ASSESSMENT OF LEAN CONCEPTS IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY

by

PRETTY RAMARU

A DISSERTATION

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JOHANNESBURG, SOUTH AFRICA

SUPERVISOR: PROF. C.O. AIGBAVBOA

CO-SUPERVISOR: MR. D.O. AGHIMIEN

CO-SUPERVISOR: DR. A.E. OKE

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A DISSERTATION submitted in partial fulfilment of the requirement for the award of the degree Magister Technologiae in Construction Management in the Faculty of Engineering and the Built Environment, Department of Construction Management and Quantity Surveying at the University of Johannesburg, Republic of South Africa

JOHANNESBURG, FEBRUARY 2020

DECLARATION

I, PRETTY RAMARU, declare that this dissertation is the result of my own assessment and research, except for the content indicated in the references and by comments included in the body of the report, and that it has not been presented elsewhere for a similar purpose. It was submitted to the University of Johannesburg (Department of Construction Management and Quantity Surveying), as a requirement to obtain a **MAGISTER TECHNOLOGIAE** degree in **Construction Management.**

___________________ ___________________

Signature Date

University of Johannesburg

Doornfontein Campus

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DEDICATION

I dedicate this dissertation to my mother, Ms Takalani Happy Ramaru, and grandmother, Mrs Tshikope Selina Ramaru.

Lastly, I dedicate this to my cousins who come after me: may all of you one day come across these works and use them as a source of inspiration to motivate yourselves beyond limits, to infinity and beyond.

ABSTRACT

The South African construction sector has been confronted with the issues of not meeting project schedules, budget and specifications set by the client and architect or engineer. Several studies have demonstrated that the applied models of project management and tools it employs fail to deliver projects on time, at agreed budget and at desired quality. Lean construction promotes the construction development and accomplishing the project objectives by reducing waste. However, in spite of the potential benefits of lean construction and assuming its awareness among stakeholders, little has been reported regarding its execution for performance enhancement and the successful fulfilment of clients' needs in the South African construction industry. Therefore, the aim of this study is to assess lean concepts and to recommend the most effective options for lean concepts' adoption in South Africa. A quantitative approach has been used for this study. The data used in this study was derived from primary sources using a structured questionnaire. The questionnaire was distributed both physically and using Google Forms. Out of the 200 questionnaires distributed, 152 were returned. However, only 151 questionnaires were usable, representing a 75.5% response rate. The data collected were analysed using the descriptive statistics (mean item score) and multivariate statistics (exploratory factor analysis) and Cronbach's alpha reliability test. Findings from the data revealed that there is a high level of awareness of lean principles and there is an average level of awareness of lean techniques within the South African construction industry. The study also revealed that there is an average level of application of lean principles while there is a low level of usage of lean techniques within the South African construction industry.

The study further revealed that the barriers to the adoption of lean concepts can be categorised as understanding of lean concept, stakeholders and construction process, procurement and technical barriers as well as government support and organisational related issues. The study also shows that to improve lean concept in construction, factors related to knowledge, as well as organizational and operational measures are crucial. If the concept of lean is adopted in the South African construction industry, significant benefits relating to improved construction delivery, equipment efficiency and labourers' efficiency can be achieved. The study recommends that the government, relevant professional bodies and stakeholders should embrace and encourage the adoption across board through awareness, education, and training on its principles and approaches in the South African construction industry . **Keywords:** Construction projects, lean concepts, lean construction, lean principles, lean techniques, project success and South African construction industry

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ABBREVIATIONS

AEC	Architectural, Engineering and Construction
BER	Business Enterprise and Regulatory Reform
BEE	Black Economic Empowerment
CI	Construction industry
CIDB	Construction Industry Development Board
CMAA	Construction Management Association of America
EPWP	Extended Open Works Program
FET	Further Education Training
GDP	Gross domestic product
GFCF	Gross fixed capital formation
IGLC	International Group of Lean Construction
LC	Lean construction
LCI	Lean Construction Institute
LCI-UK	Lean Construction Institute UK
CLIP	Construction Lean Improvement Programme
LPDS	Lean project delivery system
LP	Lean principles
LPS	Last Planner System
LT	Lean techniques
MDG	Millennium Development Goals
PCA	Principal component analysis
PM	Project manager
PPC	Percent Plan Complete
SACI	South African construction industry
SAICE	South African Institution of Civil Engineering
SMEs	Small and medium enterprises
SPSS	Statistical Package for the Social Sciences
TQM	Total quality management
UK	United Kingdom
UKCI	United Kingdom construction industry

USA	United States of America
USACI	United States of America construction industry
VSM	Value stream mapping
WBS	Work breakdown structure
EFA	Exploratory factor analysis
4P	Product, price, place and promotion
5S	Sort, set in-order, shine, standardize, sustain
KMO	Kaiser-Meyer-Olkin

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PUBLICATIONS

	Journal(s)	
Name of Journal	Built Environment Project and Asset Management	International Journal of productivity and Quality Management.
Title of the paper	Lean Construction in South Africa: Unraveling its Level of Awareness and Potential Benefits	Bolstering Measures for Adopting Lean Construction in the South African Construction Industry
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CHAPTER ONE

INTRODUCTION

1.1 GENERAL BACKGROUND

The construction industry (CI) plays a crucial part in the nation-wide economy and economic improvement of any nation. The significance of the CI is because of the role it plays in the economy; however, that role varies significantly among different countries. In both developed and developing countries the construction business plays a key part in the economy by contributing to the gross domestic product (GDP) by utilizing a sizeable section of the working population which represents a portion of the capital arrangement and collaborates strongly with other commercial sectors (Hillebrandt, 1985). In addition, Khan (2008) indicated that in developing states, the CI is a dynamic division providing mostly new infrastructure such as roads, railways, airports as well as new health facilities, schools, housing and other structures. In developed states the focus is on professional services and on rehabilitation and refurbishment construction (Ruddock, 2009; Bon and Bietroforte, 1999).

The CI is not only one of the major industries that makes a contribution to the economy, but it is also viewed as a standout amongst the most very divided, ineffective and topographically scattered industries globally (Salleh, 2009). Relevant literature by Memon, Abdullah and Abdu (2010) and Al-Najjar (2008) revealed that through the years the construction sector has encountered the struggle of keeping developments within budget, within the planned schedule and with the desired safety and quality. An alarming number of projects fail to be conveyed on time, within the planned cost and a reasonable standard. These need extra work and re-works. Ashkena and Matta (2003) refer to the large number of projects failing irrespective of the considerable amount of innovation and the application of new techniques. Arbulu and Ballard (2004) identified an extra critical issue as the absence of a successful framework set up to deal with the working relationship between construction firms and their suppliers. Fluctuations in supply and demand also adversely affect the cumulative cost of project management as well as time delivery and decreasing project value and security.

Furthermore, Koskela (2000) and Lepatner (2007) indicated that the failure and ineffectiveness of the construction management models (time, budget, value exchange off, work breakdown structure, basic way strategies, and earned worth) to deliver projects on time, at budget, and at desired quality is obvious to practitioners and researchers. For instance, repeating bad encounters on projects, as shown by common quality issues, lack of good communication and supervision among undertaking partners. Exploration of project plan failure by Ballard and Howell (2003) and showed that "usually only half of the tasks on week basis plans are finished earlier than the agreed completion week" and that a large portion of these planning failure were likely to be experienced by the contractors through active management of inconsistency.

The lean construction (LC) concept is understood as a new model for project management, there by challenging the conventional concept around construction and project management (Ballard and Howell, 2004:40). Mossman (2009) defines LC as a "technique to plan creation frameworks to limit waste of resources, time, and effort, bearing in mind the end goal to yield the greatest imaginable amount of major cost". Abdelhamid (2004) also outlined LC as a general ability design and delivery logic with an all-encompassing purpose of increasing the incentive to all partners regarding proficient, synergistic, and constant alterations in the legally binding courses of action, the item plan, the construction procedure outline and strategies choice and the manufacturing network,

According to Johansen and Walter (2007), the implementation of the lean practice in the CI is exceptionally restricted and slow. Even though different countries have gained great rewards by implementing LC concepts, there appears to be minimal execution of lean owing to some of the obstacles preventing its successful execution. Mossman (2009) has shown that one of the main obstructions to the execution of lean is the low level of awareness among construction professionals in the CI. In relation to this, a study conducted by Olatunji (2008) in Nigeria to assess the awareness of lean among construction professionals shows that the level of awareness is very low as only two out of the ten respondents demonstrated that they are aware of the lean concept.

It is based on this information that this research assessed lean concepts within the South African construction industry (SACI) with the purpose of understanding the present state of the practice of LC within the industry. In addition, this study makes recommendations to further improve the delivery of construction projects through encouraging the utilization of LC. To achieve this, the level of awareness of lean concepts among construction professionals in the SACI, the level of adoption of lean concepts, the obstacles to the execution of lean practice, the measures for improving lean concepts' adoption and the benefits of adopting lean concepts in SACI were assessed.

1.2 MOTIVATION FOR THE STUDY

The key motivation for this study arises from the need to assess the adoption of LC for construction projects in Gauteng Province, South Africa (SA). The study covers the gap in knowledge with respect to the current state of the SACI towards adopting lean concepts and improves the knowledge base of adopting lean concepts in the construction projects. Furthermore, it endeavours to fill the gap in the area of the adoption of lean concepts for construction projects and provides knowledge about the benefits of implementing lean concepts in construction projects. These could be adopted in other countries as well. The result of the research contributes towards a better understanding of the LC concept. Furthermore, this study helps to recognise the obstacles to the execution of LC, as well as measures for improving lean concepts adoption in Gauteng Province.

1.3 SIGNIFICANCE OF THE STUDY

The idea of lean principles has been recognized in several studies. Nonetheless, the understanding of the adoption and the execution issues of lean within the SACI should be further highlighted. Hence, the study aimed to aid the following contributions to the body of knowledge: awareness and knowledge of lean practice in the CI, the obstacles to the execution of lean concepts, the measures for improving the execution of lean concepts and the benefits of lean concepts in construction projects.

Moreover, this study will assist the different construction participants (construction professionals, clients and the construction industry at large) to adopt lean practices in construction projects from planning to completion of the project. Specifically, the study will be valuable to individuals who are involved in the construction industry as it could enlighten construction policy makers on the inherent benefits of the adoption of lean concepts for construction projects in the SACI. This will similarly be beneficial to the clients and end-users. It is anticipated that the findings of this study will stimulate research interest and that awareness of the lean concepts will provide an information base for companies planning to execute lean construction.

1.4 PROBLEM STATEMENT

The desire to complete a project on time under the arranged project cost, with the best quality is a mutual objective for all agreement parties, including the client, contractual worker and professional team (Alkhathami, 2004). The effective implementation of construction projects is frequently impacted by either achievement aspects that assist project parties to achieve their objective as agreed, or components which hamper project completion (Salleh, 2009).

Conventionally the CI has been characterised as an industry with numerous issues and absence of productivity (Alinaitwe, 2009). In addition, the construction sector has been confronted with issues of meeting project schedules, budget and specifications set by the owner and architect /engineer (Chun, Kumaraswamy and Palaneeswaran, 2009). Confirmation from study by Abdelhamid (2004) demonstrated that the applied models of project management and tools it practises (work separate structure, basic way and earned esteem management) fail to deliver project on time at the agreed budget and at the desired quality. This was also supported by the Construction Management Association of America (CMAA) in its 6th annual study of proprietors which indicated the concern about work techniques and the cost of waste in construction projects (CMAA, 2004).

Several research studies have testified how lean construction has contributed to execution advancements and accomplishing value for the client's money within the construction sector of a few nations. One case study research undertaken taken in the United States of America (USA) in 1998 details the amazing benefits of implementing lean in construction projects (Garnett, Jones and Murray, 1999). Office construction periods were reduced by 25% within 18 months; schematic design time decreased from 11 weeks to two weeks; there were turnover increments of 15-20%, decrease in projects budget and additional scope of work from clients. However, in spite of the potential benefits of lean construction and assuming its awareness among stakeholders, little has been reported regarding its execution for performance enhancement and the successful fulfilment of clients' needs by South African construction consulting firms. Additionally, the utilization of the lean idea in the CI is still limited (Johansen and Walter, 2007). It is additionally not clear whether consulting firms in the South African construction sector are prepared to embrace it. A gap in knowledge in this manner exists with respect to the current state of the SACI towards adopting lean concepts. Hence this study aims to assess lean concepts in the South African construction industry.

1.5 RESEARCH QUESTIONS

Based on the matters outlined in the problem statement, the research questions below were used to provide the logical direction to the study:

1. What is the level of awareness of lean concepts in the South African construction industry?
2. What is the level of adoption of lean concepts in the South African construction industry?
3. What are the barriers to the adoption of lean concepts in the South African construction industry?
4. What are the measures for improving lean concepts' adoption in the South African construction industry?
5. What are the benefits of adopting lean concepts in the South African construction industry?

1.6 OBJECTIVES OF THE STUDY

The purpose of the study is to:

1. To investigate the level of awareness of lean concepts in the South African construction industry;
2. To explore the level of adoption of lean concepts in the South African construction industry;
3. To identify the barriers to the adoption of lean concepts in the South African construction industry;
4. To determine the measures for improving lean concepts' adoption in the South African construction industry and
5. To identify the benefits of adopting lean concepts in the South African construction industry.

1.7 PURPOSE OF THE STUDY

The purpose of this exploration is to assess the present state of LC in the SACI through determining the level of awareness and usage of lean principles and techniques in the SACI. Furthermore, barriers to the implementation of lean concepts are examined. The study also aims at assessing measures of improving the adoption of lean concept. Moreover, the benefits of lean concepts are also provided.

1.8 VALUE OF THE STUDY

The examination of lean concepts in the SACI aims at establishing the level of awareness and knowledge of lean principles and techniques, the level of usage of lean principles and techniques in the SACI; improving the knowledge and understanding of obstacles to the adoption of lean concepts; establishing measures of improving the implementation of lean concepts in the SACI and highlighting the benefits of lean concepts. It is anticipated that the study will be useful to construction organizations as it will enlighten government, the relevant professional bodies and the stakeholders about the knowledge of lean concepts. In addition, it will also encourage them to embrace the adoption across the board through awareness, education, and training on lean principles and approaches. The result of this study will promote the knowledge of firms planning to execute LC.

