed in the literature review. The data collected on identified barriers which are also present in the South African industry,

Table 6.33 sets out the barriers chosen by the respondents, ranked by most chosen (no. 1) to least chosen (no. 19).

Table 6.33 Barriers to the implementation of Lean construction in the South African construction industry, ranked from most to least encountered

Barrier	Rank
Labour issues (strikes / disputes)	1
Lack of skilled artisans	2
Subcontractors not following the main contractor's management practices	3
Poor knowledge management practices (when staff resign, their knowledge leaves the company with them)	4
Long organisational processes (ordering / recruitment)	5
Long processes due to centralised decision-making	6
Loss of resources due to theft	7
Loss of resources due to material waste and rework	8
Lack of technological capabilities of staff	9
Lack of proactive measures on site (staff dealing with crises on a regular basis) crises	10
Poor change management practices (difficult and frustrating when new systems are being implemented)	11
Lack of an efficient performance management system	11
No culture of continuous improvement in the organisation	12
Lack of top management support to implement new initiatives	13
Lack of funding for training at all levels of the organisation	14
High productivity is rewarded with a heavier workload	14
Lack of top management commitment to implement management tools	15
Lack of the appropriate software applications to manage production	16
Lack of internal information flow (between employees of the organisation)	16
Lack of top management to change to more dynamic management systems	17
Lack of external information flow (between different stakeholders on the project)	18
Taking initiative is discourage and being careful is encouraged	19

Respondents were further asked to choose the three most prevalent barriers that they encounter from their respective selections. The barriers selected are shown in Table 6.34 ranked from most (no. 1) to least prevalent.

Table 6.34 Barriers to the implementation of Lean construction in the South African construction industry, ranked from most to least prevalent

Barrier	Rank
Labour issues (strikes / disputes)	1
Lack of skilled artisans	2
Long organisational processes (ordering / recruitment)	3
Subcontractors not following the main contractor's management practices	4

Poor knowledge management practices (when staff resign, their knowledge leaves the company with them)	5
Long processes due to centralised decision-making	6
Loss of resources due to theft	7
Lack of top management commitment to implement management tools	8
Lack of an efficient performance management system	9
Loss of resources due to material waste and rework	
Lack of proactive measures on site (staff dealing with crises on a regular basis)	11
Lack of technological capabilities of staff	11
Poor change management practices (difficult and frustrating when new systems are being implemented)	12
Lack of internal information flow (between employees of the organisation)	
No culture of continuous improvement in the organisation	12
Lack of top management to change to more dynamic management systems	13
Lack of external information flow (between different stakeholders on the project)	
Lack of top management support to implement new initiatives	14
Taking initiative is discourage and being careful is encouraged	14
Lack of funding for training at all levels of the organisation	14
High productivity is rewarded with a heavier workload	15
Lack of the appropriate software applications to manage production	16

6.3.3 Correlation

Correlation is typically used to study the relationship between two variables. Correlation measures the relationship via a correlation coefficient which ranges between -1 and 1. When the correlation coefficient is zero, there is no relationship between the variables. When the correlation coefficient is greater than zero, there is a positive relationship, with 1 being the strongest possible positive relationship. In the case of the correlation coefficient being less than zero, we have a negative relationship, with -1 being the strongest possible negative relationship. The closer the correlation coefficient is to zero, the weaker the relationship.

Correlation is calculated in the following way:

$$\text{Correlation} = \rho = \frac{cov(X, Y)}{\sigma X \sigma Y}$$

where σX and σY represent the standard deviation of the variable X and Y respectively.

Before calculating the correlations, the missing values were removed from the analysis (Glen, 2024).

In order to test whether the correlation between the variables is significant or not, we have to check the following assumptions:

• Is the covariation linear?

• *Do both variables* follow a normal distribution?

The generalised hypothesis test would be as follows:

H0 : There is no significant linear correlation i.e. $\rho = 0$

Ha : There is significant linear correlation i.e. $\rho \neq 0$

Here, we will test for significance using 5%. This means, if our resultant *p*-value is less than 0.05, we would reject the null hypothesis above and conclude that we have a significant correlation between the two variables.

Spearman's rank correlation test computes the correlation between the rank of the X and Y variables and is useful in cases where we have a violation in the normality assumption of the variables. We will conduct the correlation analysis for both the old and new variables to ensure that we have stable and interpretable results and do not overlook anything in the analysis. Furthermore, all three possible methods of correlation are reported here. It might highlight how drastically some results (methods of calculating the correlation) change as assumptions are violated. Typically, Pearson's correlation is used when all assumptions are adhered to and Spearman's and Kendall's correlations are used when we have violations in the assumptions and are typically considered the non-parametric alternatives.

6.3.4 Correlation between Q6 and Q7 – The number of problems versus number of tools being used

We will firstly investigate whether the variables follow a normal distribution. This is investigated by performing the Shapiro-Wilk test of normality (Table 6.35), where a small *p*-value less than 5% would indicate a violation in the normality assumption.

Table 6.35 Shapiro-Wilk test of normality

	p-value
Q6	0.0039
Q7	0.0001

Since both *p*-values are less than 5%, we have a violation in the normality assumption and conclude that Q6 and Q7 are not normally distributed. For this reason, Spearman's correlation will be used to compute the correlation analysis for all analysis in this section (Figure 6-19).

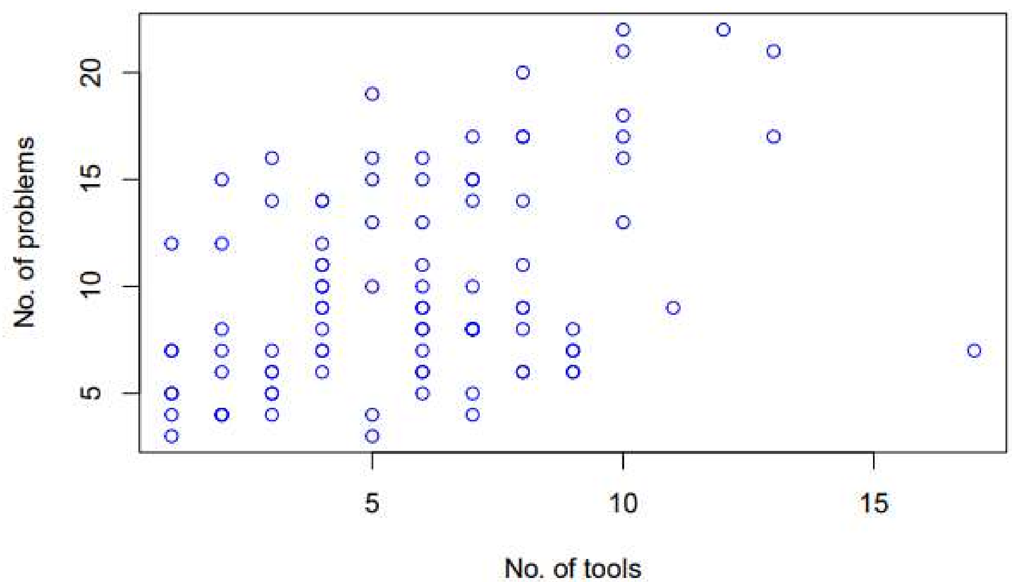

Figure 6-19 Number of problems versus number of tools

Based on the plot above, we could observe that we have a positive linear trend between these two variables, indicative that we could have a relationship here. This is depicted in Table 6.36.

Table 6.36 Spearman's Correlation Analysis – Number of problems versus number of tools

	p-value
Correlation Coefficient	0.4112
p-value	<0.0001
Significance	Yes, it is significant

Since the correlation coefficient of 0.4112 is positive, we have a moderate, positive association between the number of problems and the number of tools. The *p*-value is less than 0.05, which indicates that this relationship is statistically significant, allowing us to reject the null hypothesis and conclude that there is significant linear correlation between these two variables.

6.3.5 Correlation between Q6 and Q9 - The number of types of waste versus number of tools

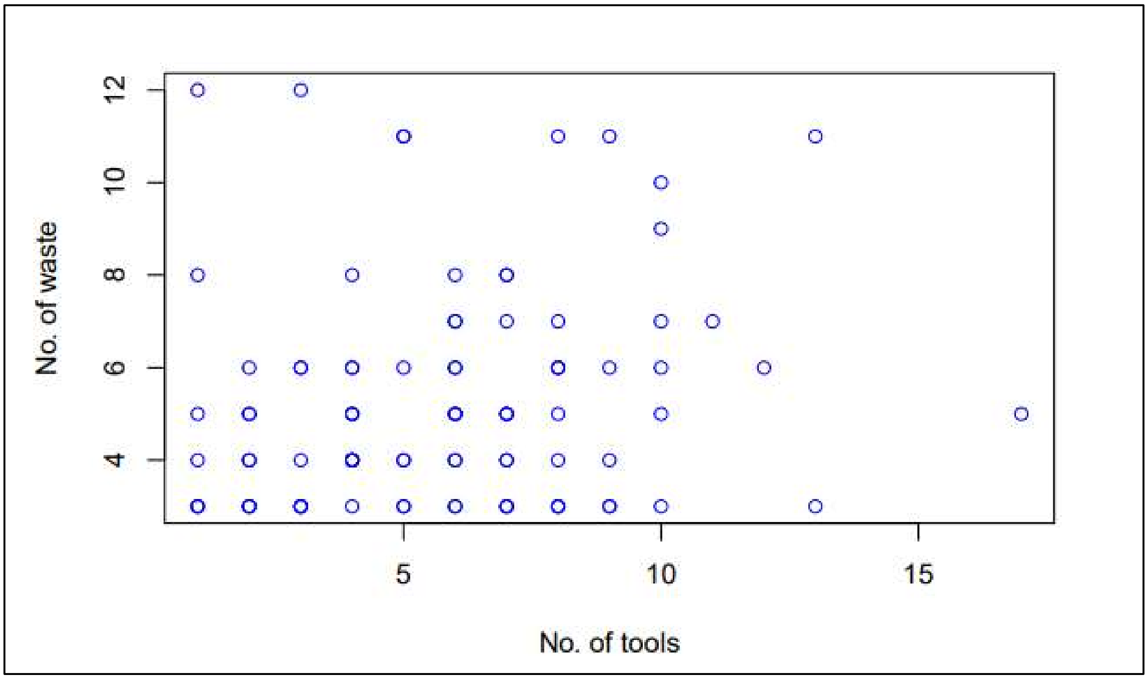

Figure 6-20 Number of types of waste versus number of tools

Based on the plot shown in Figure 6-20, we note that we might have a weak, positive linear trend between these two variables.

Table 6.37 Spearman's Correlation Analysis - Number of types of waste versus number of tools

	p-value
Correlation Coefficient	0.1984
p-value	0.0579
Significance	No, it is not significant

In Table 6.37, since the correlation coefficient of 0.1984 is positive, we have a weak, positive association between the number of types of waste and the number of tools. The *p*-value is greater than 0.05, which indicates that this relationship is not statistically significant, allowing us to not reject the null hypothesis and conclude that there is no significant linear correlation between these two variables at a 5% level. However, if we were less stringent and used a 10% level of significance, we would have a significant relationship here.