1.9 RESEARCH METHODOLOGY

Research methodology is the processes by which investigators approach their work of portraying, clarifying and estimating phenomena (Rajasekar, Philominathan and Chinnathambi, 2013). This area of the study summarises the exploration approach and plan, the targeted population and the topographical area where the study was done. Also described in this section are the instruments utilized in gathering information and the strategies implemented to ensure the legitimacy and consistency of the information collecting instruments.

1.9.1 Research approach and design

This research study embraced the quantitative research method. A descriptive survey design was also used; thus, a structured questionnaire survey was designed. The surveys were circulated to the respondents who are construction experts within the SACI.

1.9.2 Research area and target respondents

The sample part for this exploration was bounded geographically to the province of Gauteng, SA. The research was limited to respondents who are involved in Gauteng construction projects, who have extensive experience and possess decision-making powers. They include architects, project managers, construction project managers, civil engineer, electrical engineer, mechanical engineer, quantity surveyors and contractors.

1.9.3 Sample and data collection

This research employed a random sampling approach; consequently every one of the members associated with the construction industry had an equivalent chance of being selected. In the study, the structured questionnaires were utilized for primary data gathering, supporting by the reviewed literature which formed the secondary data. The questionnaires were distributed to the respondents by hand and through emails.

1.10 DELIMITATIONS

In such a study there will be few limitations to be experienced. Owing to time and cost constraints, only one province was covered for the study, namely Gauteng (South Africa) ,with the targeted respondents Architects, Project Managers, Construction Project Managers , Electrical Engineers, Mechanical Engineers ,Civil Engineers ,structural, Quantity surveyors.

1.11 ETHICAL CONSIDERATIONS

Ethical consideration issues are vital in this study. This requires people to participate in the study voluntarily. Participants were not bound or convinced into participating in the study. The consent of the participants was sought before they were involved in the study. The study participants who were utilized for obtaining information remain anonymous. The privacy of the participants will be strictly protected throughout the study.

1.12 OVERVIEW OF CHAPTERS

This research study was organized into nine (9) separate chapters as follows:

Chapter 1: Introduction

This chapter discusses the background of the study. This section furthermore discusses the problem statement, the research questions as well as the research objectives. The point and centrality of the exploration are likewise expressed in this part. This section consequently provides an arrangement of how the study was conducted.

Chapter 2: Overview of the lean principles in construction projects

This section assesses other published books, diaries, thesis, articles, journal papers and conference papers on lean construction concept. The literature review indicates the current position of literature concerning the existing knowledge of lean construction principles in different countries globally and how these can be used to eliminate waste, deliver projects on time and within budget with satisfactory standards.

Chapter 3: Lean principles in developed countries

This chapter reviews international literature on lean construction. The international countries investigated are the United Kingdom (UK) and the USA which were selected on account of their adoption of lean concepts. The research intended to gather information on the lessons learnt by international countries with respect to the level of awareness of LC, the challenges faced when executing LC, the measures for improving the adoption of LC and the benefits of adopting lean concepts.

Chapter 4: Lean principles in African countries

This chapter reviews other published books, diaries, thesis, articles a similar subject by certified researchers and scientists on the African continent. The countries investigated are Nigeria, Morocco and South Africa. The research intended to gather information on the lessons learnt by the international countries with regard to the level of awareness of LC, the obstacles to the adoption of LC, and the benefits of adopting LC.

Chapter 5: Research Methodology

This section outlines the study approaches and strategies that were used to carry out the study. This chapter emphasises the quantitative method used and the type of data collection tool selected and discuss the questionnaire respondents and their selection criteria. The study used google form and a structured questionnaire as data collection instruments to ensure concise and clear data. The population area, as well as the sampling of the population, is presented in this chapter.

Chapter 6: Findings and analysis

The information collected from the respondents using a structured questionnaire is analysed and presented in this chapter, utilising descriptive and exploratory factor analysis. The use of statistical methods such as pie charts and graphs were employed to evaluate information and draw up results. The examined findings then provided a response with regard to the initially generated questions.

Chapter 7: Discussion of findings

In this chapter, the findings presented in the previous section are discussed further and compared to the studied literature to determine whether the research questions have been answered and research objectives achieved. Implications of the study are also presented in this section.

Chapter 8: Conclusion and recommendations

The conclusion and recommendations of the study are discussed in this section. In this chapter, the findings presented in the previous chapter are discussed further and compared with the reviewed literature to see whether the findings and the literature review agree on the variables discussed. It also provides recommendations with regards to further research are provided.

1.11 Conclusion

This section presented the study of lean construction and explained its various components. The research problem was identified, and the research rationale, research questions and objectives were determined within the study. The following chapter explores lean construction and its components in detail.

CHAPTER TWO

LEAN CONCEPTS IN CONSTRUCTION PROJECTS

2.1 INTRODUCTION

This chapter gives a hypothetical summary of the previous theories with respect to the state of the CI with regard to challenges confronting the industry in the developing countries, the environmental impact of the industry, waste generation in the construction sector, the approaches of minimising waste and a general overview of the lean concept and its adoption in the CI.

2.2 THE CONSTRUCTION INDUSTRY

The CI adds a lot to the economic growth of the country, delivering physical services and infrastructure backload in communities (Bohari, Skitmore, Xia, Teo, Zhang and Adham, 2015:1744). In SA, the CI is accountable for the realisation of civil and building infrastructure (i.e. roads, bridges, houses, offices.) (PWC, 2013:27). The government's effort towards financial improvement and urbanisation has made a great call for physical improvements which in turn provide infrastructure which helps the social and business domains such as housing, education, trade and manufacturing (Bohari et al., 2015:1744).

However, the physical surroundings and the CI are related mainly to the demands on natural resources, and this has resulted in a massive ecological impact on global population development and the related effects for natural resources (CIB and UNEP-IETC, 2002:13). Moreover, construction activities have a harmful effect on the surroundings and individuals' well-being and animals (Nahmens and Ikuma, 2012:155). It is broadly recognized that the sector consumes natural resources, consuming more than half of mineral resources extracted from the environment and hence adds the biggest portion of waste to landfill (CIB and UNEP-IETC, 2002:13). Waste generation has become a genuine problem from which the CI is suffering (Hosseini et al., 2011:414), and one of the key obstacles influencing its performance. The CI is heterogeneous and significantly involved with projects that encounter challenges from planning and design factors, stakeholders involved, availability of resources, that are exposed to an uncertainty which is found in design and planning, presence of various interests of stakeholders, availability of resources, environmental factors, the economy of the country and statutory regulations (CIB and UNEP-IETC, 2002:13). Thus, the South African construction industry, like most construction industries worldwide, faces several challenges that influence the performance of construction projects.

The CI has a few features which distinguish it from other sectors; such incorporate the allocated environment, one-off projects, and multi members. As indicated by Harvey and Ashworth (1993), there are certain features of the CI which differentiate it from other sectors. Thomassen (2004) additionally shares a similar view, the distinguishing features consist of the physical nature of the item; the item is regularly produced on the customer's premises; several of its projects are one-off designs, the organisation of action of the industry and where design has typically been distinct from development.

2.2.1 Issues facing the construction industry

CI throughout the world encounters various obstacles. However, those that developing states are encountering are significantly more complex (Ofori, 1990). They go together with socio-financial pressure and shortages of resource (Ofori, 2000:2). Salleh (2009) indicates that circumstances of instability and hazard continue to challenge the CI, but be likely to be serious in developing countries. These instabilities and risks include the following:

Uncertainty: Construction is one of the first businesses to experience the impacts of a financial collapse (Unido, 1993). The uncertainity time puts the contractors in a place where they are unable to have the consistency and experienced supervision stuff

Limited assets: Numerous developing states have limited assets; they are regularly destroyed by shortages of assets such as currency, skillful workers and applicable technology.

Unskilful workers: Lack of skillful workers is due to the scarcity of job opportunities within the developing countries (Moavenzaden, 1954).

Low levels of yield, overruns and extreme wastages: Studies about emerging nations have indicated that projects are frequently accomplished with a budget of up to 30 per cent in regard to the initial contract cost whereas variation orders result in additional costs of 8.3 per cent (Al Momani, 2000).

Additionally, the developing states have a tendency to lack vital understanding, funds, skill and capability to assist the advancement of their particular construction industry (Othman, 2013). In agreement to NCC (2005), other factors which are contributing to the ineffectiveness and construction project failure significant are the following: competency of contractors; professionals, because of rare assets and inadequately involvement; slight efficiency and quality; incompetent procurement coordination; dishonesty and financial negligence in both public and private sectors; bribery and money-related misconduct in public/private sectors; apparatus for leasing and professional growth; poor working conditions, including and occupational risks on construction locations.

The paragraph above has little value: most of it is unintelligible owing to totally inappropriate words being substituted.

Other issues recognized by Royat (1994) included lack of equipment, insufficiencies in utilizing materials, unpredictable characteristics in managerial structure, imbalanced competition, restricted funds, planning instabilities and a lack of human resource improvement.

2.2.2 Waste in the construction industry

Lately, waste in CI has been a subject of concern for numerous researchers globally. Also, there have been increasing concerns in recent years about the unfavorable impact of waste on the environment. This is waste resulting from all activities throughout the construction process and thus, measuring waste in construction is very difficult. Furthermore, project managers assume 'waste' as physical waste; however, there are recognizable wastes within the CI which are known as "non-value adding activities" according to the LC concept (Hosseini et al., 2011:414).

The term 'construction and demolition waste' is defined as any type of physical waste produced during construction activities (Hosseini et al., 2011:415). Formoso et al. (2002) suggested the definition of 'waste' should not only comprise physical waste but also waste created in activities such as times of transportation. In addition, excess materials, rework, delays and defects are those wastes usually related by researchers (Senaratne and Wijesiri, 2008:35). According to Hamzah, Chen and Irene (2012), waste is seen as any construction procedure or activity that requires costs but does not directly or indirectly increase value to the construction projects.

A research study conducted by Alwi et al. (2002) proposed that waste can essentially influence the execution of the development projects. Hampson (1997) accepted that construction execution may influence efficiency over all divisions of the economy. Waste in construction is characterized in seven categories of waste: overproduction, time on hand (holding up), and transportation, additional/inappropriate preparing, inventories, development and making faulty items (Ohno, 1988). According to Tersine (2004:20), waste in fabricating and development includes overabundances in stock, time overruns, budget of quality, absenteeism of safety, renovation, pointless transportation, line time, long departures, setup, management, arrangements, reviews, accelerating, poor administration practices.

Furthermore, Koskela et al., (2013:5) stated that waste can be distinguished as operational or prepare waste. Activities can be waste machines or individuals which are not doing anything and these are considered to be operational wastes. The other five (overproduction, transportation, extra preparing, inventories and making inadequate items) are procedure waste. According to Abdul Rahman *et al.* (2012:10), the seven kinds of waste can be clarified as follows:

i. Overproduction is recognized as creating more than required. This usually comes about in amount and quality issues; an organization realizes that it'll lose various units along the production process to ensure that the clients' orders are met. This may result in use of materials, employee hours or utilization of tools. Overproduction issue can be dealt with by understanding the apparatus procedure capacities of the manufacturing machines.

ii. Waiting is associated with laziness which is generally caused by poor synchronization. The delay occurs at whatever point items are not being prepared or moving. The inaction is possibly during delays for designing, repairs, raw materials, planning, quality confirmation outcomes, reviews, or validation orders.

iii. Transportation (material/equipment movement) has to do with the moving of materials or tools within the construction location. The working environment of the construction location can on a very basic level be the major reason contributing to useless transportation. Moreover, unusual handling, utilization of insufficient tools or poor routes can also increase this sort of waste. It is worth noting that, each movement has to have a reason since every movement has cost. Work procedure movement interferences can altogether add to the costs of transportation. These wastes incorporate waste of workers' hours, waste of space on location, waste of energy, and the possibility of waste of material during transportation. Appropriate lying of machines within the manufacturing location has been demonstrated to not offer fair assistance of decreasing waste produced by transportation but also decrease work in progress. Moreover, this may be connected to the construction industry where a suitable strategy for site layout would be capable of decreasing useless material movement.

iv. Processing (extreme processing/over-processing) happens in circumstances where handling or change movement does not add value to the item or benefit from the customer's opinion. This can always be achieved by the quality issue of the work completed. The main apparent illustration of over-processing is regarding the surface textures or mechanism. Techniques such as measurable process control, five why's, and inaccuracy sealing, among others, can be utilized to assist in classifying and eliminating the causes of this waste. This waste can moreover be avoided by changing the advance utilized for construction.

v. Record (stock/storage waste) -Too much stock is seen as waste since there is no value action in stock. Additionally, stock involves space, negatively affects capital, and causes costs, among others. Organizations frequently plan more than required to fulfil a demand. The issues related to stock may be due to quality issues with the manufacturing procedure and may moreover be as a result of insufficient resource provision or uncertainty regarding the amount estimations.

vi. Movement (motion) is associated with ergonomics and is seen in all existence including extending, twisting, lifting, and walking. The waste produced by movement is concerned with the ineffective or pointless movements made by workers in work hours. This waste may be caused by poor work strategies, need of tools, or poor work space preparation. Furthermore, a long distance which must be covered inside a work location to perform or fulfil assignments is additionally considered waste of time and exertion. Excessive movements may make or increase the level of harm, accidents, and their related costs.

vii. Making imperfect items (rejects/unacceptable/unnecessary work) happens when the completed or not completed items are not up to the quality requirements. Usually the common waste delivered by the CI where part of the work is done in an unacceptable quality. The process of remedying the defects may results in waste of materials. Faults can happen for a variety of reasons, for instance, non-commitment, insufficient planning and control, insufficient qualification of the project/work group, or poor integration of plan and construction. New procedures to deal with imperfections must be used.

In addition to Ohno's seven kinds of wastes, different investigators have identified the eighth and other wastes. For example, Macomber and Howell (2004) illustrates a few wastes which can broadly be classified as failure to utilize individuals' capacities, skills and abilities; behavioural waste; data waste; and a waste of great thoughts.

Similarly, Womack and Jones (2003) have included the eighth waste, which is the design of merchandise and facilities which do not fulfil the needs of the client. Additionally, Burton and Boeder (2003) have included waste of human potential as the eighth sort of waste. Waste of human potential is illustrated with the failure in using people's energy. Other than Ohno's seven sorts of wastes, one of the vital wastes for the most part detected in construction in accordance with Koskela et al. (2013:8), is the making-do. Making-do waste is related to a circumstance where a procedure is carried out before all the preconditions, necessities or information has been prepared.

2.2.3 Methods of minimising waste in the construction industry

Viana, Formoso and Kalsaas (2012:318) stated that the construction management community generally has a poor understanding of waste compared to other subjects, and numerous studies about waste have centered on the results, not on the root causes that ought to be avoided. Waste is regularly agreed to have two components, with the aim to reduce or remove for implementation (Koskela, Sacks and Rooke, 2012).

Procedures for controlling construction wastes have been the subject of a few investigative projects. As stated from past studies, most of the issues regarding waste on building are associated with imperfection in organizational framework (Formoso et al., 1999:320). Hence there have been a few calls for waste managing. Waste managing includes collection, transporting, treatment, restoration and transfer of waste (Hwang, 2011:396). It includes waste minimization and operative waste control techniques. According to Ferguson et al. (1995), there are three waste minimization techniques that can be utilized on construction projects. These are reduce, reuse and recycle. El-Haggar (2007) created a waste administration hierarchy structure and noted that a waste administration plan includes five steps, namely reduce, reuse, recycle, recover and dispose.

The advantages related to the implementation of this system include financial savings, decrease in the request for landfill, construction industry appearance enhancement, efficiency and quality advancement, and improved resource administration (Hwang, 2011:397). Poon et al. (2004:159) highlighted the importance of adopting certain measures in order to decrease waste. They noted the necessity to execute measures at the design and construction phases in order to avoid and limit waste. Such arranging incorporates the preparation of a detailed waste management plan as well as executing waste control measures during the construction period. According to them, this measures ought to incorporate a great housekeeping and on-site sorting of materials, which enable reuse and reusing. In support of these views, numerous other analysts have highlighted other measures required to be put in place for the successful waste administration on construction locations. A few of these measures include authoritative control, controlling landfill regions, establishing on-site sorting facilities, usage of a waste minimizing system plan, standardization of plans to increase capacity and decrease the quality of off-cuts, stock control measures to maintain a strategic over requesting of materials and fair in-time conveyance technique (McDonald and Smithers, 1998; Poon et al., 2001:159; Shen et al., 2002; WDO, 2006).

In contrast to the above, waste can also be minimised by the adoption of lean construction. According to Koskela and Howell (2002), lean management may be a way to plan, to reduce waste of materials, time, and effort in order to yield the greatest quality of value.

LC targets identifying and limiting wastes (Ballard and Howell, 1994) through the following four standard section: firstly, built-in quality - avoiding re-work; secondly, customer centre; thirdly, reduction of delays - inclusion of supplier in planning activities; and fourthly, construction of a constant flow - accessibility of the required resources and parts, when and where they are needed. By utilizing the lean improvement it is conceivable to deliver better developments. This is a result of the joint action of all meetings and the quality control in the construction industry (Juanfang and Xing, 2001). It is intended to reduce time and cost, concentrating on the relations between activities (Pinch, 2005).

2.3 LEAN IN CONSTRUCTION

2.3.1 Overview of Lean concept

Common et al. (2000) and Mossman (2009:145) explained that the lean concept has existed since the beginning of the 1900s. Henry Ford presented the philosophy of the assembly line that revolutionised car production. The principles of LC come from the adoption of lean concept in production as established by the Toyota Motor Company in Japan. Engineer Taiichi Ohno, the company head of production engineering, centred his efforts on discovering means to transform waste 'muda' into value (Womack and Jones, 1996; Howell, 1999; Sarhan and Fox, 2013:2). With the adoption of lean concepts in the CI, there have been accounts of great rewards when decreasing waste on site through the implementation of project'

The concept 'lean" was instituted by a study group using a report of universal auto fabrication (Kempton, 2006). The first reasoning was to build up a conveyance procedure that addressed clients' issues with next to no stock, and inability to address clients' issues was measured as waste. Working without stock implied that the assembly line needed to accelerate, and every individual engaged with that procedure needed to enhance his aptitudes so as to achieve the construction objectives (Forbes and Ahmed, 2004).

The main idea behind lean is to guarantee the stream of important value while disposing of waste. At the point when waste is expelled from the manufacturing process, procedure durations drop till the point when physical cut-off points are arrived at(Kempton, 2006). Furthermore Waste in building and engineering arises from similar action-focused reasoning. There it is necessary to keep up load on each movement to assure consistent change through the reduction of cost and time of every action (Kempton, 2006).

Lean theory and principles together provide the basis to another category of task administration (Dulaimi and Tanamas, 2001). Lean is a method to plan construction to restrict waste of resources, time and effort, keeping in mind the end goal to deliver the greatest quality (Koskela and Howell, 2002). LC considers a construction project as a short-term manufacturing framework committed to objectives of only conveying the project, expanding value, and limiting waste (Koskela, 2000). LC had three bases of motivation, the effect of which has been maintained by disappointment with the applied achievements of project management (Koskela, 1999).

Snare and Stehn, (2008) indicated that previous studies about LC have customarily centered on a top-management initiated project performance to progress development projects. Hypothetical and experimental evidence demonstrates that error-proofing and persistent enhancement is measurably associated to employee inspiration, which employees follows constant schedules in the occasion that they are clear to them (Abdelhamid and Salem, 2005). They additional expressed the view that labourers do not take specific responsibility of their work and repairs of machine and tools.

A study by OGC (2000) revealed that the point for LC is to work on persistent enhancement, waste removal, solid client attention, value for cash, great quality supervision of projects and supply chains, and enhanced communications. Jorgensen and Emmitt (2009) indicated that LC has been embraced by the CI as a means of supply chain advancement. According to Snare and Stehn (2008), the implementation of advanced administration practices, such as supply chain supervision and lean philosophy, form a manufacturing background to the irregular and project-based development industry is in any case complicated.

2.3.3 Lean tools/techniques in the construction industry

The lean techniques (LT) are the backbone of LC and have advanced since the start of its application within CI. Antillon (2010:20) defines LT as “procedures, frameworks, concepts, systems, approaches, and items that when applied, assist organizations execute lean through the workplace”. There are various LTs encountered in the construction industry, namely 5S, just-in-time, visual management, total quality management, activities, and kaizen (continuous improvement), just to name few (Antillon, 2010:19).

Most of the reviews and experimental studies to date have testified that the foremost adapted techniques to be executed within the construction recorded are total quality management, the 5S process, increased visualisation, just-in-time, value stream mapping, kanban system, prefabrication, waste elimination, standardisation, five why’s, last planner system, continuous improvement, first-run studies (plan, do, check, act), error proofing (Poka-Yoke), Ishikawa diagram, failure modes, effects and criticality analysis (Salem et al., 2006).

Table 2. 1: Lean construction techniques/tools

Lean construction techniques/tools	Definition	Authors
Kanban (Pull system)	The word "Kanban", a Japanese word, which literally means "billboard or signboard" is utilised in monitoring the quantity of material/ apparatuses in the store. This practice is embraced within the CI as an instrument to drag materials and apparatuses all through the value stream on a JIT method. It is an information control method which controls the developments or flow of assets so that parts and supplies are requested and discharged as they are required.	Memon et al. (2018), Sarhan et al. (2017), Tezel and Aziz (2017a)
Increased Visualisations (Visual Management)	Additionally named "Visual management", it assists to create the procedure of construction easy, transparent, harmless for all participants on site. Visualization apparatus makes operations and quality necessities clearer utilizing charts, demonstrated programmes, painted assigned stock and tool areas. To increase visualization, encourage communication between the supervisors of construction projects, encourage data runs through digital ads, security symbols, and optical execution dashboards.	Bajjou et al. (2017b), Salem et al. (2005), Tezel and Aziz (2017b)
Work Standardisation (Standard Operating Strategies)	This technique can be characterized as a set of strategies, mechanisms, or methods in which there is replication and consistency resulting to effective practices, similarly called Standard Operating Strategies (SOP). This strategy permits building in the most limited conceivable time and with the least of struggles. Recently, development of lean construction has shown an improved development of the construction industry. Certain complications are observed as a result of unpredictable environment of the construction practice to fully implement this technique. However, much better and sustainable results are obtained by use of this philosophy.	Fitchett and Hartmann (2017), Ruan et al. (2016) Tezel et al. (2018)
Prefabrication	It comprises utilizing modularized and manufactured construction tools to solve the related construction issues experienced throughout on-site construction (i.e. small yield quality, low efficiency, high inconstancy, and poor security).	Bajjou et al. (2017b), Thaís da et al. (2012)
Last Planner System (LPS)	The LPS is a co-operative preparation method that creates a common design by expanding the consistency of the guarantee of development work trades. In construction, LPS is reflected as an active device to regulate workflow and decrease project instability. One of the key benefits is that it replaces positive planning with accurate planning by evaluating the last planner's execution centred on their capacity to accomplish their promises	AlSehaimi et al. (2014), Habchi et al. (2016), and Salem et. al. (2005)
Value Stream Mapping (VSM)	Is a data and material stream mapping apparatus technique for visually evaluating, recording and improving the flow of a procedure in a way that highlights improvement opportunities, which is utilized to clearly imagining the current vale flow and planning upcoming state of the development procedure while decreasing all causes of waste (overproduction, waiting, inventory, relocations and many others).	Bajjou et al. (2017c) , Memon et al. (2018), Yu et al. (2009)

Waste Elimination (Muda)	This strategy is the key of LC theory. It targets at increasing a philosophy amongst the workers to remove the different causes of waste (overproduction, quality defects, unnecessary transportation, Over-Processing, waiting, inventory, relocations, and unused representative inventiveness).	Khanh and Kim (2015), Zhang et al. (2017)
Kaizen (Continuous Improvement)	This is Japanese business philosophy for continuous improvement. This is a method that aims to create an environment in which responsibilities are assigned to each worker and also encourages and motivates the workers to identify loopholes to increase quality and effectiveness through the removal of waste. This procedure strengthens the thought that each procedure can and should be constantly measured, examined, and enhanced in terms of assets utilized, the time needed, quality required by clients, and other execution standards related to the construction method.	Ansah et al. (2016), Caldera et al. (2018), Sarhan et al. (2017)
First-run studies (plan, do, check, act)	Is a regular method that is implemented through four stages: Plan: recognizing and finding procedure disappointments; do: emerging and executing possible arrangements; assessing the efficiency of the anticipated arrangements; and act: standardising and sustaining the most excellent solution. First Run studies are utilized to redesign basic projects, portion of constant nonstop development exertion; and incorporate efficiency studies and audit work strategies by re-designing and streamlining the distinctive capacities included.	Bajjou et al. (2017a), Ballard and Howell (1997), Tezel et al. (2018)
Total Quality Management (TQM)	TQM is a managing method that aims to incorporate all organizational purposes (client benefit, construction, engineering, and design) to meet execution targets and client needs. Total Quality Management uses a mixture of statistical process control and problem-solving teams to advance procedure ability and assure that external features do not negatively impact the procedure leading it out of control.	Akhund et al. (2018), Ciarnienė and Vienažindienė (2015), and Ullah et al. (2017)
Error proofing / Fail Safe for Quality and Safety (Poka-Yoke)	Poka-yoke, a Japanese word, is a mechatronic tool that works to check mistakes and faults from streaming through the method. It permits expanding the quality of the development procedure and progressing conditions safety for the labourers. This method is restricted to the conventional practice of quality control, in which only a sample size is examined and conclusions are taken after inadequate parts have already been treated. This can be relative to visual inspection (Poka-Yoke gadgets) from lean fabricating.	Ansah and Bajjou et al. (2017c), Shingo (1986), Sorooshian (2017)
Ishikawa Diagram (Fishbone diagram)	This is an active quality device utilized to recognize the sources of a characteristic issue. The Ishikawa chart is considered as an influential device for root causes analysis (RCA) method.	Bajjou et al. (2017a) Dakhli et al. (2016),
Pareto analysis	The Pareto chart is a chart emphasising the foremost important sources having an impact on the investigated system and thus permits creating advance activities to increase the present condition.	Aziz and Abdel-Hakam (2016), Mandujano et al. (2016)
Failure mode, effects and criticality analysis (FMECA)	Risk investigation is a fundamental step within the construction project management, and AMDEC is one of the foremost utilized devices in this field. It is a strategy of subjective exploration of the consistency which makes it feasible to evaluate the dangers of the presence of disappointments, to assess their results and to distinguish their root sources.	Ansah and Sorooshian (2017), Ferng and Price (2005)
Five why’s	It is a procedure of solving problem utilized to recognize the foundation sources of targeted issue. The inquiries are generally particular to the project and not restricted to five questions. The Five Why’s are normally reliant on each project individually and are not limited to five questions.	Bajjou et al. (2017b), Sarhan (2017)

Source: Adapted from Bajjou and Chafi, 2018

An evaluation tool to assess the transferability of lean fabricating practices to construction and to discover the effect of LC tools on the execution of development projects was established by Salem et al. (2006). The following assumptions and suggestions were made:

(i) LPS is prepared to be utilized within the CI with extra attention on variance investigation.

(ii) The increased visualisation (visual management) is utilised in construction projects, focusing not only on security but additionally on housekeeping and quality

(iii) A few developments of first-run studies prior to being implemented.

(iv) For example, the PM is in control of driving the technique, founding the activities that must be reported and going through them every month.

(v) The 5s technique needs an alertness course, training conferences and some corrective activities.

2.3.4 Principles of lean construction

Lean thinking is a theory that organisations utilize to change their way of thinking. It links diverse thinking such as waste removal, continuous advancement, accessibility of resources, cooperation and supply chain management cooperatively (Green, 2000). These thoughts have turn out to be a concept of success. In addition, lean thinking recognizes five principles to execute LC. These LPs assist the participants to manage the companies in flexible way to meet the clients' requirements. Furthermore, Womack and Jones (1996) and Antillon (2010:12) simplified LP into five groups, which are specified below. These LP are to be followed sequentially throughout the process (Sarma and Lachan, 2014). Womack and Jones (2010) describe five LPs to reduce waste in companies, such as outline value stream; accomplish stream inside the work procedure; accomplish client pull at the correct time; and make progress toward flawlessness and persistent.

Discussions about these standards are given within following sub-sections so as to improve the knowledge of LP as applied to construction.

2.3.4.1 Value

Identifying value from the clients' understanding is the primary principle (Antilon, 2010:12). When a company begins executing lean, the redefinition value of its services from the clients' viewpoint is the initial step. It leads to acknowledgment of waste while defining all that includes no value from the clients' viewpoint (Sarma and Lachan, 2014). Furthermore, recognition of time is the most important value to the customer.