6.3.6 Correlation between Q11 and Q7 - The number of changes versus number of problems

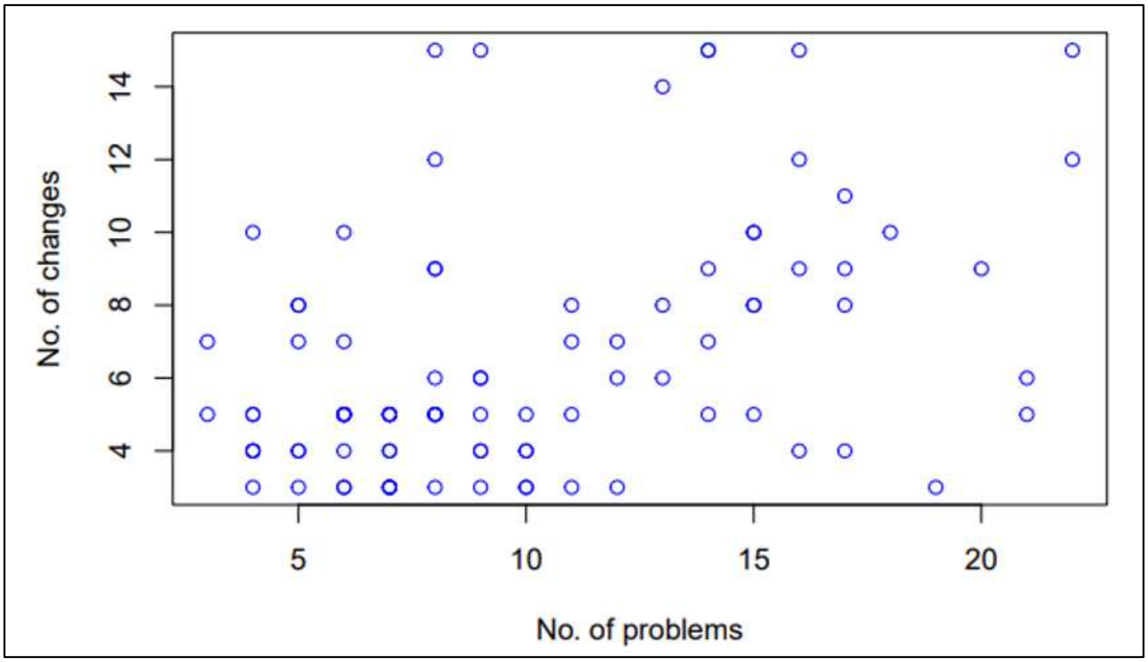

Figure 6-21 Number of changes versus number of problems

Based on the plot in Figure 6-21, we note that we have a strong positive linear trend between these two variables.

Table 6.38 Spearman's Correlation Analysis – Number of changes versus number of problems

	p-value
Correlation Coefficient	0.3847
p-value	0.0002
Significance	Yes, it is significant

In Table 6.38, since the correlation coefficient of 0.3847 is positive, we have a moderate, positive association between the number of problems and the number of changes. The *p*-value is greater than 0.05, which indicates that this relationship is statistically significant, allowing us to reject the null hypothesis and conclude that there is significant linear correlation between these two variables at a 5% level.

6.4 DISCUSSION

6.4.1 Introduction

From the literature review, research on the barriers to the implementation of Lean construction elsewhere in the world, showed that there are many possible barriers which could be present in a construction market in several combinations. The presence of these barriers impedes the flow of a construction project and does not contribute to the protection of value to the client. These barriers were organised in five themes, namely organisational, environmental, labour/workforce, material, and exogenous barriers.

The barriers were organised under the respective themes as indicated in Table 6.39.

Table 6.39 Barriers to the implementation of Lean construction found elsewhere

Theme 1: Organisational Barriers	1.1 Poor change management practices 1.2 Acceptance of the status quo 1.3 Lack of resources 1.4 Lack of knowledge / education in Lean implementation 1.5 Lack of commitment to continuous improvement. 1.6 Lack of efficient performance measurement systems 1.7 Lack of a knowledge management system 1.8 Lack of technological capabilities 1.9 Level of organisational maturity
Theme 2: Environmental Barriers	2.1 Government policies 2.2 Lack of green building initiatives 2.3 Unstable market conditions
Theme 3: Labour/ Workforce Barriers	3.1 Employee culture and attitudinal issues 3.2 Fragmentation of responsibilities 3.3 Resistance to adapt to new technology
Theme 4: Material Barriers	4.1 The complexity of Lean implementation 4.2 Fragmented / project-based nature of the industry 4.3 Extensive use of subcontractors 4.4 Procurement practices.
Theme 5: Exogenous Barriers	5.1 Design-related challenges 5.2 Traditional construction management thinking

Limited literature is available on the barriers to the implementation of Lean construction in South Africa. From the available literature, organisational, labour and exogenous barriers were identified and organised under the five main themes as identified for barriers elsewhere. The barriers to Lean construction implementation in South Africa documented by researchers are indicated in Table 6.40.

Table 6.40 Existing literature available on the barriers to the implementation of Lean construction in South Africa

Theme 1: Organisational Barriers	Poor change management practices Acceptance of the status quo Lack of resources Lack of efficient performance measurement systems
Theme 2: Environmental Barriers	No identifiable research could be found on environmental barriers to Lean construction in the South African construction industry.
Theme 3: Labour/ Workforce Barriers	3.1 Employee culture and attitude
Theme 4: Material Barriers	No identifiable research could be found on environmental barriers to Lean construction in the South African construction industry.
Theme 5: Exogenous Barriers	5.1 Design-related challenges

From the results of this study, several barriers to the implementation of Lean construction in South Africa which are similar to barriers elsewhere were identified. These findings confirms that barriers identified by researchers elsewhere in the world are also present in the South African construction market context.

6.4.2 Poor change management practices

38.71% of respondents indicated that poor change management practices are an issue that they regularly encounter during their construction projects. This is a major barrier to the implementation of Lean construction practices as the core of implementation of this system would be to change processes and thinking across all departments and levels of the organisation. The implementation of Lean construction would constitute a paradigm shift for the organisation and thus if this is not managed from a change management perspective, the probability for successful complete implementation is low.

When asked about the lack of top management support on projects, 38.71% of respondents indicated that they encounter lack of top management support, which creates a problem on their projects. Further to this, 36.56% of respondents indicated that they encounter lack of top management commitment to implement management tools on projects that they manage, and 29.03% of respondents indicated that their top management do not want to change to more dynamic management systems. This phenomenon is linked to change management practices, because successful change is implemented with top management taking the lead on these efforts by acting out the vision that is communicated to employees.

6.4.3 Acceptance of the status quo

From the literature available, from an organisational perspective, acceptance of the status quo and from a workforce perspective, employee culture and attitude are two major barriers to the implementation of Lean construction, both in the South African market and elsewhere.

From the data analysed, 58.47% of respondents are not currently using Lean construction practices, and in the past have not used Lean construction practices but indicated that they would be interested to implement Lean construction if given the opportunity to do so. From the respondents, only 2.54% indicated that they would not be interested to implement Lean construction practices if given the opportunity to do so, but they are accepting the status quo due to no opportunity to do so by the company or no motivation for management to implement these practices.

From the literature available, the best way to foster innovative alternative practices is for a need to be addressed. Thus, a possible solution would be for the client to specify their requirements for the implementation of Lean construction management practices on projects, so that organisations are forced to respond to this need.

6.4.4 Lack of resources

To efficiently implement a Lean construction management system, substantial resources would be required to ensure an efficient approach where the initiative is implemented using a multi-pronged approach. Requirements for the successful implementation of Lean construction include appointing additional resources (Lean practitioners and expert consultants), training courses, incentive schemes, decreased production rates while training takes place, and the organisation goes through a learning process while becoming familiar with the new processes.

From the responses received, 37.63% indicated that they encounter a lack of funding for training purposes on the projects that they manage. If one considers that in general, there is already a lack of resources to train staff, the probability of having resources available for the training required, in addition to costs of the full implementation of a new management system, is very low.

When asked about practitioners' access to the resources required to implement changes in their construction project management practices, 56.99% of respondents indicated that they do not have access to the resources required to implement changes. Amongst the respondents, only 1% indicated that they would not make any changes to their current management practices if all required resources were made available to them. 99% of respondents indicated that they would implement some degree of change to their current construction project management practices.

When asked about the types of changes that practitioners would implement if the financial resources were made available to them, the most selected types of changes were related to the training of unskilled labourers, training of site managers, and appointment of additional site supervisory personnel. The training of personnel at different levels and addition of site supervisors would facilitate the implementation of Lean construction practices if a multi-pronged approach was to be selected for implementation.

Ironically, because of the acceptance of the status quo phenomenon, organisations would often only start to look at alternative more efficient systems to implement once their current systems are not working and the organisation is in peril. At this stage, the cost of implementing a system, which would be beneficial to turn the company around, makes the system not feasible for implementation due to the lack of resources that can be used to implement the system.

6.4.5 Lack of knowledge or education in Lean construction implementation

In this study, 19.57% of respondents indicated that they are very familiar with Lean construction practices, while 45.69% indicated that they are somewhat familiar, and 34.49% indicated that they are not at all familiar with Lean construction practices. From these results, the barrier of lack of knowledge or education in Lean construction implementation is present in South Africa.

From the fragmented use of elements of Lean construction planning tools, it is evident that some knowledge of the tools utilised within Lean construction management exists, but that further education in Lean construction management tools is needed for construction managers to utilise the tools that are already in place within a Lean context.

6.4.6 Lack of commitment to continuous improvement.

When asked about the use of Total Quality Management (TQM) on their projects, 55.91% of respondents indicated that they implement TQM practices on construction projects. In TQM, the view that any work stage has a customer which is the next stage of the project, with the final stage being the final customer receiving the completed project. This definition differs from the traditional framework, where quality management is often regarded as a reactive activity to manage risk, while in the Lean construction framework, the focus is on meeting the client requirements.

From the results of the study, there is room in the South African construction sector for a shift to be made in understanding the customer's needs and meeting them accordingly. This shift can be facilitated when moving from the traditional view to the Lean construction management paradigms.

Linked to TQM above is the concept of Continuous Improvement (CI), where the work process between the various customers up to the end customer can be described as arriving at one stage (customer), changing state, and moving to the next stage (customer), until the product (final delivered project) is achieved. In this process, incremental improvements are made in processes with the objective to continually increase quality, resulting in increased customer value.

A barrier to the implementation of Lean construction practices is the lack of commitment to CI. From the responses, it is evident that this barrier also exists in the South African construction market. When asked about a culture of CI on projects that respondents manage, 39.78% indicated that the lack of a culture of CI is a problem that they regularly encounter. This barrier is closely linked with difficulties in change management and innovation.

9.67% of respondents indicated that they use Post Occupancy Evaluation (POE) as a tool when managing projects in South Africa. The low usage rate of this tool amongst practitioners could be ascribed to the fact that obtaining feedback on the performance of an end product is normally carried out by the design team led by a principal consultant in order to inform future designs for the benefit of the design team. This tool is useful in the Lean construction framework because it forms part of CI, where the client's feedback after using the finished product is recorded and used to improve future project projects of similar nature, or design processes.

6.4.7 Lack of efficient performance measurement systems

38.71% of respondents indicated that the lack of an efficient performance measurement system is a problem that they often encounter on projects that they manage. This barrier is linked to the barrier of traditional construction management thinking, where a project is measured on the success of the project being completed within the time, cost and scope parameters set out. In these projects, client satisfaction is often not measured as part of project performance. This lack of suitable performance measurement systems can be a barrier to the implementation of Lean construction in South Africa.

6.4.8 Lack of a knowledge management system

59.13% of respondents indicated that they regularly encounter poor knowledge management practices on projects that they manage. It is important for a knowledge management system to be in place to improve the transfer of tacit knowledge within the organisation. This leads to the improvement of institutional knowledge and to the effectiveness of the overall organisation. An efficient knowledge management system would also increase the continuous improvement efforts of the organisation. A documented and implemented knowledge management system would improve information flow across different levels of the organisation, but also between stakeholders that the organisation deals with to improve decision-making processes. A sound knowledge management system facilitates the implementation of Lean construction management processes, and thus the lack of such a system poses a barrier to the implementation of Lean construction management practices.

6.4.9 Lack of technological capabilities

35.48% of respondents indicated that they use a Building Information Modelling (BIM) system to manage projects. In Lean construction management, BIM can be implemented to improve production planning and control in a collaborative way by facilitating internal and external information flow across all the stages of a project. This tool is thus regarded as a critical element of a Lean construction management system. A possible reason for the low use of BIM by the respondents of this study, the lack of technological capability due to the high cost of implementation of this type of technology. The cost is related to acquisition of the new technology, training of staff in using the technology and the lack of know-how in the subsequent implementation.

31.18% of respondents indicated that they use Just-in-time (JIT) to manage their projects, as this system means ordering material from suppliers to receive it as close as possible to the time when it is needed for the project. In the Lean thinking framework, JIT is necessary to limit inventory to reduce waste and rework, however, the low usage of JIT methods in the sector can be understood in the context of a series of supply constraints in the South African construction industry, most notably the COVID-19 pandemic, intermittent blockages in the Suez Canal, and delays at local ports. The benefits of improving cashflow and capital outlay in acquiring inventory of material much earlier than anticipated, is the mitigated risk of project delays due to supply constraints not under the control of the Project manager.

29.63% of respondents indicated that they use Performance-Based Requirements (PBR) as a tool in their project management system. This tool is useful in the Lean construction management system, as it specifies the client requirements that should be met. A PBR analysis by a project stakeholder on their scope of work within a project would therefore be useful to ensure that the focus stays on the client requirements and would facilitate performance metrics to be rewritten to specific performance requirements.

15.05% of respondents indicated that they use Quality Function Deployment (QFD) when managing construction projects in South Africa. This tool is similar to PBR in the sense that the focus is on client requirements and the tool enables practitioners to define the client’s requirements for the final product.

27.95% of respondents indicated that they use prefabrication when managing projects. This method could be due to the type of projects that the respondents are managing, where the scope for prefabrication of elements are limited within the South African building standards.

2.15% of respondents indicated that they use reverse logistics as part of their project management system. In the construction industry, reverse logistics refers specifically to the effort to recapture value by refurbishing, recycling, or disposing of the material end products (such as demolition waste or oversupply) in the most efficient way. The low usage of reverse logistics could be an indication of the slow uptake of this practice, as it will meet sustainability goals of the project, but requires additional resources (cost- and time-related) to successfully implement across projects.

Respondents were given an opportunity to add any additional tools that they use to manage construction projects. Three respondents (3,22%) indicated that they use CCS, and one respondent (1.07%) indicated that they use “Cable Management System” software. One respondent (1.07%) indicated that they use the “Process Group” method as a tool to manage their projects.

CCS is a type of software used for project estimation, planning, and execution. The software enables users to take off quantities, estimate project rates based on first principles and set up project schedules with linked resources. While CCS is a useful tool for projecting and monitoring progress and costs on a construction project, this system is set up from the traditional view of construction management.

“Cable Management System” software is used by practitioners to document cable networks for the management of overall cabling networks. While this is a tool for mapping systems, it is indicative that practitioners are using different types of software to manage their projects and the use of different software programs by practitioners in the industry would be a useful topic for future research.

The” Process Group” method refers to the groups of project processes as defined by the Project Management Institute (PMI) in their “Guide to the Project Management Body of Knowledge” (PMBOK)®. These processes are grouped under process groups and knowledge areas. These are combined in a matrix format to create individual processes which intersect with each other. The process groups represent stages or phases of a project, and thus represent the processes in sequence from start to finish of a project. This method is normally used with the help of project management software. More research into the use of project management software in South Africa would be useful to have further insight into how this software is being applied in the South African construction industry.

6.4.10 Government policies

Governments are, in part, responsible for the successful implementation of Lean construction management tools through implementing policies and regulations to encourage organisations to implement Lean construction management tools. Bureaucracy and policies can be major barriers to the implementation of Lean construction management. 65.59% of respondents indicated that they encounter issues related to government policies and bureaucracy while managing construction projects.

From the answers to the open-ended questions about the root cause of issues encountered during construction projects managed by respondents, nine respondents indicated that the government requirement to implement local subcontractors on government projects, even though the technical capabilities required are not readily available in the local area, as a root of major problems encountered on their projects. This requirement is part of the Construction Industry Board's Contract Participation Goals (CPGs) (South Africa, 2000) and the Construction Industry Development Board (CIDB)'s B.U.I.L.D. Programme (South Africa, 2000), which are requirements implemented by the South African government as part of their reconstruction and development plan.

The implementation of CPGs on government projects has had the unintended consequences of reduced quality of work due to the main contractor having to procure local subcontractors and labourers who do not have the necessary technical skills to perform according to the requirements of the project, and work stoppage due to the community and local business forums' involvement in the project.

Further to government policies, 79.56% of respondents indicated that the long lead time from tender submission to project award is a problem that is often encountered on projects that they manage. 65.59% of respondents also indicated that contractual issues due to one of the stakeholders not performing their duties, are also a problem that they encounter on a regular basis on the construction projects that they manage. The long lead times, government policies and issues of contractual parties not performing their duties were also indicated as the three most-encountered issues caused by external stakeholders on the projects that the respondents manage.

Further to these types of policies which do not support the implementation of Lean construction practices, the lack of policies intended to encourage Lean construction implementation is also a barrier in the South African construction industry. To facilitate the implementation of Lean construction, governments need to support collaboration and research in Lean construction practices and need to develop policies which could unlock the widespread implementation in the industry.

6.4.11 Employee culture and attitudinal issues

79.56% of respondents indicated that, on a regular basis, they encounter labour issues, in particular, strikes and disputes, on their projects. Of these, 56,98% of respondents indicated that labour strikes and disputes is one of the three problems that they encounter most often during the course of their construction project. This is a major problem which causes waste due to work stoppage and production loss on construction projects and translates into increased timelines and costs. As Lean construction implementation relies heavily on efficient coordination and collaboration between team members, the prevalence of strikes and labour disputes is a significant barrier to the successful implementation of Lean construction in South Africa.

70.96% of respondents indicated that on a regular basis, a lack of skilled artisans is a problem that they encounter on their projects. 53.76% of respondents indicated that this lack of skills at artisanal level is one of the three problems that they encounter most often on construction projects that they manage in South Africa. Respondents had an opportunity to add their opinions on the reasons for these problems in the form of open-ended questions, and 19 respondents indicated that the closing of training centres for artisans in South Africa is a likely reason for the lack of skilled artisans in the industry. Despite the reopening of training centres and adapted artisan programmes, the lack of skilled artisans has been identified as a major problem within the South African economic sector.

There is a high probability that the lack of skilled artisans on a construction site would result in numerous mistakes on site and elements that are not delivered according to the required specifications. This leads to waste and rework on a construction project, which ultimately leads to increased costs and delays on the overall project timeline. The prevalence of this problem encountered on construction sites makes it difficult to plan the project using the “Flow” view instead of the “Transformation” view.

In terms of lack of skilled artisans, construction management practitioners in South Africa would benefit from implementing the *Andon* culture, where a technically skilled foreman is placed on site. This foreman assists group leaders when a technical problem is encountered, before the defect occurs. This would entail a culture change on site where it is acceptable for an employee to stop the work to resolve a technical problem, so that skills can develop over time. This proposed method seemingly counteracts the flow that needs to be achieved on site due to small stoppages but contributes to the overall flow of the project due to on-site quality improving over time and a culture of skills transfer and development being fostered.

Linked to the problem of the lack of skilled artisans, 47.31% of respondents indicated that lack of technical capabilities of staff is a problem that they regularly encounter on construction projects that they manage. In addition, 46.23% of respondents indicated that a lack of proactive measures on site is a problem that they regularly encounter on construction projects that they manage. These problems could potentially also be alleviated by the implementation of a culture of *Andon*, so that the culture of employees at all levels on site as well as the level of skills transfer, and the acceptability of stopping work to ask for technical assistance to avoid rework, would improve the overall flow of the project.

6.4.12 The complexity of Lean Implementation

The complexity of the Lean construction management philosophy is a major barrier to the implementation of Lean construction management. If there is a good understanding of complexities of Lean construction within a firm, it might not necessarily be transferred to a subcontractor procured by that firm. If subcontractors are extensively used, or high-risk specialised activities are performed by appointed subcontractors, the problem of complexity of Lean implementation can become relevant.

Subcontractors often might not have the time or interest to study and gain a complete understanding of Lean construction management and the specific Lean construction management system employed by the main contractor. The main contractor would often also not have the time or interest to train a subcontractor in their Lean construction management system. The reason for this lack of interest could be lack of resources, time constraints, as well as business interests, as companies might implement Lean construction management practices to increase productivity and competitiveness. Lean construction management systems and tools are not yet standardised, and thus organisations who have successfully implemented Lean construction management systems would not necessarily want to “train” outside organisations on their methods.

65.59% of respondents indicated that a problem they often encounter on site is the fact that subcontractors do not follow the main contractor’s construction project management systems. Further to this, respondents were given an opportunity to supply their opinion on the problems encountered due to subcontractors in the open-ended response section, and nine respondents indicated that the requirement to use local subcontractors on government projects, even in instances where there are no skilled subcontractors available, creates major problems.

6.4.13 Traditional construction management thinking

From the results, out of 116 responses received to the question about the construction management tools used by respondents, 86 respondents indicated that they use CPM to manage construction projects. This translates to 74.14% of respondents who are using CPM.

This method, where the construction manager needs to create an understanding of all the activities which need to be undertaken to complete the project and identify the longest sequence of dependent activities from start to completion, is a traditional way of scheduling tasks and can often be found in the form of a Gantt chart, with the critical path identified using a red line.

Clients often require the project schedule to be presented in this form, with the critical path of the project clearly identified and agreed upon by the client, consulting team and contractor. This is an important aspect of contractual claims for the extension of time (EOT) of a project's completion date. In the event of a situation where the contractor is of the opinion that they are entitled to an EOT, either as a result of a delay on the project not within their control, or additional scope added that cannot be executed consecutively with the existing activities, the effect of the delay on the critical path would be scrutinised firstly by the contractor to establish their basis of claim, but also by the principal agent from the consulting team when the claim is evaluated and adjudicated.

As a result of the critical path method being the focus for these claims, and being widely used in the industry, it is clear why such a large percentage of the respondents indicate that they use this tool on their projects. It is interesting to note that the critical path method is not the only method to analyse delays, but it is certainly one of the methods which is most widely used in the South African construction industry.

In addition to delay analysis and claim substantiation, this method can be effective for time and cost planning and management of a series of well-defined activities within a project, but it still ignores the non-transformation activities by assuming the traditional transformation view of a construction project. Construction managers using this transformation method as their basis of thinking about project management, do not benefit from the flexibility in project planning, which can be achieved by adopting the "flow" outlook. By changing to a "flow" perspective of the project, project costing and planning models can be adjusted to include non-value-adding activities and expose sources of "invisible" waste.

Tools such as the Location Based Management System (LBMS), Value Stream Mapping (VSM) and Last Planner System (LPS) would be more suitable to use for planning construction projects from the Lean construction management "Flow" perspective.

LBMS is a planning system which aims to provide continuous workflow per crew by scheduling work in such a way that crews can mobilise once and complete all work of the same type in a specific location. This method focuses on grouping similar tasks together in a continuous activity by aligning planned production to the time available for each activity, thereby creating continuous flow. The difference between this method and CPM is that with CPM, the focus is on shortening the duration of each fragmented activity to identify the shortest overall timeline of dependent activities, while with LBMS, the focus is to group similar tasks together to create continuous activities. From the results, only 2% of respondents indicated that they use LBMS on their construction projects.

The purpose of VSM is to identify the value stream of a project to identify and subsequently reduce the non-value-adding activities on the project. This tool is useful in the context of Lean construction management in that it enables practitioners to visualise the flow of work and to eliminate waste. From the results, 2% of respondents indicated that they use VSM on their construction projects.

The LPS is a Lean construction management tool that consists of four levels of planning activities (Master scheduling, Phase scheduling, Lookahead planning, and Weekly work plans combined with PPC, which become more detailed as the planned date for the activity to start draws nearer. The work is planned in collaboration with the team members who will do the work or who decide what activities will be done. Only 5.37% of respondents indicated that they use the LPS tool to manage construction projects.

From the low indicated usage of planning tools used in the “Flow’ perspective, in contrast with the high indicated usage of CPM from the “Transformation” perspective by practitioners, practitioners are still managing projects from the traditional view of construction management, which is a barrier to the implementation of Lean construction practices.

A further indication of the tendency of practitioners in the South African construction industry to adhere to the traditional construction management view, is the response to the usage of daily production reports as a construction management tool. 61.29% of respondents indicated that they make use of daily production reports as part of their construction management activities.

While this tool is an effective tool to obtain data about production on site, if these reports are used as a construction management tool to drive and determine production on site, it might have the unintended consequence of site staff trying to keep up the appearance of daily production rates. This behaviour would in turn lead to waste being created due to site staff “making do” on site.

This type of waste is often not evident on site, thus in the traditional construction management view, a site might seem productive due to the numbers reported on daily production reports, but overall, unseen waste is created due to site staff "making do" to achieve production targets, destroying overall value on the project. The shift from the traditional view of construction management to the Lean construction, "Value"-based view, would focus on value creation and unseen waste.