2.3.4.2 Value stream

A value stream management (VSM) is an evaluation and planting instrument that lean practitioners utilize to execute lean thinking. VSM assists to identify ineffectiveness in an end-to-end procedure (Sarma and Lachan, 2014). Furthermore, VSM screens all the activities being completed by agreed time. Individuals, materials and equipment are monitored by chart which tracks down the flow of data along the progress (Sarma and Lachan, 2014). The construction industry has experienced some work breakdown structure (WBS) benefits which are visualising the production flow, allowing seeing waste in the system, creating a framework for designing a complete system, illustrating collaboration between data and material flow and creating an execution strategy for upcoming lean activities (Fewings, 2013).

2.3.4.3Flow

Flow is an important procedure of achieving and adjusting the interrelated exercises through which an item can be created (Fewings 2013). Koskela and Howell, (2002) demonstrated that the flow perspective has been recommended to be given more consideration in construction rather than highlighting on the change perspective. In overseeing flow, Koskela (2000) displayed seven flows towards the ideal implementation of a work bundle. These incorporate space, team, past work, apparatus, data, materials, and outside circumstances such as climate. Every flow has its individual nature and should consequently be supervised. Amongst these flows, the physical flow of resources is likely to be the most straightforward to deal with whereas the external condition is generally the flow of tools which might occur.

2.3.4.4 Pull

Pull actually recognizes the necessity to convey the product to the client as quickly as the client wants it at the main level. According to Bicheno (2000), pull is the capacity to convey the item to the client at the most punctual conceivable time. The rule of this principle makes use of time to meet the client requirements and hence modifying and conveying them more typically when the client needs them (Garnnet et al., 1998).

2.3.4.5 Perfection

This is a basic idea at the strategic phase since it characterizes the necessity for the approach of functioning and classifying to convey construction items to life. To accomplish excellence implies always bearing in mind what is being completed, how it is being completed and connecting the ability and information of all those included within the procedure to advance and transform it (Womack and Jones, 1996; Dulaimi and Tanamas, 2001). Bicheno (2000) shows that the rule of perfection includes creating precisely what the client needs in terms of quality and amount at the proper time at a reasonable cost and with least waste; the genuine target is zero waste. Excellence can be accomplished through a constant advancement in removing all kinds of hindrances and non-value adding tasks along the flow procedure (Dulaimi and Tanamas, 2001).

2.4 ADOPTION OF LEAN CONCEPTS IN THE CONSTRCTION PROJECTS

LC has been explained in many ways to the construction professionals, stakeholders and companies however there are conflicting explanations amongst professionals (Hines et al., 2004; Pettersen 2009). Green and May's study refers to three models that have been developed (2005). Construction companies may be confused by the different clarifications of LC. Green named them a "complex cocktail of ideas" (1999). However, it has similarly been characterized as a few diverse things at once such as a set of strategies, a social-technical model, a dialogue, and a social product (Green and May, 2005:500).

Although LC ideas have lately obtained attention as an advanced method of improving construction execution and work efficiency, the industry is slow in taking up lean concepts (Matias and Cachadinha, 2010). The slow uptake of lean construction is linked to a number of barriers. Alinaitwe (2009) has determined the barriers to the execution of LC in both developed and emerging economies. These obstacles have been categorised into technical barriers, managerial barriers, barriers related to human attitudes, financial barriers, barriers related to the process of LC, government barriers, and educational barriers.

Application of lean strategies has been slow. Out of companies studied by McGraw Hill Development (2013), 28 per cent have applied LC in one project; 35 per cent are aware of lean principles, but have not applied any practices; and 37 per cent of contractors are not aware of lean principles. Seddon (2011) illustrates that the genuine test of lean value takes place in the private businesses with high income. He discloses that lean is casually implemented in numerous commercial businesses outside of vehicles manufacturing (2011).

Womack and Jones (1994) proposed that after companies excel in LP, organizations must change into a lean enterprise, which is when the company executes lean into all its vital and trade capacities, not only at the meeting route . Lean initiative is the final step in the construction industry, which includes the entire supply chain which incorporates sources of material at one end to clients at the other. Furthermore, Gao and Moo (2014) proposed the 4P model (product, price, place and promotion) as the main positive features of any LC system. The 4P show comprises four successive stages for a LP implementation. The initial stage is value. The second is procedure that removes waste. The third stage is valuing, stimulating and developing individuals and associates. The final is issue resolving by concentrating on development and learning (Liker 2004).

As indicated by Johansen and Walter (2007:21), the utilization of the lean idea in the development sector is still exceptionally confined and slow. Even if different countries has gained substantial advantages by implementing LC ideas, there is by all accounts little execution of lean in the United Kingdom (UK) construction sector within the course of the most current two decades, since there are few barriers to the adoption of LC (Mossman, 2009:27). One of the significant hindrances to execution of lean ideas in development is the low level of awareness among construction specialists. In connection to this, exploration work by Olatunji (2008) in Nigeria to determine the awareness level of construction experts about lean shows that the level of awareness is low, indicating that only two out of the ten respondents indicated that they aware about lean.

2.5 BARRIERS TO THE ADOPTION OF LEAN CONSTRUCTION

With respect to implementing LC practices, concepts from the manufacturing sector have been rejected based on the belief that the CI is different (Sarhan and Fox, 2013:4). Given the complexity and size of the projects involving many stakeholders, these often lead to uncertainties and constraints. It has also been detailed that numerous lean adopters are not as effective in gaining benefits of lean, unlike Toyota which is the top specialist of lean manufacturing (Liker, 2004). Despite the effectiveness of LC practices, its implementation has been met with a series of barriers and different researchers through their studies investigated several challenges to implementing LC practices.

The most common challenge in LC implementation is that “lean systems are inherently knowledge-intensive” (Mwacharo, 2013:26). Some researchers confirmed that lean is more than tools; it entails a change in flexibility, thinking, discipline, teamwork, assurance, and a comprehensive structure. Therefore, some organisations do not encourage the use of LC practices because it takes time in developing lean thinking.

In addition, when implementing LC practices companies face challenges. The common mistake is to think that lean is a reduction of inventory and labour (ultimately reducing costs). According to Mwacharo (2013:27), lean reduces inventory by identifying and solving one problem at a time. But inventory reduction should not only be for finding the sources of waste.

Understanding the application of lean tools and principles and making sure that all those are involved in the process require the support of top management. According to Kim (2002:7), LC practices can be complex and complicated systems. This presents a challenge if not applied correctly by the organisations.

Additionally, the construction industry is used to the traditional practices and the LC system is different. It comes with new tools which are distinctly different from the traditional tools (Sarhan and Fox, 2013:8). A study conducted in Canada by Bicheno and Holweg (2009:44) indicated that the greatest barriers of implementing LC are lack of understanding lean construction process and going back to the traditional ways of doing things.

Sarhan and Andrew (2012) identified the following as the key obstacles of LC: lack of adequate lean awareness programmes, culture and human attitudinal issues, lack of adequate time for innovation, poor procurement selection strategies and inaccurate designs.

The top management of each organisation includes a key role in achieving a successful implementation of innovative methods (Salem et al., 2005:52; Hudson, 2007). The achievement of lean practice lies in their commitment to evolving and executing an operative plan and satisfactorily giving the desired resources and support to oversee changes emerging from the execution. However, barriers recognized in a few studies appear to be related to administration matters. A thorough review of research by Common et al. (2000) indicated that the absence of concentration and commitment from top management, trouble in understanding the idea of lean construction, absence of training, lack of enthusiasm from the customer, lack of exposure to the need to implement the lean development idea, lack of appropriate training, weak communication among customers, consultants and contractual workers all proved to be barriers to the implementation of lean principles.

The execution of LC may be influenced by technical barriers which are technical. These barriers are considered technical since they have an influence on executing certain LC principles and instruments such as consistency, straightforwardness, adaptability and benchmarking (Koskela 1992:72). A few of these were recognized by Ballard and Howell (1998) as the need for buildable plans, inaccurate and inadequate designs, poor performance measurement approaches, non-existence of approved execution methodology, absence of prefabrication, and uncertainty in supply chain. Alinaitwe et al., (2009) carried out research in Uganda around the barriers to the implementation of LC and the results were: lack of standardizes procurement strategies, lack of a participative management style of the stakeholders; inadequate or lack of infrastructure for transportation and lack of control over factors of supply chain management.

A study carried out by Shang and Sui Pheng (2014b:163) amongst big Chinese development firms discovered that the main obstacles to the adoption of LC are “absence of a long-term philosophy”, “the lack of a lean culture in their organisations” and “the utilization of multi-layer subcontracting”. According to Shang and Sui Pheng, (2014), the capacity to work on long-term objectives has been a basic element within the achievement of lean initiatives such as Toyota.

Through conducting a survey review amongst SA construction organisations, Aigbavboa et al. (2016:197) established numerous barriers to the execution of LC within the SACI, such as “poor pre-planning”, “unqualified workers”, “poor communication, and human approach towards change and absence of interest from clients.” Sarhan and Fox (2013) carried out a survey review among 140 construction professionals, the findings shows that the obstacles to the usage of LC within the UK are associated with social issues.

An assessment executed by Dulaimi and Tanamas (2001) amongst average to big contracting companies within the CI in Singapore discovered that there is lack of management of contracting companies to supply their workers with training in LC concepts. Omran and Abdulrahim (2015) established that “lack of managerial culture and need of information and skills” that support collaboration were the foremost challenging barriers to the organisation of LC within the Libyan CI. Correspondingly, Ayalew et al. (2016) demonstrated that 74 per cent of respondents think that absence of information around LC concepts and unskilful labourers is the main significant obstruction to LC organisation within the Ethiopian CI. Furthermore, Adegbembo et al. (2016) stated that the need for LC knowledge and consciousness amongst Nigerian professionals is the main obstruction to its usage. Ciarnienė and Vienažindienė (2015) detailed that 74 per cent of the overviewed respondents considered "lack of information and inspiration" as the main barrier to the adoption of LC in Lithuania.

Al-Aomar (2012) argued that "lack of lean perception among top management and employees", "inadequate training and the expensive lean training" and "absence of lean professionals and proficiency" are the main barriers to embracing LC concepts in Abu Dhabi's CI. Moreover, Neeraj et al. (2016) detailed that the major boundaries within the United States of America (USA) are "inadequate information on the usage of LC", which was categorised first with 47 per cent. On the other hand, there are certain barriers depending on the perspective of each country, such as "insufficient money related resources" and "lack of government support", which were more main one in developing countries.

2.6 MEASURES FOR IMPROVING THE ADOPTION OF LEAN CONSTRUCTION

Construction industries worldwide face problems that directly and indirectly affect the application of LC practices in their construction projects. Given this reason, it is imperative to understand the components that make the execution of LC difficult (Hessen, 2000). Several drivers and strategies have been identified by different researchers.

Kim et al. (2008: 385) stated that there is a necessity to understand LP and the tools for effective execution of LC in the CI. Training of staff at levels of LC can advance production and performance of construction projects (Alarcon and Seguel, 2002:8). The following are the measures relating to education and skill development: educating of staff at all stages on lean; engagement of competent site operators; knowledgeable experts; introduction of the lean concept to school curriculums; and the awareness of the lean idea to companies, professional bodies and major stakeholders. In addition, and the CI has to support workshops and research conferences to promote the exchange of knowledge on LC.

According to Bashir et al., (2010:5), the appointment of lean experts is considered the most significant measure to increase the implementation of LC practices within the CI. The companies can utilize a lean professional to direct both managers and workers during the first application (Bashir et al., 2010:5). However, Olatunji (2008:292) revealed that adequate funding of projects is the basis for executing LC and it can improve the use of LC practices.

The identity of the project pioneers can have an influence on the supporters and hence the execution of a project (Hochstatter, 2015:56). Subsequently, LC depends on the potential and capacities of top managers in order to effectively achieve many of its purposes. The decentralisation of construction management and top management commitments are the most important measures to improve the use of LC and construction managers should be dedicated to change.

In addition, Li et al. (2012:49) suggest that communication among owners, contractors, subcontractors, designers, and suppliers is the basis for executing LC and can improve the use of LC practices. He further confirms that improvement of communication can enhance the reliability of the construction system and reduce the idle time, inventories and cost, in addition to assuring the successful execution of LC. In order to move forward the execution of LC, Li et al. (2012:49) propose the coordination between the contractors and subcontractors as a requirement and effective communication between owners, temporary workers. Subcontractors, designers, and suppliers are the basis for implementing lean construction. This helps ensure the whole project is continuous and reliable, which is the prerequisite for delivery with zero-time and zero inventories.

It is essential that the government supports the application of LC because it can positively encourage the motivation of stakeholders. Olatunji (2008:292) lists various government-related drivers such as government reorientation in their approach to projects' execution; provision of basic infrastructure and an enabling environment favourable to lean; establishment of standards for construction; favourable government policy; change in the organisational culture of stakeholders (i.e. bureaucracy, power culture); construction markets' stability and professional bodies working with the government to introduce lean. The ultimate purpose of these is to improve organizational conditions and achieve greater satisfaction of stakeholders.

Olatunji (2008:292) further suggests the following as drivers for the effective execution of LC practices: minimisation in the usage of subcontractors, usage of precast elements, usage of specialist contractors, and reliance on indigenous professionals.

Organizations can experience successful implementation of LC through the way project participants are able to change their behaviours to suit this new approach of project delivery (Salem et al., 2005). According to Hochstatter (2015:56), collaboration and team spirit among participants and a good relationship with suppliers can also improve the application of LC practices in the organisation. Furthermore, human resources also have a key effect on lean execution and its achievement (Kim, 2002:43).

Kim et al., (2002) discovered examine the following features for effective LC execution in the CI: organizational support, training coordination and communication, attitude factors including involvement upon employees' ability and commitment, contract factors comprising self-interest (derive involvement, coordination), the role and accountability of project participants and planning systems factors which include production control, work structure and Last Planner.

2.7 BENEFITS OF ADOPTING LEAN CONCEPT IN CONSTRUCTION

According to Shang and Sui Pheng (2014), the repetition of projects delay and increasing of construction project cost is considered as an essential issue within the CI. In addition, the CI is additionally categorized by poor quality, poor security and bad impacts on the surroundings (Bajjou et al., 2017a).

Although the CI worldwide encounters several challenges when implementing LC, some industries have recognised the opportunity to embrace improvements through lean implementation (Vilasini, 2014:8). They have gained a better-quality safety (e.g. decreased site accidents and decreased unneccesary movemement on site by the labourers'.