Another "Value"-based tool in the Lean construction management kit is Value Engineering (VE). 58.06% of respondents indicated that they use VE as a construction management tool. As the objective of implementation of VE is to reduce the end cost of a construction project while maintaining the technical quality and function of the project as required by the client. The outcome is the increase of value for the client. The widespread use of VE in the South African construction industry can be ascribed to client budget constraints, which necessitates revising the design to be more cost effective for the project to continue, more than the explicit objective in increasing value for the client. This scenario is also indicative of the traditional way of thinking by practitioners in the South African construction industry.

It was interesting to note when asked about the use of the production planning tool elements of LPS, Lookahead planning and PPC, some respondents indicated that they use these elements, but a much lower percentage indicated the use of the LPS tool. 61.29% of respondents indicated that they use Lookahead planning as a tool and 38.70% of respondents indicated that they use PPC as a tool to manage construction projects. From these results, practitioners are using elements of LPS outside of the overall LPS tool.

When asked about problems that practitioners regularly encounter on construction projects that they manage, 58.06% of respondents indicated that long organisational processes are an issue on their projects. Further to this, 54.83% of respondents indicated that long processes due to centralised decision-making structures are a problem that they encounter on a regular basis on their projects. Six respondents indicated in the open-ended answer section that a cause of their problems encountered on site is due to bureaucratic processes which causes delays.

These results support the tendency in the industry to adopt the traditional construction management view, where non-transformational processes are ignored. In the Lean construction management view, the focus would be on the facilitation of "flow" and thus delays due to long decision-making processes would be identified as a waste, and through continuous improvement efforts, processes would be enhanced with the goal to eliminate "invisible" types of waste within the non-transformational processes.

6.4.14 Perception that waste is an inevitable part of a construction project

55.91% of respondents indicated that they agree that waste is inevitable on a construction project. This perception that waste is an inevitable part of a construction project is closely linked to the barrier of the traditional view of construction management practices and acceptance of the status quo, but have been listed as a separate barrier to the implementation of Lean construction in South Africa due to the prevalence of problems related to waste indicated by respondents, as well as the perception of more than half of the respondents that waste is an unavoidable part of a construction project.

51.61% of respondents indicated that they encounter the loss of resources due to theft on a regular basis, while 50.53% of respondents indicated that they regularly encounter waste in the form of rework. The change in perception that waste is inevitable would facilitate the implementation of Lean construction management in the South African construction industry.

6.4.15 Waste

Respondents were asked about types of waste that they regularly encounter on construction projects that they manage. The following types of waste were selected:

- Demolition of defective workmanship
- Waiting for decisions by external stakeholders
- Double handling of material
- Waiting for information
- Theft and shrinkage
- Waiting for resources due to logistical issues
- Rejection of defective products or materials
- Making-do with resources on site
- Production halt due to safety reasons
- Unnecessary movement of goods or people
- Excess inventory not used on the project
- Production halt due to environmental incidents

The types of waste most encountered by the respondents are demolition of defective workmanship, waiting for information such as drawings, requests for information (RFI) responses and instructions, and double-handling of material.

Respondents indicated that three types of waste which have most noticeably increased on South African construction sites after the COVID-19 pandemic, are waiting for resources due to logistical issues, waiting for decisions to be made by external stakeholders, and theft / shrinkage of material.

From these results, many of the types of waste that can be addressed through the implementation of Lean construction management are encountered by practitioners in the South African construction industry.

6.4.16 Effects of COVID-19 pandemic on construction project management practices

The COVID-19 pandemic had a noticeable effect on the management methods used by construction management practitioners. 33.33% of respondents indicated that they are using different construction management methods as a direct result of the COVID-19 pandemic, while 33.33% indicated that they are looking into alternative methods of construction management.

From these responses, there is a need for alternative construction management practices in the industry. The implementation of Lean construction management would be suitable to enable practitioners to manage projects in a more efficient manner while eliminating waste and striving for Continuous Improvement to create the maximum possible value for the customer.

The effect of a large percentage of practitioners changing their management methods due to the pandemic, shows that change is possible if there is initiative to change.

6.4.17 Conclusion

Several barriers to the implementation of Lean construction were found to be present in the South African construction industry.

The barriers were organised under different themes namely, organisational, environmental, labour/workforce, material, and exogenous barriers.

The following organisational barriers to the implementation of Lean construction were found to be present in South Africa:

- Poor change management practices.

- Acceptance of the status quo.
- Lack of resources.
- Lack of knowledge or education in Lean construction management implementation.
- Lack of commitment to Continuous Improvement (CI).
- Lack of an efficient performance measurement system.
- Lack of knowledge management systems.
- Lack of technological capabilities.

The following environmental barriers to the implementation of Lean construction were found to be present:

- Government policies.

The following labour / workforce barriers to the implementation of Lean construction were found to be present:

- Employee culture and attitudinal issues.

The following material barriers to the implementation of Lean construction were found to be present:

- The complexity of Lean implementation.

The following exogenous barriers to the implementation of Lean construction were found to be present:

- Traditional construction management thinking.
- The perception that waste is inevitable.

Some barriers unique to the South African construction industry were identified. These include government policies related to CPGs, community involvement and the construction mafia involvement. A further barrier unique to the construction industry in South Africa is the lack of skilled artisans, a gap in skills created by the closure of artisanal training centres during the 1990s, which was only addressed again from 2014.

6.5 CONCLUSION

One of the research objectives is to propose an adapted model of Lean construction which might be more suitable for the South African context. The following theories to construct an adapted model of Lean construction implementation are proposed:

Barrier identified: Poor change management practices

Recommendation: The prevalence of poor change management practices is a barrier to the implementation of Lean construction management as the implementation of these practices constitutes a shift in thinking and processes from the traditional view of construction management. It is proposed that the trigger for change to happen within an organisation must be due to innovation to create value for the customer instead of due to the organisation being forced to make changes due to being in financial difficulties. It is proposed that the implementation of Lean construction management be included in client requirements of construction projects, as innovation is brought about by an organisation needing to adapt to client requirements.

Barrier identified: Acceptance of status quo

Recommendation: From the literature available, the best way to foster innovative alternative practices is for a need to be addressed. Thus, similar to the recommendation to address poor change management practices above, a possible solution would be for the client to specify their requirements for the implementation of Lean construction management practices on projects so that organisations are forced to respond to this need.

Barrier identified: Lack of resources

Recommendation: The lack of resources required to implement Lean construction practices poses a major barrier to the implementation of Lean construction in South Africa. The initial outlay of resources is often seen as a "luxury" and ironically, companies looking into alternative methods of construction management such as Lean, usually do so because of being in financial peril. This barrier can be overcome by a change in thinking from traditional construction management to a big-picture view and assessment of the overall gains that could be achieved if the necessary time and resources are invested in implementation.

Barrier identified: Lack of knowledge or education in Lean construction implementation

Recommendation: A lack of knowledge or education in Lean construction practices exists in the South African construction industry. It is recommended that awareness of Lean construction principles is increased. This can be achieved by educational institutions adapting their construction management teaching methods to include alternative views on traditional construction management practices and including Lean construction education in Built Environment educational programmes, not just Construction Management programmes, but also in the wider Built Environment community. Clients can be made aware of the benefits of the implementation of Lean construction practices by stakeholders with training programmes and workshops. Built Environment Councils can target the continuous professional development (CPD) training of employees to Lean construction training as well as appoint specialists to do in-house training or guide employees on how to implement Lean construction management practices efficiently.

Barrier identified: Lack of commitment to continuous improvement.

Recommendation: The lack of commitment to continuous improvement by organisations poses a significant barrier to the implementation of Lean construction practices. This barrier is intricately linked to issues with change management processes and innovation. The implementation of lessons learnt from the client's perspective could foster a structured way to create a culture of continuous improvement in the South African construction industry.

Barrier identified: Lack of efficient performance measurement system

Recommendation: This barrier is linked to the barrier of traditional construction management thinking where a project is measured in terms of time, cost and scope parameters and deemed successful if the project is satisfactorily completed within these parameters. The recommendation is that client satisfaction be added as a metric to measure the performance of a project, so that the focus can be shifted to client satisfaction as one of the parameters when projects are costed, planned and executed.

Barrier identified: Lack of knowledge management system

Recommendation: The lack of a system that documents information flow and transfer of tacit knowledge between stakeholders of the same and across organisations, hamper the implementation of Lean construction management practices. The recommendation to overcome this barrier is linked to fostering a culture of continuous improvement and practitioners needing to change the traditional view of construction management.

Barrier identified: Lack of technological capabilities

Recommendation: The barrier of the lack of technological capabilities of practitioners could be addressed by a change in client requirements. If the use of technology such as BIM and other software to facilitate Lean construction management practices is listed as a client requirement, organisations will be required to make the necessary changes in terms of resources and training to facilitate the implementation of Lean construction management.

Barrier identified: Government policies

Recommendation: Government policies, in particular the implementation of CPGs requirements for the contractor to make use of subcontractors and labourers from local communities on government projects poses a significant barrier to the implementation of Lean construction practices. As these policies are implemented to foster social and economic advances, a solution needs to be found to address this barrier in conjunction with other contractor development programmes and establishing performance measurement systems and databases to empower the client and contractor to set the correct expectations within the framework of the project.

Barrier identified: Employee culture and attitudinal issues

Recommendation: The barrier of employee culture and attitudinal issues is a major barrier to the implementation of Lean construction in South Africa. To overcome this barrier, a culture shift is necessary where work stoppage due to proactively managing quality and training employees on a technical level is acceptable. If this culture shift can take place where a culture of learning and skills transfer is fostered over time, skills transfer and development would take place. This culture shift can only take place if the traditional project metrics are relooked to include customer satisfaction, instead of the traditional view of time, cost and scope.

Barrier identified: Complexity of Lean construction management implementation

Recommendation: The complexity of Lean construction management implementation is intensified with the addition of subcontractors who do not necessarily follow the same construction management practices as the main contractor. If a main contractor successfully implements Lean construction management practices, the main contractor will not necessarily want to spend time and resources "training" competitors. Standardisation of Lean construction management tools could be a solution to eliminate some of the complexity of Lean construction management implementation in South Africa.

Barrier identified: Traditional construction management thinking

Recommendation: The CPM which is within the transformational view of the construction project instead of the "flow" view, is widely used in the South African Construction industry, while planning tools used in Lean construction from the "Flow" perspective, such as LBMS, VSM and LPS are not widely used in the industry. From these results, practitioners are still managing projects from the traditional view of construction management, a major barrier to the implementation of Lean construction practices. Possible solutions to overcome this barrier could be education and awareness in Lean construction practices, client requirements specifying the implementation of selected Lean tools to shift the general practices in the industry from the traditional view to the “Flow” view to render the project more efficient.

Barrier identified: Perception that waste is an inevitable part of a construction project

Recommendation: This barrier can be overcome by the increase of awareness in Lean construction management practices and the standardisation of Lean construction management tools so that the South African construction industry can commence the shift to Lean thinking, in which the elimination of waste is constantly strived for instead of accepted as an unavoidable part of the construction project.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

From the study conducted, the implementation of Lean construction practices can improve the efficiency of the execution of construction projects. Lean construction implementation includes increased environmental, economic, and social benefits.

Environmental benefits include the decrease in different types of waste, reduced emissions and total energy used to produce the end product in the form of a construction project. It should be noted that the implementation of Lean construction practices does not automatically result in project sustainability. While environmental benefits are produced because of Lean construction efforts, sustainability is achieved when the client requirements include sustainability, enabling value to be created by the implementation of processes to achieve the client needs.

Economic benefits due to the implementation of Lean construction include increased profits due to improved productivity as well as decreased losses, due to the elimination of different types of waste. The successful implementation of Lean construction tools can result in improvements in process control and planning, productivity, safety, quality, and predictability. This results in the reduction of project variability and accompanying risk.

The social benefits associated with the implementation of Lean construction practices include improved transparency, improved communication flow, the establishment of a culture of continuous improvement, enhanced collaboration and reduced conflict, and improved customer satisfaction.

The original understanding of Lean construction is based on the Transformation-Flow-Value generation (TFV) theory of production. In this theory, resources such as workers and machines are regarded as transformation-oriented elements, flow-related elements such as materials and information which can proceed from process to process and thus create flow, and customer-oriented elements which is related to value generation and value creation through the elimination of value loss.

The “Flow” concept in Lean construction implementation, refers to an opposite view of the traditional “conversion” view of the processes within a construction process. The traditional view regards a project as a set of activities in which raw material and labour are transformed into a final product: the completed project. Traditional costing models based on this view divide the project into elements (material and labour) and calculate the cost of transforming these elements into the final product. In this view, only tangible waste is accounted for, but non-value-adding activities, which can also create waste (albeit invisible), are ignored.

In the traditional construction management view, there is an effort to optimise production so that the elements which can be managed (the conversion activities), are optimally controlled. On the other hand, in the “Flow” view, conversion activities are still optimised, but waste activities are minimised at the same time. This is achieved by changing the view of the construction project from “activity” or “conversion” to a view of all processes as “Flow”, which consists of both conversion and waste activities. In this process, the project manager scrutinises all activities to see that waste activities are minimised as far as possible, and value-adding activities are maximised.

Various tools have been developed to adapt planning and control activities for Lean construction activities, as traditional methods of scheduling project tasks still assume the traditional transformation view of the construction project while ignoring non-transformation activities.

The “Value” concept in Lean construction implementation refers to the extent to which the customer requirements were fulfilled in the completed project. In the Lean construction management system, activities are classified as either value-adding or non-value-adding. Output value of the end project could be increased through the reduction of non-value-adding activities as well as the systematic consideration of customer requirements, where the start of the next activity of a sequence is regarded as a customer in a series up to the receipt of the completed project by the end customer. An example of this in construction, is that during the design phase, the customer is the construction phase, while the end customer is the client.

Customer value consists of both product performance and freedom from defects, which are both related to the extent to which the project conforms to the client requirements. From the definition of value in the Lean construction management framework, value should always be evaluated from the customer’s perspective.

During the design phase, value can be defined as how well the implicit and explicit requirements have been incorporated in the final design solution, the level of optimisation achieved, and the impact of design errors discovered after handover of the project. The value of design for the construction phase is the degree to which constraints and requirements of construction processes have been considered and the impact of design errors discovered during construction. Value requirements should thus be known and effectively communicated to the design team by the client as value is created by identifying and adhering to the customer's requirements. This emphasises the importance of facilitating a clear, complete and detailed client brief where information on the client requirements is obtained, confirmed by the client, and communicated to all members of the design team.

During the construction process, the degree of freedom of defects discovered during use of the end product indicates the degree to which the project was carried out according to the client requirements in the detailed design. During this stage, value can be created by eliminating wasteful activities, as well as adding additional services which are perceived as valuable by the client.

The Lean construction management view further differs from the traditional (conversion) view of construction management in the understanding of what waste is on a project. In Lean construction, waste has a broad meaning which includes invisible types of waste caused by the disruption of "Flow" activities. This is in contrast with the traditional construction management view where waste is regarded as using too many resources to perform a certain function.

Types of waste encountered on a construction project can be organised under the following eight main categories:

- Product defects.
- Over-production of goods.
- Inventory excess.
- Unnecessary processing.
- Unnecessary movement of goods.
- Unnecessary movement of people.
- Waiting time.
- Making-do.

Waste due to product defects occurs when an element of the product does not meet customer requirements according to the specifications. The waste is created due to additional resources that must be applied to remove the defective element and discard the materials already processed. In addition, rework (an additional category of waste) would be necessary to correct the defective element.

The second category of waste, overproduction of goods, occurs when too many resources are produced for the task at hand. On a construction project, this type of wasteful situation would lead to other sources of waste such as excess inventory and unnecessary movement of goods.

Waste due to inventory excess on site can also be caused by poor scheduling of materials, “push” instead of “pull” scheduling, and inefficient processes. The waste of unnecessary processing refers to any type of over-processing during the project activities. This includes double-processing due to defects having to be corrected, double-handling of materials and elements being constructed to a higher quality than required by the customer.

Unnecessary movement of goods occurs when material and machinery need to be moved around due to inefficient planning, excess inventory not planned for on site, or due to the workspace not being planned effectively (double-handling of material). This situation could cause other types of waste such as waiting time and making-do. In the same way, the waste of unnecessary movement of people occurs when human resources need to move around due to inefficient planning of the workspace, the materials or equipment required to complete an activity not being available on the worksite, and employees being moved to other worksites to avoid waiting time. In a construction context, this type of waste is not as evident as in a production milieu, as site managers could choose to shift to the making-do scenario to keep up the appearance that daily production targets are achieved on site.

The waste of waiting time occurs when additional steps are carried out to accommodate inefficient processes, rework, and excess inventory. This cause of waste is related to the traditional view of the construction supply chain where processes are seen as conversions.

The eighth waste of making-do, refers to an activity that is started without all the resources required to complete the activity being available. This situation often occurs when a manager tries to prevent schedule delays by trying to maintain production rates, despite not having the correct resources available to achieve this. This is a hidden waste as the consequences are increased waiting time and variability, which in time leads to a decline in overall productivity and increase in cost.

In the context of the Lean construction management system, the creation of “Flow” reduces variability in processes and subsequently reduces the occurrence of making-do.

Although not regarded as one of the eight types of waste in the section above, it is important to included institutionalised waste created by contractual governance. This waste occurs when stakeholders adhere to unfit-for-purpose contractual arrangements, where the focus is on “win / lose” transferral of risks. From a Lean perspective, this traditional method of contractual governance creates more waste with traditional procurement arrangements. A collaborative and transparent approach is more conducive to the creation of the “Flow” required to eliminate waste.

Various theoretical frameworks have been developed to explain the proposed processes and concepts of Lean construction management implementation. Several models have also been developed to rate or measure the degree to which organisations or projects within an organisation have successfully implemented Lean construction management practices.

7.2 RESEARCH PROBLEM AND OBJECTIVES

Organisations can benefit greatly from the implementation of Lean construction management practices. Despite the benefits of Lean construction management, the widespread implementation of Lean construction management is not evident in organisations around the world. Barriers to the implementation of Lean construction management that prevent the efficient implementation must exist.

Little information is available on the barriers to the implementation of Lean practices in the construction industry in South Africa. This research study addressed the deficiency in the information available on barriers to Lean construction implementation by addressing the following problem statement:

What are the main barriers to the implementation of Lean construction practices in the South African construction industry?

The aim of this study was to establish the key barriers to the implementation of Lean construction practices in the South African construction industry. Identifying the barriers would provide insight to a modified Lean construction model for the South African context.

The research objectives were to identify the barriers to the implementation of Lean construction practices present in the South African construction industry and to propose a model of Lean construction that would be more suitable in the South African context.

The research objectives were as follows:

- To conduct a review of the existing literature on the barriers to the implementation of Lean practices in the construction industry.
- To determine which barriers are specific to the South African construction industry through questionnaires distributed to practitioners within the industry.
- To collect data on the barriers present in the South African construction industry.
- To analyse data collected in order to rank the barriers present in the South African context.

- To propose a model of Lean construction practices that would be more suitable in the South African context.

The associated research questions were as follows:

Question1:

Which barriers to the implementation of Lean construction practices have already been identified in other countries?

Question 2:

Which barriers to the implementation of Lean construction practices are prevalent in the South African construction industry?

Question 3:

Are there barriers to the implementation of Lean construction practices that are unique to the South African context?

Question 4:

How would the current model of Lean construction practices have to be modified in the South African context to overcome the existing barriers?

7.3 RESULTS

The results of the research questions were as follows:

Question 1: Which barriers to the implementation of Lean construction practices have already been identified in other countries?

From the literature review, various barriers to the implementation of Lean construction have been identified. The most prevalent barriers can be organised under the following five themes:

Theme 1: Organisational Barriers

- Poor change management practices.
- Acceptance of the status quo.
- Lack of resources.
- Lack of knowledge / education in Lean implementation.
- Lack of commitment to continuous improvement.

- Lack of efficient performance measurement systems.
- Lack of a knowledge management system.
- Lack of technological capabilities.
- Level of organisational maturity.

Theme 2: Environmental Barriers

- Government policies.
- Lack of green building initiatives.
- Unstable market conditions.

Theme 3: Labour / Workforce Barriers

- Employee culture and attitudinal issues.
- Fragmentation of responsibilities.
- Resistance to adapt to new technology.

Theme 4: Material Barriers

- The complexity of Lean implementation.
- Fragmented / project-based nature of the industry.
- Extensive use of subcontractors.
- Procurement practices.

Theme 5: Exogenous Barriers

- Design-related challenges.
- Traditional construction management thinking.

<u>Question 2: Which barriers to the implementation of Lean construction practices are prevalent in the South African construction industry?</u>

Theme 1: Organisational Barriers

- Poor change management practices.
- Acceptance of the status quo.
- Lack of resources.
- Lack of knowledge or education in Lean construction management implementation.
- Lack of commitment to Continuous Improvement (CI).
- Lack of an efficient performance measurement system.
- Lack of knowledge management systems.

- Lack of technological capabilities.

Theme 2: Environmental Barriers

- Government policies

Theme 3: Labour / Workforce Barriers

- Employee culture and attitudinal issues.

Theme 4: Material Barriers

- The complexity of Lean implementation.

Theme 5: Exogenous Barriers

- Traditional construction management thinking.
- The perception that waste is inevitable.

Question 3: Are there barriers to the implementation of Lean construction practices that are unique to the South African context?

From the results, some barriers specific to the South African construction industry were identified. These barriers are:

- Unrealistic CPG targets imposed on government contracts.
- Community and business forum involvement.
- Construction Mafia.
- Lack of knowledge in dealing with SMMEs.
- Client retaining authority over contractual authority of principal agent.
- Lack of technical ability due to the skills gap created by closure of artisanal training facilities.

7.4 IMPLICATIONS OF THE RESEARCH

This research increased the understanding of the barriers to the implementation of Lean construction in South Africa. Previously, little research has been conducted on this subject and this study makes a substantial contribution to this field of knowledge.

This research will be useful to all stakeholders in the South African construction industry. Stakeholders include clients, professional service providers, consultants, contractors, subcontractors, and suppliers. These stakeholders would benefit from the research presented, as it could inform business models and practices which can be adapted to overcome various barriers presented. Results of this research can be used in strategic planning documents to guide construction companies' management teams in structural changes, procedures and support required to facilitate the implementation of lean construction practices in their company.

The research would further benefit educational institutions, built environment councils and associations and government policymakers to inform them of the barriers which can be overcome by shifts in policies as these institutions could influence policy and construction management theory. These shifts could be achieved by educational institutions integrating the results of this study into the curriculum to educate future practitioners on the theory, benefits and possible constraints that they will encounter in the implementation of lean construction.

7.5 RECOMMENDATIONS FOR FUTURE RESEARCH

The research on the barriers to the implementation of Lean construction in South Africa could be expanded to include not only Construction Management Professionals. This study could be expanded to include professionals from other disciplines such as professional architects, quantity surveyors and client representatives.

During the study, a low level of BIM usage was observed amongst the respondents. It would be beneficial to conduct further studies into the use and implementation of BIM in the South African construction industry. Further research can be conducted on the use of construction management software by construction project managers in South Africa.

There is ample opportunity for future research to identify more barriers, to conduct further research on the specific barriers identified, and to investigate how the identified barriers have evolved over time in line with the evolution of the South African construction industry. Further to this, developing and measuring the success of strategies to overcome the barriers identified

Linked to the need for further research on the barriers to Lean construction, there is need a to raise awareness regarding Lean construction practices in South Africa. A possible way to raise awareness and facilitate conversation and further research into Lean construction suitable for the South African context, could be the establishment of a Lean Construction Institute in South Africa.

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APPENDICES

APPENDIX 1: CONFIRMATION OF ETHICAL CLEARANCE

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

4 August 2022

Reference number: EBIT/262/2021

Ms YL Jacobs
Department: Construction Economics
University of Pretoria
Pretoria
0083

Dear Ms YL Jacobs,

FACULTY COMMITTEE FOR RESEARCH ETHICS AND INTEGRITY

Your recent application to the EBIT Research Ethics Committee refers.