A study by Erol et al. (2017) conducted a comparison between the lean and non-lean situations of a residential building project in Turkey. The results of this study illustrate that the overall project period was decreased by to 6.15 - 9.56 per cent after including LP. By applying LPS on an industrial project in Egypt, Issa (2013) stated that these approaches made a difference to decrease the whole term of the venture by 15.57 per cent. In addition, Adam and Howell (2012) evaluated the impact of executing LC practices in 50 housing units in Nigeria. By embracing LPS, they managed to finish the project in 65-72 days, which show inspiring outcomes when matched to the conventional approach (not in less than 120 days).

The most important benefit of using LC in organisations is the reduction of waste (Luo et al., 2005: 342). By eliminating waste in the construction, LC encourages the following:

minimising double handling and movement of labourers and tools, stability of team, coordinated flows, removal of material limitations, minimising input difference, minimising challenging systems and changeovers. According to Womack, and Jones (2003), the most important benefit is greater customer satisfaction. When implementing lean construction under customer focus, construction companies are able to meet the desires of the client, outline value from the viewpoint of the project and use flexible resources and adaptive preparation to respond to changing needs and opportunities. Mossman (2009:26) also supported this by outlining the LC benefits that flow from construction organisations and which are known to be the most important advantages of applying LC practices in the CI are as follows: increased productivity, improved reliability, improved quality, more client satisfaction, increased predictableness, shortened schedules, less waste, eliminated cost , enhance build-ability and enhancements to design.

Cleanliness and organization are important benefits because without them opportunities for improvement and sources of problems are often obscured. Salem et al., (2005) stated that specifically a clean working environment makes it simpler to see defects, missing parts or leakage on equipment, improve work security and decreases the chance for accidents. Also, lean construction results in efficiency of equipment, the use of relevant equipment, high performance of adequate equipment and the use of relevant equipment. It is worth repeating that housekeeping is a good starting point and a way to develop and reinforce the work practices, attitudes and skills important for waste reduction, constant development in productivity and lean construction.

According to BPP Learning Media (2014), the practisers of LC believe that LC helps organisations to deliver on demand, reduce inventory, maximise the usage of multi-skilled employees, flatten the management structure and focus resources.

Furthermore, Modi and Thakkar (2014) believe that advantages of implementing LC practices in the CI are decrease in cost, decrease in lead time, waste decrease, enhancement in production, quality development or decrease in defects, and decrease in cycle time.

Teamwork is about the groups of people who are dedicated to a mutual purpose and work together as a team in a co-ordinated and equally supportive way (Aziz and Hafez, 2013). The benefits of lean construction labour related discussed by BPP Learning Media (2014) are as follows: labour reduction while maintaining or increasing throughput, maximising the use of multi-skilled employees, improving effective communication between stakeholders, encouraging collaboration, and encouraging lean thinking among all employees involved in the project.

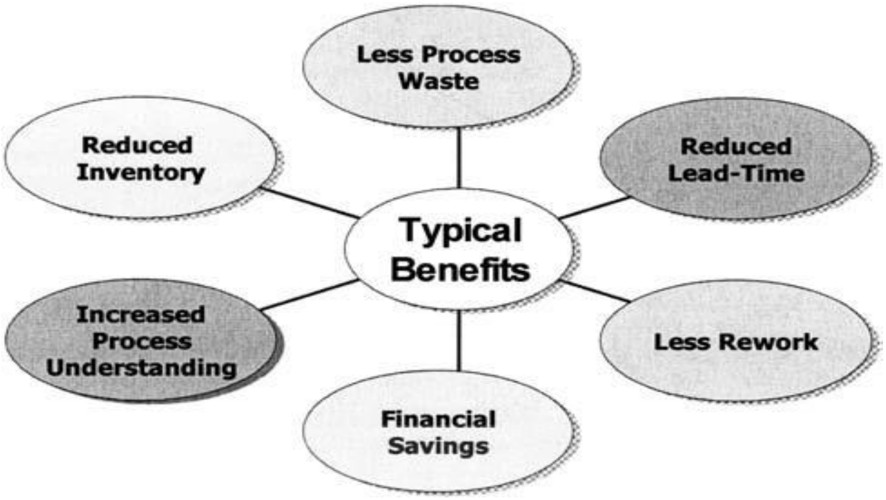


Figure 2.1 Typical benefits of lean construction

Source: Womack and Jones, (2003)

2.8 LESSON LEARNT

Literature reviewed in this chapter revealed the issues facing the CI amongst many others to be uncertainty, limited assets, and unskilled workers, low levels of yield, overruns, extreme wastages, capability of local contractors and professionals, incompetent and non- apparent procurement coordination, dishonesty and financial negligence in public/private sectors, occupational hazards on construction sites and a lack of human resource improvement. Literature identified the seven categories of waste in construction to be overproduction, time on hand (holding up), transportation, additional/inappropriate preparing, inventories, and development and making faulty items. It further revealed how this waste can be minimized through reducing, reuse, recycle, recover, disposal and the adoption of lean construction principles. Literature reviewed further revealed the lean techniques in CI to be the last planner system, increased visualisation, daily huddle meetings, first-run studies, 5S process, and fail safe for quality and safety. Literature identified five important LPs that assist the project participants to manage projects in flexible way to meet clients’ needs to be value, value stream, flow, pull and perfection.

Literature also showed that although LC ideas have lately gained attention as innovative method of improving construction execution and work efficiency, the industry is slow in adopting lean. It further revealed that the slow uptake of LC is linked to a number of barriers such as the non-existence of lean understanding, absence of sufficient lean awareness programmes, absence of sufficient time for innovation, poor standardized procurement strategies, inaccurate and incomplete designs, absence of top management commitment, lack of appropriate training, lack of interest from clients and poor communication among stakeholders, amongst others. From the literature reviewed the following are deduced and identified as the potential drivers of LC: educating of employees at all levels on lean, appointment of skilled site operators, appointment of experienced professionals, introducing the lean concept to school curriculums, advancement of lean concept to companies, professional bodies and major stakeholders, appointment of lean experts and adequate funding of projects amongst others. From the literature reviewed the following are deduced and identified as the potential benefits of LC: improved safety (reduced trip hazards and fatigue), improve environmental performance, reduction of waste ,reduce project duration, increase the productivity, Meet client's needs, reduced project cost, improve quality, efficiency of equipment, improved collaboration and decreased defects.

2.8 CHAPTER SUMMARY

From the reviewed literature in this chapter it was found that the ultimate purpose of lean construction is to decrease waste through the holistic integration of its levels, principles and techniques. The companies' top management and government commitment is also encouraged and advocated to ensure a thorough application of LC at its deepest level to ensure sustainable outcomes and solutions. The following chapter will review international literature, exploring the issues encountered by the CI of countries beyond the continent of Africa.

CHAPTER THREE

LEAN CONCEPTS IN THE UNITED STATES OF AMERICA AND UNITED KINGDOM

3.1 INTRODUCTION

This section gives a theoretical review and conceptual perspective of lean concepts in the construction industries of two international countries, namely the United Kingdom (UK) and the United States of America (USA). These nations were selected based on their application of lean within their respective CIs. This chapter firstly reviews literature which looks at the overall state of the CIs in the respective countries. Secondly, the chapter focuses on the general summary of the execution of lean concepts in CIs. Lastly, lessons learnt regarding lean concepts in the respective countries are presented.

3.2 LEAN PRINCIPLES IN THE UNITED STATES OF AMERICA

3.2.1 The USA construction industry

The CI is regarded as one of the biggest sectors in the whole of the USA (Bello, 2012). It is a significant contributor of the economy as it accounts for thirteen per cent of the GDP in the country, making it the largest manufacturing industry (Harvey et al., 1996; US Bureau of statistics, 2000). The BLS (2010) reports that it comprised 7.2 million dollars remuneration and salary jobs, and 1.8 million salary and 1.8 million self-employed and unpaid family employees .Furthermore, fewer than a hundred thousand enterprises have a project volume over ten million USD, with the ten biggest firms executing around fifteen per cent of non-residential construction work .According to Hendrickson (2008), sixty per cent of all construction in the USA is executed by the top four hundred construction companies .

The USA construction industry (USACI) is categorised into building construction, heavy civil engineering construction and speciality construction (BLS, 2010). The building construction segments provide services such as the construction of residential, institutional, and commercial infrastructure and heavy civil construction includes the construction of bridges, dams, airports and the like (Hendrickson, 2008). According to BLS (2010), out of the 884 300 registered construction companies, 30.5 per cent of the companies are building contractors, 6.5 per cent are heavy construction contractors and the rest are specialist trade contractors.

In addition, Na and Roger (2008) carried out an investigation of efficiency on the CI and discovered that: the normal construction employee works at only 40% proficiency, there is serious shortages of qualified, skilled workers and forecasts that the situation is becoming worse. Business Week's 2007 Investment Outlook Report shows that the return on equity (ROE) for all USA industries is 17.9%, while the ROE for the CI is a mere 9.7%, in spite of the recent construction boom. Industry clients are disappointed with poor quality, showdown, and excessive variation orders in number and dollar value, planning delays and litigation (Garrison, 2007).

3.2.2 Adoption of lean concepts in USA

The International Group of Lean Construction (IGLC) introduced LC in 1993 in USA. The IGLC purpose is to meet the client’s requirements, significantly advance the Architectural, Engineering and Construction (AEC) method (IGLC, 2010). Studies shows that the construction experts in USA have tried to execute lean techniques into the genuine construction projects and have been effective in terms of decreasing waste and making income. Salem et al. (2006) carried out a field study with the assistance of coordinated perceptions, interviews, surveys, and documentary analysis to assess the efficiency of some LC strategies, such as the last planner, increased visualization, daily huddle meetings, first-run studies, the 5s process and fail safe for quality. The study centred on the first stage of a four-floor university garage project found within the USA. The building was cast-in-place reinforced concrete. It was discovered that there is a necessity for behavioural changes and education in the effective use of lean tools. The key barrier for LC is that the project manager or the contractor may query the usage of the LP at an early phase of execution of lean at any new project location. This is because the benefits of lean application are only seen in the long term. The long-term advantage of lean is that the project is built below or at least within the estimated budget and within the planned time as lean stresses reducing the waste.

Lean concepts have been executed in the CI of USA (Abdullah et al., 2009). The studies carried by Johansen et al. (2002) and Common et al. (2000) within the Netherlands and the UK, strongly propose that the CI has normally been slow in adopting LC (Johansen and Walter, 2007). Furthermore, a brief study trip was carried out by Koskela (1998) to the USA in February 1998. The objective of the research was to examine whether US construction firms were implementing LC approach and, if so, what outcomes were being accomplished and whether they encountered any barriers within the process. The study was also planned to connect up with the Lean Construction Institute (LCI), which had been established by Ballard and Howell (1998), two top researchers in this area, in conjunction with a few companies. With the assistance of the LCI, the opportunity developed to involve in a yearly company conference driven by the Neenan Company. They are Colorado States' fourth biggest develop, design and build company and through the support of their owner, David Neenan, have adopted a lean thinking philosophy. Four company case studies were accomplished as an outcome. In addition, the University of California at Berkeley and Stanford University were also visited.

The main results of the study visit are as follows: There is a little but increasing community in the US of academics and specialists looking to improve LC, mainly in association with the LCI and the two top companies are the Neenan Company in Colorado and Pacific Contracting in San Francisco. The outcomes revealed the following: office construction times decreased by 25 % in 18 months; schematic design decreased from 11 weeks to 2 weeks; turnover increased by 15- 20 % (Pacific Contracting), efficiency increases, satisfied customers were looking to come back again, and project costs decreased. Innovations include prefabrication, every day work monitoring, single piece flow on site, integrated engineering, procurement construction processes and 3D design.

Gilbert (2008) conducted a study on the distribution of lean strategies within the USCI to set up an understanding of lean principles. In order to accomplish this, a survey was established and circulated to 113 construction-contracting companies who were represented at the 2008 University of Florida spring career fair. Forty-four of the contracting companies answered to the survey, indicating a 39% rate of return. The outcomes of this study showed that there was a slight distribution of lean principles within the USACI and pointed out that only 23% of respondent organisation were aware of LC. This lead to the conclusion that "most of general contractors, specialty contractors, and construction management firms in the construction industry are unfamiliar with the term lean construction as an approach to managing the construction process" (Gilbert, 2008:86).However, there appears to be at least some embracing of LP among bigger companies surveyed (more than 200 employees), and the responses received showed that those companies who were aware of the concept of LC and who had embraced at least some of the approaches "believe that it is advantageous" (Gilbert, 2008:87).

Song and Liang (2011) carried out case study about contractors and established that in addition to the reconsidering of current construction methods, there was a need for modern tools to execute LP. Their study detected waste in both project-level contractor coordination and operation-level construction performance. To execute waste elimination solutions at the operation level, construction simulation and 3-D visualization tools were applied. One of the core reasons leading to wastage at the construction site was the absence of communication and management. Song and Liang established a vertically integrated programing framework that highlights an interface with the critical path method (CPM) based schedules, a location-based look-ahead scheduling algorithm, and a graphic weekly planning strategy to advance it.

In 2013, McGraw Hill Construction carried out a research study of lean practices within the USCI between both general and speciality contractors. This quantitative study produced responses from 193 contractors comprised of two groups i.e. construction contractors that were associates of the LCI (37%) and construction contractors that were not associates of the LCI (63%). Of the non-LCI member organisations, 28% had applied at least one lean practice, 35% were aware of LC but had not employed any lean practices, and 37% were not aware of LC at all. This study demonstrates that 63% of construction contractors were aware of LC; but less than half of those associations aware of LC had truly executed a lean practice. However, this study does show a rising move towards LC in terms of awareness and implementation.

3.2.3 Implementation of lean concepts in the USA construction projects: case study

This case study was adapted from Hamzeh in 2011. The project was a projected 555-bed hospital and medical campus in San Francisco, California. The $1.7 billion project included a 16-story hospital. This was one of a kind case study since the project was executing integrated project delivery and integrated form of agreement, engaging project stakeholders who are interested in experimenting with lean practices, implementing LPS for production control, using target value design to steer design towards meeting the owner's value proposition, and using building information modelling broadly.

A construction team was chosen on this project and assigned with developing new planning methods, categorizing education needs, developing education programmes, and examining deployment models. The group included group pioneers and supervisors from the architects/engineers and the construction managers/general contractors. The evolution group drew up an education programme to train different perspectives of lean concepts, principles, and techniques. This program comprised five fundamental areas: presentation of lean history, concepts and techniques; essential training modules; lean conveyance; and lean management. Coaches from the project were afterward allocated to produce and teach the fundamental training modules. These modules incorporate value stream mapping, 5S (sort, set in-order, shine, standardize, sustain), reliable promising, learning from experiments, learning from breakdowns, choosing by advantages, and A3 reports.