Approval is granted for the application with reference number that appears above.

1. This means that the research project entitled "Barriers to the implementation of lean construction in the South African civil engineering construction industry" has been approved as submitted. It is important to note what approval implies. This is expanded on in the points that follow.
2. This approval does not imply that the researcher, student or lecturer is relieved of any accountability in terms of the Code of Ethics for Scholarly Activities of the University of Pretoria, or the Policy and Procedures for Responsible Research of the University of Pretoria. These documents are available on the website of the EBIT Research Ethics Committee.
3. If action is taken beyond the approved application, approval is withdrawn automatically.
4. According to the regulations, any relevant problem arising from the study or research methodology as well as any amendments or changes, must be brought to the attention of the EBIT Research Ethics Office.
5. The Committee must be notified on completion of the project.

The Committee wishes you every success with the research project.

Prof K.-Y. Chan
Chair: Faculty Committee for Research Ethics and Integrity
FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

APPENDIX 2: RESEARCH QUESTIONNAIRE

Questionnaire : Section 1

The purpose of this questionnaire is to find out which barriers to lean construction implementation are present in the South African Construction Industry and to ascertain whether there are any barriers which are specific to the South African Context.

You were chosen as a respondent because you are regarded as a suitably experienced construction practitioner and your experience and viewpoint is of academic value to this project.

Your participation is voluntary and you can withdraw at any time without penalty. Throughout the survey your privacy will be protected and your participation will remain confidential. I do not wish to analyse data individually and all the data will be transferred to a computer programme to analyse the entire group. This means that you are assured of anonymity.

Question 1:

By selecting the "Yes" option I hereby voluntarily grant my permission for participation in this anonymous survey. The nature and the objective of this research have been explained to me and I understand it.

I understand my right to choose whether to participate in the research project and that the information provided will be handled confidentially. I am aware that the results of the survey may be used for academic publication.

□ Yes

1. Project information

1.1 Title of research project: Barriers to the implementation of lean construction in the South African civil engineering construction industry

1.2 Researcher details:

Researcher name: YL Jacobs

Department: Department of Construction Economics, University of Pretoria

Email address: leanconstructionsa@gmail.com

1.3 Research study description.

This project aims to identify the barriers to lean construction implementation in the South African Construction industry. Participants will be required to complete a questionnaire related to their knowledge and experience of lean construction practices in the South African Context. There are no risks involved with completing this questionnaire and the participant can opt out at any time if he / she no longer wishes to participate in the study. In completing this questionnaire, the participant will help in furthering academic knowledge of lean construction practices within the context of the South African Construction Industry.

2. Informed consent

2.1 I, ______________________________ hereby voluntarily grant my permission for participation in the project as explained to me by YL Jacobs.

2.2 The nature, objective, possible safety and health implications have been explained to me and I understand them.

2.3 I understand my right to choose whether to participate in the project and that the information furnished will be handled confidentially. I am aware that the results of the investigation may be used for the purposes of publication.

2.4 Upon signature of this form, the participant will be provided with a copy.

Question 2: To what extent are you familiar with the Lean Construction Management System?

Very Familiar (I have theoretical knowledge of lean tools and have had the opportunity to implement lean tools on at least one project)

Somewhat Familiar (I have theoretical knowledge of lean tools, but have not had an opportunity to implement them on any projects)

Not at all Familiar (I do not have theoretical knowledge of lean tools and have not implemented them on projects)

Question 3: Do you use any lean construction tools when managing construction projects?

Yes, I am currently working on a project that where lean tools are implemented

No, but I have in the past worked on projects where lean tools were implemented

No, but I would be interested in implementing lean construction tools if given the opportunity

No, and I would not be interested in implementing lean construction tools in the future

Question 4: Please indicate which the following general construction management tools you have used during a construction project:

Last planner system (LPS)	
Just-in-Time (JIT)	Location Based Management System (LBMS)
Percent Plan Complete (PPC)	Value Stream Mapping (VSM)
Look-ahead planning	Performance Based Requirements
Daily production reports	Quality Function Deployment (QFD)
Continuous improvement	Post Occupancy Evaluation (POE)
Prefabrication	Total Quality Management (TQM)
Reverse Logistics	Other Tool 1: (please specify)
Value Engineering	Other Tool 2: Please specify
Building Information Modelling (BIM)	Other Tool 3: Please specify
Critical Path Method	

Question 5: If you selected "Other" in the previous question, please specify which tools you use:

Other Tool 1: _____________

Other Tool 2: _____________

Other Tool 3: _____________

Question 6: Many universal problems are encountered daily on a construction project.. Please select which of the problems below you have encountered most often on construction projects:

Lack of skilled artisans
Labour issues (strikes / disputes)
Long organisational processes (such as ordering / recruitment)
Long processes due to centralised decision-making
Lack of top management commitment to implement management tools
Lack of top management to change to more dynamic management systems
Poor knowledge management practices (when staff resigns, their knowledge leaves the company with them)
Poor change management practices (difficult and frustrating when new systems are being implemented)
Lack of top management support to implement new initiatives
Taking initiative is discouraged and being careful is encouraged
Subcontractors not following the organisational management practices
Lack of funding for training at all levels of the organisation
Lack of an efficient performance management system
Lack of the appropriate software applications to manage production
Lack of internal information flow (between employees of the organisation)
Lack of external information flow (between different stakeholders of the project)
No culture of continuous improvement in the organisation
High productivity is rewarded with a heavier workload
Lack of proactive measures on site (staff busy dealing with crises on a regular basis)
Loss of resources due to theft
Loss of resources due to material waste & rework
Lack of technological capabilities of staff
Other: Please specify
Other: Please specify
Other: Please specify

Question 7: If you selected "Other" in question 6, please specify the problems that you encounter:

Other Problem 1:
Other Problem 2:
Other Problem 3:

Question 8: From the previous question, please choose the three problems that you encounter most often:

(List of ticked items from previous question will be presented here as checklist)

Question 9: In your opinion, what is the main cause of the three problems chosen in Question 6?

Problem1:

Problem 2:

Problem3:

Question 10: Many external factors negatively impact the productivity of construction projects. Please tick which of the problems below you encounter most often on construction projects:

Government policies or bureaucracy

Long lead times from tender to project award

Unstable material prices

Unstable construction market conditions

Fragmented nature of the construction project (Client/Contractor/Consultant having different interests)

Lack of information sharing between project stakeholders

Low profit margins

Corruption (Fraud / Bribery)

Lack of client funding to complete the project

Inaccurate designs having to change while construction is underway

Contractual issues due to client / consultant / contractor not performing their duties

Delays due to disputes & claims

Client changing the design while construction is underway (due to their requirements changing)

Other: Please specify

Question 11: If you selected "Other" in Question 10, please specify the external factors which negatively affect the project encountered:

Other: Please specify

Other: Please specify

Other: Please specify

Question 12: From the previous question, please choose the three factors that you encounter most often:

(List of ticked items from previous question will be presented here as checklist)

Question 13: In your opinion, what is the main cause of the three factors selected in question 12?

Most encountered external factor
1:____

Most encountered external factor
2:____

Most encountered external factor
3:____

Question 14: In your opinion, where does the root of the majority of construction management related problems lay?

Internal (Due to behaviour of individuals'/systems within organisation that I work for/project that I manage)

External (Due to behaviour of stakeholders in the project who are not part of my organisation)

Structural (Due to industry practices / Governmental policies)

Question 15: In your experience, have the three problems listed become less, more or stayed the same after the start of the COVID pandemic?

They have become less

They have become more

They have stayed the same

Question 16: Please indicate the degree to which you agree with the following statement:

Waste is an inevitable part of a construction project.

Completely agree

Somewhat agree

Neither agree nor disagree

Somewhat disagree

Completely disagree

Question 17: Please indicate which types of waste you encounter during the daily management of your construction project (Please check ALL that apply):

Demolition of defective Workmanship
Rejection of defective Products/Material
Double-handling of material
Waiting for resources due to logistics issues
Unnecessary movement of goods / people
Waiting for decisions to be made by external stakeholders
Waiting for information (Drawings, RFI's etc.)
Excess Inventory not used on the project
Making-do with the resources available on site
Theft / Shrinkage
Production halt due to Safety incidents
Production halt due to Environmental incidents / approvals pending
Other Type of Waste 1 (Please specify)
Other Type of Waste 2 (Please specify)
Other Type of Waste 3 (Please specify)

Question 18: If you selected "Other" in question 17, please specify the other types of waste that you encounter on your project:

Other Type of Waste 1____
Other Type of Waste 2____
Other Type of Waste 3____

Question 19: From the previous question, please choose the three types of waste that you encounter most often:

(List of ticked items from previous question will be presented here as checklist)

Question 20: In your opinion, what is the main cause of the three types of waste selected?

Problem 1:
____
Problem 2:
____
Problem 3:
____

Question 21: Please indicate which types of wastes have noticeably INCREASED after the declaration of a national disaster due to the COVID Pandemic on 15 March 2020:

Demolition of defective Workmanship

Removal of defective Products

Double-handling of material

Waiting for resources due to logistics issues

Unnecessary movement of goods / people

Waiting for decisions to be made by external stakeholders

Waiting for information (Drawings, RFI's etc.)

Excess Inventory not used on the project

Making-do with the resources available on site

Theft / Shrinkage

Production halt due to Safety incidents

Production halt due to Environmental incidents / approvals pending

Other (Please specify)

Other (Please specify)

Other (Please specify)

Question 22: Please indicate the degree to which you agree with the following statement:

I do not have access to the financial resources required to implement any changes to my current construction practices.

Completely agree

Somewhat agree

Neither agree nor disagree

Somewhat disagree

Completely disagree

Question 23: Please indicate the degree to which you agree with the following statement:

If I had access to the financial resources required to implement changes to my current construction management practices, I would:

Make major/substantial changes to my current way of working

Make minor/slight changes to my current way of working

Make no changes to my current way of working

Question 24: If funds were made available for you to make changes to your current way of working, please indicate areas you would make changes to (Please select ALL that apply):

Train unskilled labourers
Purchase construction software applications or licences
Appoint more site supervisory personnel
Upgrade office IT infrastructure
Upskill site management
Safety & environmental training
Quality training & accreditation (such as ISO accreditation)
Acquire support with contractual issues (such as appointment a construction law consultant to assist with claims & disputes)
In-house team building events / workshops
Host site team building events (where all site stakeholders participate)
Acquire Governance and risk management tools or consultants
Acquire productivity data collection tools on sites
Train employees in efficient communication
Train site management in soft skills (to improve collaboration and conflict management between stakeholders on site)
Acquire waste prevention systems
Other changes to implement 1: Please specify in the next question
Other changes to implement 2: Please specify in the next question
Other changes to implement 3: Please specify in the next question

Question 25: If you selected "Other" in question 24, please specify the other types of changes that you would make if you had funds available for this purpose:

Other Type of Change
1____
Other Type of Change
2____
Other Type of Change
3____

Question 26: From the items chosen, please indicate which three would be the most important to allocate funds to:

(List of ticked items from previous question will be presented here as checklist)

Question 27: Has the COVID Pandemic affected the way you manage construction projects ?

Yes, I am using different management methods as a direct result of the COVID pandemic.

Yes, I am using different managing methods, but it is not a direct result of the COVID pandemic.

No, I am using the same methods as before the pandemic but looking into alternative methods.

No, I am using the same methods as before the pandemic and do not plan to incorporate alternative methods.

End of Questionnaire

APPENDIX 3: RECOMMENDED IDENTIFICATION OF WORK

The Project and Construction Management Professions Act, 48 of 2000 regulates the two professions, Construction Project Manager, and the Construction Manager (SACPCMP, 2008: 25). The following excerpt from the act describes the profession of the Professional Construction Manager (Pr. CM) and the Professional Construction Project Manager (Pr. CPM) as well as the services offered by these professions.

1.1 Description of the profession

The role played by both the Professional Construction Manager and the Professional Construction Project Manager is to provide leadership and management of the construction process from conception to commissioning. The profession seeks to co-ordinate the activities of the professional team, construction team and all role players in an integrated manner to maximise resources. The Professions lead by planning, scheduling, communicating and motivating all team members to achieve a common set of objectives whilst leading and building teamwork.

1.2 Description of the services offered by the Professions

<u>The Professional Construction Project Manager (Pr. CPM) offers the following services:</u>

A. Agreeing client requirements and preferences, assessing user needs and options, appointment of necessary consultants in establishing project brief, objectives, priorities, constraints, assumptions, and strategies in consultation with the client.

B. Finalization of the project concept and feasibility.

C. Manage, co-ordinate and integrate the detail design development process within the project scope, time, cost, and quality parameters.

D. The process of establishing and implementing procurement strategies and procedures, including the preparation of necessary documentation, for effective and timeous execution of the project.

E. The management and administration of the construction contracts and processes, including the preparation and co-ordination of the necessary documentation to facilitate effective execution of the works.

F. The process of managing and administering the project closeout, including preparation and co-ordination of the necessary documentation to facilitate the effective operation of the project.

The Professional Construction Manager (Pr. CM) offers the following services:

A. Manage, co-ordinate and integrate the detail design development process within the project scope, time, cost, and quality parameters.

B. The process of establishing and implementing procurement strategies and procedures, including the preparation of necessary documentation, for effective and timeous execution of the project.

C. The management and administration of the construction contracts and process, including the preparation and co-ordination of the necessary documentation to facilitate effective execution of the works.

D. The process of managing and administering the project closeout, including preparation and co-ordination of the necessary documentation to facilitate the effective operation of the project.

APPENDIX 4: PROJECT STAGES

The following describes the Project Stages as defined by the SACPCMP.

Construction Project Managers shall perform their scope of services under the following project stages (SACPCMP, 2019: 152):

Stage 1 - Project Initiation and Briefing

Agreeing client requirements and preferences, assessing user needs and options, appointment of necessary consultants in establishing project brief, objectives, priorities, constraints, assumptions, and strategies in consultation with the client.

Stage 2 - Concept and Feasibility

Finalisation of the project concept and feasibility.

Stage 3 - Design Development

Manage, coordinate, and integrate the detail design development process within the project scope, time, cost and quality parameters.

Stage 4 - Tender Documentation and Procurement

Establish and implement procurement strategies and procedures, including the preparation of necessary documentation for effective and timeous execution of the project.

Stage 5 - Construction Documentation and Management

Management and administration of construction contracts and processes, including the preparation and coordination of the necessary documentation to facilitate effective execution of the works.

Stage 6 - Project Close Out

Management and administration of project close-out, including preparation and coordination of the necessary documentation to facilitate the effective operation of the project.

APPENDIX 5: PRINCIPAL CONSULTANT

The following details the work reserved for the Professional Construction Project Manager (Pr. CPM) as Principal Consultant.

A Professional Construction Project Manager (Pr. CPM) is usually involved in a project as Principal Consultant during stages one to three of a construction project. The identification of work for Professional Construction Project Manager as Principal Consultant is as follows (SACPCMP, 2008: 25):

<u>Professional Construction Project Manager as Principal Consultant:</u>

<u>Stage 1 – Project initiation and Briefing:</u>

- Facilitate the development of a Clear project brief.
- Establish the client's procurement policy for the project.
- Assist the client in the procurement of the necessary and appropriate consultants including the clear definition of their roles, responsibilities, and liabilities.
- Establish in conjunction with the client, consultants, and all relevant authorities the site characteristics necessary for the proper design and approval of the intended project.
- Manage the integration of the preliminary design to form the basis for the initial viability assessment of the project.
- Prepare, coordinate, and monitor a project initiation program.
- Facilitate the preparation of the preliminary viability assessment of the project.
- Facilitate client approval of all stage one documentation.

<u>Stage 2 – Concept and Feasibility:</u>

- Assist the client in the procurement of the necessary and appropriate consultants including a clear definition of their roles, responsibilities, and liabilities.
- Advise the client on the requirement to appoint a Health and Safety Consultant.
- Communicate the project brief to the consultants and monitor the development of the concept and feasibility within the agreed brief.
- Coordinate and integrate the income stream requirements of the client into the concept design and feasibility.
- Agree the format and procedures for cost control and reporting by the cost consultants on the project.
- Manage and monitor the preparation of the project costing by other consultants.
- Prepare and coordinate an indicative project documentation and construction program.

- Manage and integrate the concept and feasibility documentation for presentation to the client for approval.
- Facilitate client approval of all stage two documentation.

Stage 3 - Design Development:

- Assist the client in the procurement of the balance of the consultants including a clear definition of their roles, responsibilities, and liabilities.
- Establish and coordinate the formal and informal communication structure, processes, and procedures for the design development of the project.
- Prepare, coordinate, and agree a detailed design and documentation program, based on an updated indicative construction program with all consultants.
- Manage, coordinate, and integrate the design by the consultants in a sequence to suit the project design, documentation program and quality requirements.
- Conduct and record the appropriate planning, coordination, and management meetings.
- Facilitate any input from the design consultants required by the construction manager on constructability.
- Facilitate any input from the design consultants required by the Health and Safety consultant.
- Manage and monitor the timeous submission by the design team of all plans and documentation to obtain the necessary statutory approvals.
- Establish responsibilities and monitor the information flow between the design team, including the cost consultants.
- Monitor the preparation by the cost consultants of cost estimates, budgets, and cost reports.
- Monitor the cost control by the cost consultants to verify progressive design in compliance with the approved budget, including necessary design reviews to achieve budget compliance.
- Facilitate and monitor the timeous technical coordination of the design by the design team.
- Facilitate client approval of all stage three documentation.

APPENDIX 6: PRINCIPAL AGENT

The following details the work reserved for the Professional Construction Project Manager (Pr. CPM) as Principal Agent.

A Professional Construction Project Manager is usually involved in a project as Principal Agent during stage four to six of a construction project. The identification of work for the Professional Construction Project Manager as Principal Agent is as follows (SACPCMP, 2008: 25):

Professional Construction Project Manager as Principal Agent:

Stage 4 - Tender Documentation and Procurement:

- Select, recommend, and agree the procurement strategy for contractors, subcontractors and suppliers with the client and consultants.
- Prepare and agree the project procurement program.
- Coordinate and monitor the preparation of the tender documentation by the consultants in accordance with the project procurement program.
- Facilitate and monitor the preparation by the Health and Safety consultant of the Health and Safety specification for the projects.
- Manage the tender process in accordance with agreed procedures, including calling for tenders, adjudication of tenders, and recommendation of appropriate contractors for approval by the client.
- Advise the client, in conjunction with other consultants on the appropriate insurances required for the implementation of the projects.
- Monitor the reconciliation by cost consultants of the tender prices with the project budget.
- Agree the format and procedure for monitoring and control by the cost consultants of the cost of the works.
- Facilitate client approval of the tender recommendations.

Stage 5 - Construction Documentation and Management

- Appoint a contractor on behalf of the client including the finalisation of all agreements.
- Instruct the contractor on behalf of the client to appoint subcontractors.
- Receive, coordinate, review and obtain approval of all contract documentation provided by the contractor, subcontractors, and suppliers for compliance with all the contract requirements.

- Monitor the ongoing project insurance requirements.
- Facilitate the handover of the site to the contractor.
- Establish and coordinate the formal and information communication structure and procedures for the construction process.
- Regularly conduct and record the necessary site meetings.
- Monitor, review and approve the preparation of the contract program by the contractor.
- Regularly monitor the performance of the contractor against the contract program.
- Review and adjudicate circumstances and entitlements that may arise from any changes required to the contract program.
- Monitor the preparation of the contractor's Health and Safety plan and approval thereof by the Health and Safety consultant.
- Monitor the auditing of the contractor's Health and Safety plan by the Health and Safety consultant.
- Monitor the compliance by the contractor of the requirements of the Health and Safety consultant.
- Monitor the production of the Health and Safety file by the Health and Safety consultant and contractors.
- Monitor the preparation by the Environmental consultants of the Environmental Management plan.
- Establish the construction information distribution procedures.
- Agree and monitor the construction documentation schedule for timeous delivery of required information to the contractors.
- Expedite, review, and monitor the timeous issue of construction information to the contractors.
- Manage the review and approval of all necessary shop details and product proprietary information by the design consultants.
- Establish procedures for monitoring, controlling, and agreeing all scope and cost variations.
- Agree the quality assurance procedures and monitor the implementation thereof by the consultants and contractors.
- Monitor, review, approve and certify monthly progress payments.
- Receive, review, and adjudicate any contractual claims.
- Monitor the preparation of monthly cost reports by the cost consultants.
- Monitor long lead items and off-site production by the contractors and suppliers.
- Prepare monthly project reports including submission to the client.

- Manage, coordinate, and monitor all necessary testing and commissioning by consultants and contractors.
- Coordinate, monitor and issue the Practical completion lists and the Certificate of practical completion.
- Coordinate and monitor the preparation and issuing of the Works completion list by the consultants to the contractor.
- Monitor the execution by the contractors of the defect items to achieve Works completion.
- Facilitate and coordinate adequate access with the occupant for the rectification of defects by the contractor.

<u>Stage 6 - Project Close Out</u>

- Issue the Works completion certificate.
- Manage, coordinate, and expedite the preparation by the design consultants of all as-built drawings and design documentation.
- Manage and expedite the procurement of all operating and maintenance manuals as well as all warrantees and guarantees.
- Manage and expedite the procurement of all statutory compliance certificates and documentation.
- Manage the finalisation of the Health and Safety file for submission to the client.
- Coordinate, monitor and manage the rectification of defects during the Defects liability period.
- Manage, coordinate, and expedite the preparation and agreement of the final account by the cost consultants with the relevant contractors.
- Coordinate, monitor and issue the Final completion defects list and Certificate of final completion.
- Prepare and present the Project closeout report.

APPENDIX 7: PROFESSIONAL CONSTRUCTION MANAGER

The identification of work for the Professional Construction Manager (Pr. CM) is as follows (SACPCMP, 2008: 25):

- Define and agree preliminary scope of construction works.
- Prepare preliminary construction program.
- Provide the necessary lead times required to prepare a detailed design and documentation program.
- Review and recommend practical and cost-effective construction alternatives to consultants' designs.
- Attend the appropriate planning, coordination, and management meetings as required.
- Review designs by consultants in relation to constructability requirements.
- Review designs by consultants in relation to Health and Safety requirements during construction and provide input if required on related practical and cost issues.
- Provide detailed cost information as required by the cost consultant for estimating, budgeting and cost reporting purposes.
- Prepare and submit a proposed method statement for the construction of the works.
- Review and confirm the construction strategy and method for submission of the tender.
- Prepare the construction management organogram and obtain commitment from appropriate staff as required.
- Select, recommend, and agree the procurement strategy for subcontractors and suppliers with the Principal Agent and consultants.
- Manage and coordinate the preparation and implementation of the Health and Safety requirements for inclusion in the tender.
- Manage and procure proposals for the appropriate contract insurances and guarantees required for the works.
- Review tender documentation to establish any cost-effective alternative solutions.
- Manage the preparation and submission of the tender submission.
- Prepare and agree the procurement program for subcontractors and suppliers.
- Agree list of subcontractors and suppliers with the Principal Agent.
- Manage the tender process in accordance with agreed procedures, including calling for tenders, adjudication of tenders, and recommendation of appropriate domestic subcontractors and suppliers.
- Manage, coordinate, and finalise negotiations on all contractual commitments.
- Manage the preparation and agreement of the Health and Safety plan with the client's Health and Safety consultants and subcontractors.