The collective usage procedure on the project is the establishment of the execution system displayed in this case study. By setting up evolution groups the project management group was able to produce buy-in efficiently for the method and share the value of LPS. The educational programme was influential in arranging the project team participants around lean objectives and developing a collective planning surrounding. In spite of the achievement of these efforts, the project team encountered numerous mutual barriers to change which constrain the adequacy of LPs. These include corporate organizational decisions, human capital restrictions, innovative obstacles and human resistance to change (Hamzeh, 2011). These components are not exceptional to LPS usage and will likely be barriers to any change effort.

For an effective implementation of LPS in this project there were success factors such as support and commitment from top management, availability of skills and training, establishing a knowledgeable expert team, developing and performing a training programme, execute a pilot LPS trial, executing LPS on a more extensive scale and including lessons learned and rewarding successful performance.

3.1.5 Lesson learnt

Literature showed that there is a growing move towards LC in relation to awareness and adoption; however, it was established that there is a requirement for behavioural changes and education for the successful usage of lean instruments. The literature further showed that even though usage of lean in USA was not without challenges, professionals have profited from it. They experienced a better level of specialist security and quality, client fulfilment, advanced labour productivity and saved costs when compared to not utilizing lean. Lastly, the literature showed that the adoption of LC offers long-term benefits of lean. Projects built within projected budget and planned duration.

3.3 LEAN CONCEPTS IN UK

3.3.1. The United Kingdom construction industry (UKCI)

The CI is a big industry in the UK economy, having a major influence on the environment (Akadiri and Fadiya, 2013). Holton, Glass, and Price (2010) indicated that the UKCI is usually acknowledged as including four main activities: building, civil engineering, materials and products, and associated professional services. The sector employs 3, 1 million individuals, that represents to 10, 5% of the UK employment and adds up to 10% of the GDP (Office for National Statistics, 2012). According to Worrall et al. (2010), during the 1980s the industry was transformed with the opening up of a freer market and weakening levels of traditional governmental participation. This led to a better division of the industry, with contractors' progressively subcontracting work. This in turn encouraged a working environment that was more competitively and forcefully driven by cost and hazard variables (Worrall et al., 2010)

Studies have revealed that construction activities are accountable for over half of carbon emission, water consumption, landfill waste and 13% of the raw materials utilized in the UK (Business Enterprise and Regulatory Reform [BERR], 2010) and it has the highest number of fatal injuries of key industry groups. Additionally, it is one of the foremost risks in terms of health and safety (Ashworth, 2010; HSE, 2013). According to Jones and Greenwood (2002), construction activities consume a massive number of natural resources and produce about 70% of the waste in the UK. These wastes comprise off-cuts, spoiled materials, new materials and demolitions which generally end up in landfill (BERR, 2010).

Another main issue confronting the sector is its poor safety record. The industry has the high death rate due to accidents on construction locations. This discourage workers, delays project completion, increases overall project cost, decreases efficiency and tarnishes the public image of the industry (Walsh and Sawhney 2004; Sacks et al., 2009; Thandawee 2009). Moreover, the accidents result in productivity losses, low morale and additional project cost (Abdelhamid et al., 2003; Jang and Kim, 2007).

3.3.2 Lean concepts' implementation in UK construction projects

Since 1998, the awareness programme to encourage the use of lean concepts in construction over most geological areas of the UK has been rising, as demonstrated in sessions arranged by the Construction Industry Research and Information Association and construction productivity network (Johansen et al., 2002). This awareness programme has been extended to incorporate the Construction Lean Improvement Programme (CLIP) that was made by the BERR in 2003 to advance case studies created by Construction Excellence. The foundation of the Lean Construction Institute United Kingdom (LCI-UK) and a few LC consultancy and advertising firms have moreover made a difference to improve awareness of LC principles and techniques. A few organizations and universities presently offer LC education, which has been supportive in advancing the lean idea into the standard of construction education.

Regardless of these persistent efforts, research by Common et al. (2000) has revealed that the occurrence of a lean philosophy in the big UK construction firms is less than the one confirmed. An indeed bigger gap is clear from the extent of improvement recognized within the LC literature review in other nations like those in the UK (Common et al., 2000). This is highlighted by Mossman (2009) and Bashir et al. (2010) who stated that though numerous countries gained great benefits by embracing LC, there appears to be limited usage of lean in the UKCI over the past two decades, even after the publication of the Egan report (1998). There seems to be some structural and cultural obstacles that hinder its effective execution.

In the 1990s, the UKCI was continuing with high failures and zero development. To understand the reasons behind the failure, the British government ordered an investigation into the sources and potential resolutions of this matter. The outcomes of the study were the Latham report (1994) and the Egan report (1998). These seminal reports emphasised the inadequacies and wastes failures that were endemic within CI. They moreover suggested proposals for improvements within the industry through the removal of waste or non-value-adding activities from the construction process.

Lean concept has grown into a significant concept in the UKCI, following the Egan report (1998). There has been major advancement in the programme for change in the UKCI. The lean concept has been used mainly on site activities. However, it has to be included at the executive stage to direct top management in organising change (Womack and Jones, 1996).

Just after the 1998 Egan report, Common et.al, (2000) conducted a study amongst UK construction firms to assess the transmission of LP to construction by exploring their perception into big construction firms in the UK. The exploration was conducted by means of a questionnaire, 100 were distributed to 100 large construction firms, with the purpose of finding the level at which these firms used LC practices. The study had a 35% rate of response and the findings revealed that there was a “distinct lack of understanding and implementation of the vital techniques essential for a lean practice to happen", and although there had been some usage of LC, it was in combination with conventional project conveyance approaches. The study also established "great variation" in the survey groups' awareness of LC and how LC had been implemented by the industry (Common et al., 2000).

Few studies have been carried out in order to evaluate the recent levels of awareness and usage of lean concepts in the UKCI. An illustration of such studies is the usage of the Last Planner in a UK construction project. LPS is perhaps one of the most advanced lean tools and techniques. The tool was utilised in a UK construction project to establish its value and its likely obstacles. Nevertheless, the study raised several significant structural and cultural problems for the achievement of Last Planner in the UK (Johansen and Potter, 2003).

In addition, Sarhan and Fox (2012) discovered that there appear to be positive trends within the advancement of lean practice amongst the UKCI. Need of knowledge of how to effectively execute LC principles to particular construction practices was moreover revealed.

Furthermore, a case study of LC execution in the UK construction project has been studied in order to examine their experiences with LP adaptation and also to attempt to establish the benefits which surfaced from its adoption as well as the challenges faced when implementing LP.

3.3.2.1 Implementation of lean concepts in the UK construction projects: Case study analysis

The following case study is in accordance a paper presented by Upeksha (2015) at the 4th world construction symposium. The project was a proposed 128-bedroom Travelodge Hotel comprising the restoration of an area that contained a number of derelict dwellings in Hounslow, United Kingdom with an agreed budget of £ 5.7 million. The project involved the present approaches of applying LPS and was procured under a negotiated design and construct method. This leisure project maintained nearly 95% progress at the final month of the project. The moderately few subcontractors involved during the estimation period may have simplified the coordination issue (Sicat, 2012). In any case, the effective coordination between sub-contractors, client and the core contractor with extensive participation of sub-contractors, particularly in planning and constraints analysis, is a great example that can be followed by all companies.

The two primary goals of LPS are to create improved execution to coordinate workers through constant learning and remedial activity and to cause the work to flow smoothly over the deliverables within the best achievable arrangement and rate (Anon, 2005). The last planner integrated factors in this project were master plan, stage planning, look-ahead planning, weekly work planning, percentage of promises completed on time or percent of planned completed (PPC) (Aziz and Hafez, 2013).

Detailed benefits attributed to LPS usage in this project, which clearly shows the positive result of the framework on budget and productivity were as follows: cost decreases, solid forecasts for planning, smoother construction flow, decrease in project period, improvement in proficiency, and superior collaboration of work among sub-contractors and client/main contractor.

Challenges experienced by project stakeholder when implementing LPS were moreover recognized as follows: lack of understanding due to poor training, organizational inactivity, resistance to change, poor leadership/guidance, contractual disputes, and need of lean experts. LPS has four fundamental components such as Programming Workshop which includes collaboratively creating and agreeing production sequence (and contracting the sequence when required); make-ready, comprising preparing tasks so that they can be done when needed; production planning which entails collaboratively agreeing on production tasks for the following day or week; and finally, continual improvement and enhancing the project, planning and production procedures.

3.2.4 Lesson learnt

This section presented an in-depth discussion of lean concepts in the UKCI. Literature showed that lean concepts have been utilized mostly on site activities and it revealed the rewards such as cost reductions, reliable predictions for planning, smoother construction flows, reduction in project durations, enhancement in productivity and a better collaboration of work among subcontractor and client/main contractor. The literature further showed that the challenges faced when implementing LP such as absence of knowledge owing to inadequate training, organisational inertia, résistance to change, poor leadership/guidance, contract arguments and absence of qualified professionals can prevent the implementation of lean concepts in UKCI.

3.3 CHAPTER SUMMARY

This chapter presented a review of literature relating to the UK and USA construction industries. The chapter further provided an in-depth review of LP adoption and adaptation through the examination of case studies in both countries .The findings revealed the challenges and rewards of effective execution of LP and techniques in different organisations. The following chapter will review the literature relating to two African countries, their construction industry, their experience of lean principles as well as lessons which can be learnt from both countries.

CHAPTER FOUR

LEAN CONCEPTS IN AFRICAN COUNTRIES

4.0 INTRODUCTION

This chapter gives a theoretical review and conceptual perspective of lean concepts in the construction industries of African countries, namely Nigeria, Morocco and South Africa. It firstly reviews literature, which focuses on the state of the CI generally in the respective country. Secondly, the chapter focuses on the general overview of the execution of lean concepts and the implementation of lean concepts in the CI. Lastly, lessons learnt regarding lean practice in the respective country are discussed.

4.1 LEAN CONCEPTS IN NIGERIA

4.1.1 The Nigerian construction industry

The Nigerian CI accounts for roughly 1.4% of the country's GDP and the sector is basically overwhelmed by small and medium size contractors working locally and incorporated mostly in private construction projects (Oluwakiyesi 2011; Olatunji 2008 and Dantata. 2008). Ordinarily, building projects in the nation are taken care of by private customers who only employ skilled workers and labourers, with the client in a few cases overseeing the project. On the other hand, qualified and recognized workers similarly occur within the industry; this set of contractors are lawfully enlisted to carry out development projects and are typically as a rule made up of highly experienced labourers, both refugees and residents (Dantata 2008).

In the past, the CI in Nigeria has been categorized by reduced quality work, cost and time overruns (Oyewobi et al. 2011), resulting from poor project descriptions in the planning period (Olusegun and Michael, 2011; Oke and Ogunsemi, 2011), inadequate designs in design phases (Aina and Wahab, 2011; Windapo and Martins, 2010), waste due to government, changes, delay from providers and poor site administration (Oke and Ogunsemi, 2011; Dlakwa and Culpin, 1990).

The Nigerian CI has given work for distinctive categories of workers, particularly in main Nigerian towns where development undertakings have been massive (Adeagbo, 2014) .These incorporate the government capital region, Abuja, and the different state capital cities such as Lagos, Harbour Harcourt, Ibadan, Kaduna, and Kano, amongst others. According to Adeagbo (2014).

According to Nwafor (2006), construction is the main and essential subdivision of the Nigerian economy and the issues of maintainability cover a massive range of the division. The awareness of ecological issues has increased in Nigeria (Nwokoro and Onukwube, 2011).

In a related advancement, Nigeria as an emerging nation and its CI are still battling with many essential challenges, ranging from insufficient specialized and executive know how to inadequate budget, material and apparatus capital base (Ofori, 2001). In addition, numerous development projects are confronting cost and time overruns as a result of budgetary and marketplace performance, inaccessibility of the necessary apparatus, labour work deficiency or strikes. Other components such as insufficient design, delay due to subcontractors, need of appropriate organization, poor supervision, shortage in development undertakings, lack of specialized employees, poor communication, conceptual variances in projects, insufficient viability studies, shortage of the essential technology and financial instability in the country (Aibinu & Jagboro, 2002; Omoregie & Radford, 2006; Ameh et al., 2010). According to Ameh et al. (2010), only 48.8% of the public sector and 37.2% of the private segment projects were concluded in the specified budget in Nigeria whereas 20.5% of the public and 12.5% of the private segment projects were concluded in the construction period between the years 2005 and 2010.

Though the sector is additionally full of natural resources, that will balance out the materials division and the massive shortage in physical infrastructure (road, rail, railing, airplane terminal and ocean harbour) that will be crucial to generating chances for feasible improvement (Oluwakiyesi, 2011).

4.1.2 Adoption of lean concepts in Nigeria

While there has been an adoption of LP in developed countries (Ballard and Howell, 2003), developing countries such as Nigeria are still faced with a low level of knowledge and adoption of LP (Olatunji, 2008; Ahaikwo et al., 2012). LC application in emerged and emerging countries has been acknowledged by Alarcon et al. (2005) to improve the whole construction practice. In view of this, Sacks and Goldin (2007) indicated that the building industry has become a key candidate for LC. Similarly, other researchers have discovered that the execution of lean in the CI of other countries has progress the work stream consistency (Thomas et al., 2003), upgraded planning consistency and led to project performance for enhanced efficiency (Gonzalez et al., 2010; Ballard 1997:18) by maximizing value and decreasing waste (Koskela, 1992).

Researchers tend to embrace the constructivist method categorized by participative and cooperative practice for the useful execution of the LPS since it helps the workflow of construction sites (Alsehaimi et al., 2009:54). Suresh et al. (2012) and Olatunji (2008) documented the level of client's awareness around LC in Nigeria. It was detected that their level of awareness was extremely low and clients have been acknowledge to be the centre of development since they are the dynamic drive for construction advancement (Otham, 2011).