- Manage the site establishment including the provision of all necessary temporary services, storage facilities, security requirements and other site requirements.
- Establish and maintain regular monitoring of all line, level, and datum of the works.
- Continuously monitor the compliance by the site management of the Health and Safety plan.
- Provide the necessary documentation as required by the Health and Safety consultant for the Health and Safety file.
- Manage the implementation of the requirements of the Environmental Management plan.
- Appoint subcontractors and suppliers including the finalisation of all agreements.
- Receive, coordinate, review, and obtain approval of all contract documentation provided by the subcontractors and suppliers for compliance with all the contract requirements.
- Monitor the ongoing projects insurance requirements.
- Facilitate and manage the establishment of subcontractors on site.
- Finalise and agree the Quality Assurance (QA) plan with the design consultants and subcontractors.
- Continuously monitor the compliance of the quality of the works in accordance with the agreed QA plan.
- Establish and coordinate the formal and informal communication structure and procedures for the construction process.
- Regularly conduct and record the necessary construction management meetings including subcontractors, suppliers, program, progress, and cost meetings.
- Finalise and agree the contract program and revisions thereof as necessary.
- Prepare and finalise the detailed construction program including resource planning.
- Prepare and agree information schedules for timeous implementation of construction.
- Continuously manage the review of construction documentation and information for clarity of construction requirements.
- Manage and administer the distribution of construction information to all relevant parties.
- Continuously monitor the construction progress.
- Manage the review and approval of all necessary shop details and product proprietary information by the design subcontractors.
- Review and substantiate circumstances and entitlements that may arise from any changes required to the contract program.
- Establish procedures for and monitor all scope and cost variations.
- Manage the preparation of monthly progress claims for payment.
- Receive, review, and substantiate any contractual claims within the prescribed period.

- Regularly prepare and submit a construction status report, including construction financial status report.
- Manage, coordinate, and supervise all works on and off site.
- Manage and coordinate the requirements of the direct contractors if required to do so.
- Manage, coordinate, and monitor all necessary testing and commissioning.
- Coordinate, monitor and expedite the timeous rectification of all defects for the achievement of practical completion.
- Coordinate, monitor and expedite the timeous rectification of all defects for the achievement of works completion.
- Manage, coordinate, and expedite the preparation by the relevant subcontractors of all as-built drawings and construction documentation.
- Manage and expedite the procurement of all operating and maintenance manuals as well as all warrantees and guarantees.
- Manage and expedite the procurement of applicable statutory compliance certificates and documentation.
- Manage the finalisation of the Health and Safety file for submission to the Health and Safety consultant.
- Coordinate, monitor and manage the rectification of defects during the defects liability period.
- Manage, coordinate, and expedite the preparation and agreement of the final accounts with the cost consultants and all subcontractors.
- Coordinate, monitor, and expedite the timeous rectification of all defects for the achievement of final completion.
- Prepare and present the contract close-out report.

APPENDIX 8: CONSTRUCTION WASTE

The following information details the GBCSA Net Zero/ Net positive certification measures for Construction Waste (GBCSA, 2019: 41):

AIM

The Net Zero / Net Positive Waste - Level 1: Construction Waste certification rewards projects that demonstrate net zero waste from construction activities over the duration of the construction period or addresses an additional 5% (or more) of waste from other sites.

CRITERIA

Net Zero Waste - Level 1:

- Construction Waste is achieved when it is measured to be 0kg/year to landfill.

Net Positive Waste - Level 1:

- Construction Waste is achieved when it is measured to be 5% above zero.

METHODOLOGY – MEASURED

The methodology undertakes actual measurements of the construction waste streams, potentially including construction waste from other sites, as per the relevant Green Star New Build MAN-7 credit criteria.

Pathways 1 & 2:

- The proposed methodology is to undertake the calculations as per the relevant Green Star New Build credit MAN-7 credit.
- This is demonstrated as:

100% (by mass) of all demolition and construction waste is diverted from landfill and reused or recycled.

Pathway 3 & 4:

- To be eligible to pursue Pathway 3, the project must be able to tick Yes to 100% of the measures listed in the Onsite Waste Checklist (Appendix 10).

DOCUMENTATION REQUIREMENT

Modelled

- Not Available

Measured

- As Built (New Build & Major Refurbishments)
- Net Zero Short Report (1)
- Net Zero AP Certificate
- Waste Management Plan

Additionally for Pathways 3 & 4:

- Short Report additional section(s)
- Contracts or Proof of contribution from off-site source(s)
- Waste Management licenses
- Letter from Waste Recycling Facility
- Proof (e.g. Certificate) of contribution from offset scheme (for the first year) and letter of commitment from the client (for future years within the certification validity period)

Net Zero Short Report (1) prepared by a Net Zero AP describing how the Net Zero Credit Criteria have been met by detailing the methodology and calculations, including:

- Tabulation of all categories of waste (wood, metal, concrete, general, etc.) with their corresponding quantities and indicating how they were reused/recycled.
- Summary and reference to receipts demonstrating the waste types, waste recipients, total amount (by mass) of waste and dates removed from site within a table.
- Appended receipts to verify the reporting methodology per each waste type and/or recipient service provider with dates and quantities indicated. Only requires the very first and final waste removal receipt. It is not necessary to append all receipts within the submission, provided that all receipts are however summarised within the short report.
- Where pathway 3 or 4 is applied, the Net Zero AP must have inspected the offsite waste recycling facility and verify that the items that are claimed to be recycled in the ‘Letter from Waste Recycling Facility’ are recycled and do not end up going to landfill or to some untraced avenue.

Waste Management Plan specifically used for the site, describing how all generated waste is monitored, which types of waste will be collected for recycling or for reuse, how recycling will occur, and who is responsible for the various aspects of the plan. The waste management plan should include instructions to crew and sub-contractors on recycling and reuse procedures. The waste management plan is to be developed and approved prior to demolition (if applicable) or construction start and is to be implemented for the entire construction duration.

Net Zero AP Certificate for the person that has been responsible for the Net Zero submission to the GBCSA.

For Compliance Pathways 3 + 4

Short report additional sections, not to exceed two pages, prepared by the suitably qualified waste professional, to include:

- Copy of the completed Onsite Waste Checklist.
- Photos or specifications of each of the items listed in the Onsite Waste Checklist, to verify that this forms part of the project. Each photo or specification must include a description of where specifically (location) these items exist in the project - for example, a photo of the waste bins used note that these are found in kitchens and bathrooms on floors 3, 6 and 8.
- Description of an off-site waste systems or waste offsets used, including a calculation of how much waste was required to be offset by these off-site mechanisms.

Waste Management Licenses from relevant offsite organisations responsible for offsite recycling of the project's waste, for the duration of the 3-year certification validity period or a letter of commitment from the organisation to renew their license for this period.

Letter from Waste Recycling Facility confirming that all items that are recorded by the project as being recycled are recycled by the offsite waste recycling facility and confirming that none of these end up going to landfill.

Proof of contribution from off-site source(s) demonstrating the relationship between the

project and the offsite organisation, describing what the offsite organisation is responsible for.

Proof of contribution from offset scheme and letter of commitment from the client providing evidence of the purchased $kgCO_2$ and for the difference to be purchased for the 3 years the Net Zero certificate will be valid.

ADDITIONAL GUIDANCE

It must be clearly demonstrated that evidence accounts for all the demolition and construction waste, that the stipulated proportion of waste has been reused or recycled.

APPENDIX 9: OPERATIONAL WASTE

The following information details the GBCSA Net Zero/ Net positive certification measures for Operational Waste (GBCSA, 2019: 44):

AIM

The Net Zero / Net Positive Waste - Level 2: certification rewards projects that demonstrate net zero waste from occupant operational activities over 12 consecutive months or an additional 5% (or more) of waste from other sites that is diverted from landfill.

CRITERIA

Net Zero Waste - Level 2:

- Operational Waste is achieved when it is measured to be 0kg/year to landfill over 12 consecutive months.

Net Positive Waste - Level 2:

- Operational Waste is achieved when it is measured to be at least 5% more than 0kg/year to landfill over 12 consecutive months where the additional 5% is waste received and recycled from other sites.

METHODOLOGY - MEASURED

The methodology undertakes actual measurements of operational waste streams, including audits and waste management plans in accordance with the Green Star Existing Building Performance tool.

Pathways 1 & 2

- Demonstrate waste management practices are in place through ongoing waste measurement and data collection, and waste management plans on site.

Pathway 3 & 4

- To be eligible to pursue Pathway 3 & 4, the project must be able to tick Yes to 100% of the measures listed in the Onsite Waste Checklist.

DOCUMENTATION REQUIREMENT

Modelled

- Not Available

Measured

Existing buildings / tenants / precincts

- Net Zero Short Report (1)
- Net Zero AP Certificate
- Waste Management Plan
- Waste Recycling Records

Additionally for Pathways 3 & 4:

- Short Report additional section(s)
- Contracts or Proof of contribution from off-site source(s)
- Waste Management licenses
- Letter from the Waste Recycling Facility
- Proof (e.g. Certificate) of contribution from offset scheme (for the first year) and letter of commitment from the client (for future years within the certification validity period)

Net Zero Short Report (1) prepared by a Net Zero AP describing how the Net Zero Credit Criteria have been met by detailing the methodology and calculations, including:

- Tabulation of all categories of waste (wood, metal, concrete, general, hazardous waste etc.) with their corresponding quantities and indicating how they were reused/recycled.
- Summary and reference to receipts demonstrating the waste types, waste recipients, total amount (by mass) of waste and dates removed from site within a table.
- Appended receipts to verify the reporting methodology per each waste type and/or recipient service provider with dates and quantities indicated. Only requires the very first and final waste removal receipt. It is not necessary to append all receipts within the submission, provided that all receipts are however summarised within the short report.

Waste Management Plan specifically used for the site, describing how all generated waste is monitored, which types of waste will be collected for recycling or for reuse, how recycling will occur, and who is responsible for the various aspects of the plan. The waste management plan should include instructions to crew and sub-contractors on recycling and reuse procedures. The waste management plan is to be developed and approved prior to demolition (if applicable) or construction start and is to be implemented for the entire construction duration. For guidance on the Waste Management Plan, refer to the Green Star Existing Building Technical Manual.

Net Zero AP Certificate for the person that has been responsible for the Net Zero submission to the GBCSA.

For Compliance Pathways 3 + 4:

Short report additional sections, not to exceed two pages, prepared by the suitably qualified waste professional, to include:

- Copy of the completed Onsite Waste Checklist
- Photos or specifications of each of the items listed in the Onsite Waste Checklist, to verify that this forms part of the project. Each photo or specification must include a description of where specifically (location) these items exist in the project - for example, a photo of the waste bins used note that these are found in kitchens and bathrooms on floors 3, 6 and 8.
- Description of an off-site waste systems or waste offsets used, including a calculation of how much waste was required to be offset by these off-site mechanisms Waste Management Licenses from relevant offsite organisations responsible for offsite recycling of the project's waste, for the duration of the 3-year certification validity period or a letter of commitment from the organisation to renew their license for this period.

Letter from Waste Recycling Facility confirming that all items that are recorded by the project as being recycled are actually recycled by the offsite waste recycling facility and confirming that none of these end up going to landfill.

Proof of contribution from off-site source(s) demonstrating the relationship between the project and the offsite organisation, describing what the offsite organisation is responsible for.

Proof of contribution from offset scheme and a letter of commitment from the client providing evidence of the purchased kgCO2 or for the difference to be purchased for the 3 years the Net Zero certificate will be valid.

ADDITIONAL GUIDANCE

It must be clearly demonstrated that evidence accounts for all of the operational waste, that the stipulated proportion of waste has been reused or recycled.

APPENDIX 10: GBCSA ONSITE WASTE CHECKLIST

The following document describes the onsite waste checklist for use during GBCSA Net Zero / Net Positive certification.

Onsite Waste Checklist for Net Zero or Net Positive Waste buildings to be eligible to use Pathways 3 & 4, the project must be able to tick Yes to all the measures listed in the checklist below (GBCSA, 2019:40):

Level 1 – Construction Waste

1. Does your project have a Site Waste Management Plan that details how to reduce waste and how and where to recycle the different waste streams? Y / N

2. Does your project's construction site have separate designated bins/skips for different waste streams? Y / N

3. Does your project require sizing and cutting of materials off-site (where applicable) to avoid waste generation? Y / N

4. Does your project have educational/awareness material targeting the contractors on waste minimisation and avoidance of landfill? (e.g. 'Toolbox talks') Y / N

Level 2 – Occupant Waste

1. Does your project implement on-site waste recycling? Y / N

2. Does your project undertake Waste Steam Audits of Ongoing Consumables? Y / N

3. Does your project have an Operational Waste and Materials Management Plan? Y / N

4. Does your project have educational/awareness material targeting the staff on waste minimisation and avoidance of landfill? (e.g. signage, waste seminars, communication to staff)