Nevertheless, executing the LPS in Nigeria faced with numerous barriers. Adegbembo et.al. (2016) categorized these obstacles in several classifications based on a thorough and critical analysis of an evaluation of LC practice in the Nigerian CI. These include lack of lean awareness and understanding, absence of knowledge of the necessity to embrace the lean concept and absence of proper education, poor communication among stakeholders, waste acknowledged as inevitable, incompetent utilise of quality principles, delays in material distribution, delays in decision making and the non-existence of an approved execution approach. Suresh et al. (2012) also recognized a few obstructions to the execution of LC in Nigeria. These barriers incorporate lack of specialized, skillful and proficient specialists, low incomes and pay rates, client's hesitation, low authoritative structure and management, and poor government control and authorization of controls.

These boundaries can be gathered into three main clusters comparable to the boundaries documented in Othman (2011) which comprise organizational resistance, insufficient management funding, and unrealistic anticipations. To overcome these barriers, Suresh et al. (2012) stated that a procedure must be in place to get the client's understanding and clarification, training and workshops, tools implementation and monitoring. In addition, Othman (2011) acknowledges that to conquer these three obstructions:

i. a clear case for LPS has to be created and individuals have to be sufficiently prepared and included in the execution process;
ii. the money-related benefits of actualizing LPS must be clearly expressed to the management; and
iii. Sensible time scales and restrictions must be set for the construction period.

4.1.3 Lean concepts application in the Nigerian construction projects: Case study analysis

A few Lean concepts execution in construction projects within Nigeria have been studied in order to examine their experiences with LP adoption and also to attempt to establish the benefits which surfaced to its adoption. Furthermore, these studies also intended to determine the effects of implementing lean concepts in the CI and what factors were critical for their successful implementation. In the instance of an implementation failure, understanding will also be sought in order to diagnose the failure.

4.1.3.1. This case study was explained by Adamu, Howell and Abdulhamid in 2012.

Yobe State Government in Nigeria launched the building project of 500 units of houses with the aim of executing initiatives on generating supply for the house demands. The authorities spoke of their concerns with the construction competency and included the stakeholders in the decision-making procedure around the managing approach. From these discussions, the execution of LC theories developed as an answer to the challenges related to the completed product and the waste created throughout the development process.

The case study evaluated the application of LPS within the development of 500 low cost houses with the purpose of comparing the LPS with the conventional construction strategy and analyzes the real status of the LC theories, knowledge and usage within Nigeria. The main objective was to accomplish the quality product of value within the agreed period. One of the groups that the researchers were part of used LPS and the other five groups utilized the conventional method. Within the group conducting the LPS execution, serious research and training about LPS theories were done. Other managing instruments supported the LPS execution

The development project was divided into six supervision groups and one group executed the LC concepts. The results showed that the group applying LPS managed to complete the house unit between 62 and 70 days while the groups applying the conventional management method were not able to wrap up any house unit in less than 120 days. With the implementation of LC ideas, was able to reduce the number of labourers within the construction group, removing industry waste and creating the development activities in reduced time, when compared with the groups applying the conventional managing approach.

Guiding and supervising all the activities required time could become a boring task. The subcontractors were not welcomed to contribute within the planning and monitoring process, and that showed a challenge in working together with the implementation process.

The challenges throughout the execution involved the following: necessity for information around LC and the need to adjust these perceptions to the reality of the local CI, the management method being centred on decreasing the non-adding value activities throughout the construction and reducing the waste. The instruments used centred on the activities in planning and regulation with the use of LPS. There was a certain level of opposition to the execution, particularly related to the level of documentation, construction and communication management because the lean concepts were new within the project of the research study .

4.1.3.2. This case study was explained by Ahiakwo, O., Oloke, D., Suresh, S and Khatib, J in 2013

The case evaluated the application of LPS within the development of four prototype hostel buildings in Federal University in Nigeria.With the study, their purpose was to compare the outcome of the implementation with similar prototype projects that did not implement LPS carried out simultaneously.

The information was collected through conducting interviews, undertaking participant and non-participant observations, documentary analysis and finally through survey questionnaires. The authors highlighted that the four prototype hostel buildings were constructed by four different contractors and the contract cost was approximately N300, 000,000.00 with a projected project period of one and a half years.

Only the fourth contractor agreed to execute the LPS during the process of constructing the project. This application was expedited by the first author and jointly implemented with a project engineer with assistance from the PM. The implementation commenced with the first author undertaking non-participant observations of the workflow patterns together with how site activities were coordinated. Then interview sessions were conducted to ascertain the available planning, control and management practice within the organization before the LPS application commenced.

The research highlighted that the causes of the unfinished work within the 21 weeks of LPS implementation for the project that adopted the lean concepts are as follows:

Material unavailability was the biggest or main reason for incomplete assignments. This was due to an excessive hike in prices, especially that of cement and steel reinforcements. The distance from the project site to the nearest supply location for aggregates and other building materials was also the result for shortages of materials on site. This shortage of materials was however overcome by proper planning and requesting suppliers to deliver well in advance to allow for continuous work.

The second key cause of unfinished assignments was prerequisite work. This was followed by labour supply for the reason that available workforce could not meet the project needs. Other reasons for uncompleted assignments involved late requests, bad weather conditions, defects requiring rework, equipment breakdown and incomplete design information. It was detected that the fourth contractor created significant outcomes related to time cost and quality performances. The contractor completed the project two months prior to the completion date assigned to the project, although the project kicked off three months later. In comparison the first contractor completed his project five months late and the second contractor completed the project six months while the third contractor could not complete the project but went off site owing to cost overruns.

On the other hand, the fourth contractor had all the resources, an organized flow and access of materials. This decreased intervention among working groups, making sureeach group of individuals were aware of what to do and when to do each task. Even though the four projects suffered from material unavailability, the problem of unavailability of material was overcome by the fourth contractor by engaging in short term and look ahead planning in conjunction with frequently doing a limitation investigation to imagine likely limitations to the project before they happen. Executing LPS frequently assisted the project team to obtain data of the project accomplishment and failures during weekly meetings.

4.1.4 Lesson learnt

From the literature reviewed regarding LP in Nigeria and from the case studies of construction projects implementing LP in Nigeria, the lesson learnt are as follows:

The success of the construction of 500 units and prototype hostels in Nigeria in achieving the shortest implementation period which fulfilled the required functionality, within budget and quality performance can be attributed to a numeral of factors. These include adequate client awareness and involvement at all stages of the project, adequate project team awareness, a fully empowered, well-motivated project team who share the same vision for the industry, enabling team spirit pre- and post- implementation, a well dedicated PM, and top management commitment.

The major difference between Nigerian implementation when compared to other countries is that LC is new in Nigeria, few professionals in the construction industry know about it and the adoption of LP in Nigeria is still limited unlike other developed countries. However, Nigeria has implemented lean principles in a few projects and it created significant outcomes in terms of time and cost, duration of project and quality performance.

LP and tools should be implemented at the beginning of the project to avoid major obstacles for the implementation process. Also, awareness campaigns are an important part of any effective application of LC and also training on lean construction techniques. In addition, production management is important, as it will eliminate conservative estimation and frustrations among project teams.

The outcome of the execution and adoption of LP in the construction projects is not only dependent on the contextual factors but it is also mediated and controlled by the manner in which the project being implemented is nurtured, supported and managed through its implementation process. From the LP implementation process we learn that there are obstacles met during the application and these include lack of commitment to change and innovation, unrealistic expectations and lack of top management commitment.

4.2 LEAN CONCEPTS IN MOROCCO

4.2.1. The Moroccan construction industry

According to Sarhan et al. (2017:46) and Tezel et al. (2018:247), CI symbolizes an essential contribution physically to the financial development of both developed and developing nations. The CI in Morocco adds mostly in improving the nation-wide economy and decreasing the unemployment level, adding 6.3% of total gross value added (Ministry of Territory and City Arrangement, 2015). In addition Bajjou et al. (2017b:171) showed that CI utilizes about a million individuals (9, 3%) of the active workforce.

Moroccan construction projects are normally categorized by low efficiency, which is basically due to numerous challenges such as programme delay, cost overrun and poor quality (Habchi et al., 2016:194). Moreover, Bajjou et al., (2017a:119) indicated that the

Moroccan CI has a bad effect on the surroundings because it produces a large amount of compacted waste throughout the construction developments.

In Morocco, nearly 9 million tons of compacted waste is thrown away each year in the environment (Bajjou et al., 2017b:170). Other than that, the Moroccan CI is measured as the biggest user of energy; it accounts for 36% of energy usage and 32% of the manufacturing sector (Dadhich et al., 2014:271). In addition, it is considered amongst the sector of activities as having an excessive effect on air contamination and the weakening of the ozone layer; it could be a source of 45 million tons of CO_2 (Bajjou et al., 2017b:170)

Figure 4. 1 Comparison of production/waste ratios between manufacturing sector and construction industry

Source: Bajjou et al., (2017b)

Khalfaoui and Zenasni (2014) sustain that it has made a contribution to GDP with up to 6.5%, improved the workforce with a percentage of 11.3%, and represented 50.1% of gross fixed capital formation (GFCF). Unfortunately, this industry is presently encountering few challenges, these barriers fall into two key components, namely external and internal:

i. External components: Given that this industry has been impacted by worldwide competition, arrangements between Morocco and Europe to set up a free exchange area have had a bad effect on the region. “Foreign firms cut costs, undermining the Moroccan development market” (Benhamida, 2008:265.)

ii. Internal components (these are company-specific components): Moroccan companies involving in such economical activities leads into numerous challenges, specifically informal firms and SMEs, which only form 95% of the industry, high costs, climate change, shortage of resources and local procurement, according to business assessment conducted by HCP.

4.2.2 Adoption of lean concepts in Morocco

Moroccan companies continually want to improve their activities in order to create extra potential income in terms of the basic circumstance emphasized above. In such a tight cost effective framework, the modern generation control framework is a last planner system (LPS) (Habchi et al., 2016:195). The LPS formed by Ballard (1992) has been used on supervision of a Moroccan construction site (Habchi et al., 2016:195).

LC has been introduced into the Moroccan CI; nevertheless, it is still in its earliest stages. Based on an organized survey study by Bajjou et al., (2018:545), the awareness of the Moroccan construction experts on the LC usage within the Moroccan CI were evaluated. The following conclusions were made: more than half of the respondents (172 proficient; 52.1%) agreed that LC execution would include positive effects to the Moroccan construction projects and there is a high need for LC in the Moroccan construction projects.

Bajjou et al., (2018:546) through an organized survey study with Moroccan construction experts. The evaluation of the responses associated with lean strategies execution analysis reveal that 17 lean strategies are now being utilized in Morocco (in different shapes and degrees). A total of 39 per cent of the respondents were not familiar with any LC practices, 35 per cent were familiar with LC concepts but have never utilized them in their projects and 26 per cent were familiar with LC practice and are utilizing them in their projects. The findings further show that there are a few strategies that are already executed by more than half of the respondents such as prefabrication and continuous enhancement (63 and 54 per cent respectively). However, the feedback to some other LC strategies does not reflect the same. For instance, the majority of experts within the CI are not familiar with a few techniques such as Kanban system (63 per cent), VSM (58 per cent) and Poka-Yoke (68 per cent). This result comes from the fact that these techniques have recently been introduced within the Moroccan context and not much technical training is available for such techniques.These results shows a higher awareness level of lean construction practices among Moroccan professional compared to other countries, especially in developing countries.

Bajjou et al., (2017:129) also conducted a survey circulated randomly to identify the most critical obstacles in Moroccan CI. The findings classified nine obstacles according to the rate in responses as absence of understanding about LC, unskilled human resources, inadequate financial resources, absence of commitment from top management, resistance to change, lack of government support, culture and human attitudinal issues, time and commercial pressure, fragmentation and sub-contracting.

4.2.3 Lean concepts implementation in the Moroccan construction projects: Case study analysis

4.2.3.1 Case study analysis

A few lean concept implementations in construction projects in Morocco have been studied in order to examine their experiences with lean concept adoption and also to attempt to establish the barriers and benefits to its adoption which surfaced. Furthermore, these studies also intended to understand the effects of implementing the lean concept in the construction industry and to determine what factors were critical for their successful implementation.In the instance of an implementation failure, understanding will also be sought in order to diagnose the failure.

The case study tackled the structural work of a 21-building residential development comprising 396 lodging units with four floors, each covering a surface of nearly 10600 m2 that incorporate the application of LPS. Work on this programme began in June 2015. The partners in this development were the client, the architect, engineers, the project manager (PM), quantity surveyor, and the main contractor. The representatives of the client were accountable for the execution of LPS.

This project was presented with few challenges compared to any other traditional building project because the works were required to take place on a slope platform, given the steep nature of the construction location. At the time of project take-off, meetings were held with groups that used to monitor the project. By means of preparing staff through training, they attempted to continuously present concepts of flow supervision and production control based on the essence LC, which aims to bring about a step-by-step transformation within the team's behaviour.

To allow project participants to be aware of contractor's competence, they continued first by clarifying the necessity of presenting weekly reports as a major part of site administration. They additionally calculated PPC beginning from the actual initial week. In site meetings, the barriers which led to the non-accomplishment of the planned tasks were discussed. It was recognized that they succeeded in changing a few site-based teams' behaviours (as the case of foreman, the last planner who started attending site gatherings), and in clarifying, in coordination with the contractor's PM, the assignments to be executed during the weeks to follow. In the first weeks, they concentrated only on manufacture unit control.

4.2.3.1.2 Benefits and limitations of implementing LPS

The implementation of LPS on the structural work of a 21-building residential project consisting of 396 housing units with four floors was faced with benefits and barriers.

i. Benefits of implementing LPS on the structural work of a 21-buildingresidential project consisting of 396 housing units with four floors

Traceability was part of the key benefit of executing LPS. The project's background was effectively covered since all weekly scheduled tasks, the sum of non-accomplished ones, and sources of their non-accomplishment were all kept track of.

Applying LPS provided project participants with consistent information with respect to the contractor's efficiency. As a result, decision-making continued with more awareness. For example, based on the PPC value (17%) of the week of 07 December 2015, the client was forced to caution the contractor, calling on him to assess the whole programme as well as the key project's milestones.

LPS execution guaranteed practical weekly plans, particularly while including the foreman in forecasting activities.

The six-week look-ahead implementation encouraged all the participants from talking about barriers to the adoption of LC.

ii. Limitations of implementing LPS on the structural work of a 21-buildingresidential project consisting of 396 housing units with four floors

Training on explaining week after week reports and preparation of the six-week look-ahead was at times a struggle and waste of time. Such training was required to be attended by all the project stakeholders. When one stakeholder left during the project, the same training had to be done for the newly employed stakeholder who was replacing the one who had left.

Execution of LPS is effective in recognizing the weekly and the six-week limitations when all participants are cooperative. In that case, they might have reached superior outcomes if the contractor had demonstrated signs of better interactivity. During weekly site gatherings, they wanted to distinguish the planned programme to the current progress.

After last achievement of the project, distribution of the knowledge acquired upon implementation of LPS as a first practice in Morocco was not likely to be guaranteed somewhere else.

4.2.4 Lesson learnt

From the literature reviewed regarding lean concepts in Morocco and from the case studies of construction projects implementing lean techniques in the Moroccan construction industry, the lesson learnt are as follows:

The construction projects in Morocco are normally characterized by low productivity, which is basically due to numerous challenges such as programme delay, cost overrun and poor quality. From the literature it was discovered that there is a greater awareness level of lean concepts amongst Moroccan CI professionals compared to other developing countries. It further showed that the implementation of LC in Morocco is faced with numerous barriers such as absence of knowledge about LC, unskilled human resources, inadequate financial resources, lack of commitment from top management, resistance to change, absence of government support, cultural and human attitudinal issues, time and commercial pressure, fragmentation and sub-contracting.

The case study shows that the success of LPS application on the structural work of a 21-building residential project consisting of 396 housing units with four floors was closely linked to the positive involvement of the contractor through its commitment to resolving the constraints identified during the weekly and six-week look-ahead plan.

The case study also revealed that the implementation was faced with a number of limitations such as poor coordination between the geotechnical research facility and the design firm; inexperienced subcontractors; shortage of workers within the project location; lack of manpower and materials; sometimes LPS training was a struggle and waste of time and contractor financial problems delayed the progress.

The case study further deduced and identified the following as the potential benefits of implementing LPS in Morocco: traceability of the project, stakeholders provided with constant data regarding the contractor's productivity; ensured realistic weekly schedule; promoted team spirit and information sharing among all stakeholders.

4.3 LEAN CONCEPTS IN SOUTH AFRICA

4.3.1 The South African construction industry

The CI plays an important part within the improvement and exchange of innovation; creates numerous opportunities for enterprises; and contributes directly to improving the quality of life of the clients of its products (Construction Industry Development Board [CIDB], 2016; Windapo & Cattell, 2013:65). As one of the main employers within the nation, its tasks result to the improvement of the built environment which is essential to national improvement (CIDB, 2012).

It is a different sector from and is liable for the improvement of all built environment infrastructure, which the South African Institution of Civil Engineering (SAICE) (2006) characterizes as capital stock that creates services that are expected by the such as hospital facilities, water, sanitation and power, or that encourages financial generation or serves as inputs to generation such as power, roads, and harbours. Such a framework impacts the level of financial improvement of countries. As Africa's biggest development market, most supply chains on the continent can be considered to point towards South Africa (Emuze, 2011:669).

The greatest client of the CI is the SA government, responsible for about 40% to 50% of the entire domestic construction payments (Dlungwana et al., 2002). This is because it is believed that, to guarantee and accomplish the financial development of the nation, the government must offer further commitment to the improvement of the development industry (Ntuli & Allopi, 2013:570).

South Africa has a reasonably modern and well advanced infrastructure, which has failed last to some degree recently, basically owing to under-investment and lack of skills (Emuze, 2011). However, over the previous twenty years, according to the Presidency of the Republic of South Africa (2017), the SACI has managed to achieve the following:

i. A total of one hundred and seventy-three faulty structures have been eliminated ever since 2011. Overall, 895 new schools presently provide a favourable education environment for the youngsters.

ii. Approximately more than four million funded housings opportunities have been delivered to the underprivileged, giving homes to almost 12.5 million individuals.

iii. The Extended Public Works Programme (EPWP) has since 2014 produced more than two million work opportunities towards the satisfaction of the objective of six million work opportunities by the conclusion of 2019. Of the work opportunities created, more than one million have been taken up by the youth.

However, similar to any other sector within the world, the SACI faces numerous issues that affect the execution of construction projects and development of the sector. According to Thwala and Phaladi (2009), these issues incorporate the following: access to dependable data about contracts and tenders, poor tendering, absence of mentorship, long-term technique advancement, high levels of inexperienced workers, provision of safe working environments, absence of skill improvement and training, absence of access to funding from banks, lack of access to credit for SMEs from suppliers, lack of managerial, technical and financial skills, late payments for work done, corruption, and mismatch of available skills against required skills.

4.3.1.1 Challenges facing the South African construction industry

Developing countries around the world meet numerous challenges that have a bad effect on the execution of their development projects; and South Africa is no exception. Authors such as Ofori et al. (2007:3) have recognized a few challenges said to impact the execution, development and advancement of the SACI. The challenges that have been recognized incorporate the following:

i. Public-sector capacity

Mbande (2010) noticed that there is a lack of capabilities in the SACI and in state-owned endeavours. According to SA's CIDB (2004), public-sector capacity can be a key restriction on infrastructure delivery and economic development within the SACI. Milford (2010) reports that the shortage of public-sector ability has result in an incompetent, wasteful and difficult method of financing construction projects by the government and in a few cases, late payments of more than six months.

ii. Mismatch between available skills and required skills

Mbande (2010) suggests that there is a relationship between an increase in the community as a result of the need for service delivery in SA and the extreme lack of expertise within the CI. The CIDB (2004) report recommends that the skills provided to the market through the further Education Training (FET) Framework were in many cases not suitable for the requirements of the CI, resulting in a skills shortage and a decrease ofthe performance in the CI. According to Van Wyk (2003), the high number of industry members who have no education is a genuine obstruction to the advancement of the CI.

iii. Critical global issues/Globalisation

Lewis (2007:8) points out that the effect of globalization on the development sectors in emerging nations and the regions in which worldwide trade maintains financial underdevelopment subsequently poses a challenge to the advancement of the CI in those nations. Raftery et al. (1998:730) reported that global issues attribute trends in the CI within the Asian region to the globalisation and deregulation of markets required by fiscal, technological and managerial constraints. Additionally, the recent worldwide financial collapse and its impact on the world economy pose a challenge to the execution of the CI in SA.

iv. Procurement practices/Capacity for sustainable empowerment

The CIDB (2012) indicates that the present procurement environment is a challenge because it inspires previously underprivileged professionals to establish their own companies instead of joining developed companies. This division, according to the report, has decreased the amount of professionals that can be combined within medium and large firms through access and involvement in various projects. In expansion, the particular strategy of procurement in SA (News, 2009) results in undesirable levels of opposition and obstructs the advancement of small enterprise competences and sustainability (Bowen et al., 2007:632).

v. Technology

Ofori (1990) highlights that where projects include moderately new innovation, specific contractors might not have the ability to embrace them. SA has accurate admission to the modern innovation; though the main reasons of innovation in the country are likely to limit the scope of the projects that can be embraced at any one time with the materials, tools and personnel accessible. There is similarly an issue with end-users' observations around practical alternate building approaches and advanced building frameworks, particularly within in the low-cost housing market, as well as pressure between innovation and work. Construction firms are encouraged by government strategy to utilize more labourers to improve the economy and reduce poverty (CIDB, 2007).

vi. Availability of suitable land for construction

Possibly the main vital physical limitation on construction activity is land because the source of land is largely limited (Ofori, 1990). Boshoff (2010:70) highlights that while there is a wide supply of open land, private land is not freely available in SA. The entire area of land within each cluster that can be recognised is more restricted by such variables as geology and soil conditions (Van der Merwe, 1997). Moreover, there are numerous land claim matters in the courts, zoning issues and heritage sites, all of which combine to make the cost of accessible land inhibitive, thus delaying construction practices.

vii. Availability of infrastructure

Human settlements need infrastructure to fund them. A facility cannot be formed without infrastructure such as power, pipe-borne water, roads, streetlights and sewage elimination frameworks (Ofori, 1990). According to the CIDB (2007), the government of SA spends a major amount of money on advancing its old and devalued urban and rural infrastructure. Moreover, there is a massive issue with regard to barriers on electrical capacity (Eberhard, 2008).

viii. High rate of enterprise failure/Delivery capacity and performance

Business failure, according to Arditi et al., (2000:121), is the inability of a firm to pay its commitments when they are outstanding. The CIDB (2004) report records that the amount of SA construction firms' failure is excessively high. According to this report, there has been a long-term drop in productivity within the sector, and several firms affirm income amounts as little as 1%.

ix. Statutes and regulations

Ofori (1990) identified statutes and regulations such as insurance requirements, standards, the defects liability period, height restrictions, and health and safety provisions as components that control the level of construction activity in any nation at any given time. The CIDB (2004) report shows that ever since 1994, the SA government has approved more than 1,000 pieces of legislation, which have in turn produced different regulations, giving the impression of over-regulation. These laws have influenced tender and procurement methods, employment and labour practices, BEE, planning permissions and controls, skills development and training and business practices. As a result, the construction approvals and zoning procedures of local authorities are reserved and lead to pointless holding costs for developers (CIDB, 2004).

BEE and other similar affirmative action programmes are an essential part of the development of South Africa (Brown, 2015). However, their implementation, control and monitoring have to be in order to ensure that the goal of wealth redistribution to previously disadvantaged people are achieved. Moreover, the CIDB (2004) indicates that this preferential environment creates challenge of its own as it motivates historically disadvantaged professionals to leave firms of which they are part, to set up their own. Essentially this would be a good thing. However, the industry suffers in the sense that this trend sets off breakdown of construction expertise that could be consolidated into one or two mediums. Furthermore, the Department of Public Works (2011) also indicated additional issues encountering facing the SACI's performance. The factors pointed out include the following: unregulated labour-only subcontracting, the lack of best practice standards, the ineffective enforcement of compliance with minimum standards, and the divide between design and construction.

Aigbavboa and Thwala (2014:774) pointed out that numerous vital and more difficult issues have been identified as challenging and affecting the execution, advancement and development of the SACI. A few of the outstanding challenges have occurred for a while, nevertheless, there is slight proof to illustrate that the matters mentioned previously no longer exist, owing to the scarcity of significant and consistent data on the subject (Windapo & Cattell, 2013:66).

These difficulties are found around the financial and political issues which were supported by the past apartheid administration of isolation (Aigbavboa & Thwala, 2014:774). It is also essential that the SACI is not excused from the natural challenges confronting their counterparts from other portions of the world. Higher utilization of energy and natural resources causing ecological degradation and contamination combined with greenhouse gas releases are a few among the numerous features of the sector (Windapo, 2014:6089).

Moreover, waste generation has therefore become a severe issue that the SACI is suffering from (Hosseini et al., 2011:414), and one of the main challenges impacting its performance. It is significant to make sure that waste generation is reduced in construction; thus new management practices have been introduced to limit waste generation and advance tools in reducing the damage of the surroundings by construction activities (Tan et al., 2010; Ogundiyi et al., 2015).

4.3.2 Adoption of lean concepts in South Africa

A research paper published by Shakantu and Emuze (2012) at the 20th Annual Conference of the International Group for LC highlights the development of a productive logistics structure in SACI. The research disputes that building material and waste elimination processes can be improved by the use of reverse logistics in a construction context through the application of the LC concept. While it is clearly evident that lean is being utilized globally, the concept is new in South Africa.

Since the emergence of lean and sustainable construction concepts, adaptations have been a challenge in SA. The specific characteristics of SACI being fragmented, complex and project based, which make coordination difficult, are perceived as obstacles to the execution of lean and sustainable construction simultaneously in a project (Bygballe & Sward, 2014: 3).

Through conduction of a survey review among SA construction firms, Aigbavboa et al. (2016:200) revealed that lean, if fully implemented in construction projects, will assist in decreasing waste, advance communication system also improve efficiency, employee empowerment and distribution of knowledge, however there are several barriers to the application of LC in SACI, such as poor pre-planning, shortage of skilled workers, poor communication, fragmented nature of the industry, human approach concerning change, lack of interest from clients, absence of client and supplier participation, absence of long-term commitment, absence of supply chain integration, lack of technical skills, and insufficient experience in the requirements of LC.

Aigbavboa et al. (2016:200) further revealed that for successful implementation of LC in SA, there has to be a sufficient level of awareness and commitment among construction stakeholders, including understanding the underlying concepts. Moreover, stakeholders should be trained on lean construction due to the perceived complexity of the practice. The training should be targeted towards implementation rather than theories and should also be extended to subcontractors.

In addition, Smit et al. (2011) demonstrated that the resistance to change in SA may be a human reaction, and so organizations have to take essential steps to counter it through education and communication, cooperation and participation, assistance and support, and preparation and rewards. In this way, for lean to be effectively executed, certain ideas must be applied. These include:

Awareness: Lean awareness and education promotions are essential to alert stakeholders in the CI of the opportunities and benefits of lean application. These promotions can be controlled by the collective efforts of LC professionals within and outside a country (Emuze & Ungerer, 2014).

Policy: The awareness and education programmes together would have to amend each management policy for effectiveness. A management policy usually defines the philosophies that direct decisions, techniques and procedures within an organisation (Othman, 2011). The policy should determine why the supports lean concepts, and the policy should also display how and what areas should be applied and in what projects (Emuze and Ungerer, 2014).

4.3.3 Lesson learnt

From the literature reviewed regarding lean concepts in the SACI it is apparent that although lean is being utilized globally in both developing and developed countries, the concept is new in SA.

Literature further reveals that lean, if fully implemented in SA construction projects, will assist in the decreasing of waste, advance communication systems as well as improve production and sharing of knowledge. However the implementation in SACI is faced with numerous challenges, such as poor pre-planning, shortage of skilled workers, poor communication, the fragmented nature of the industry, the human approach towards change, and a lack of interest from clients, to name just a few.

Lastly, literature recommended that the obstacles to the application of lean can be overcomed by establishing a policy that supports lean implementation, providing lean awareness and enlightenment campaigns, and training the stakeholders and subcontractors about lean implementation.

4.4 CHAPTER SUMMARY

This section presented a review of literature relating to the Nigeria, Morocco and SA. The chapter further provided an in-depth review of lean concepts' adoption and implementation through the examination of case studies in these countries. The findings revealed the challenges and rewards of the effective application of LC in different organisations. The following section will discuss research methodology and the process followed during the current study in order to attain the objective of the research.

CHAPTER FIVE

RESEARCH METHODOLOGY AND DESIGN

5.1 INTRODUCTION

This chapter examines the research approach utilized in this study so as to accomplish the study objective. The population sample, research design and the geographic area where the study was carried out are also explained. Moreover, the instrument utilized in gathering the information, as well as the procedures managed to sustain validity and consistency of the instruments are defined in order to carry out the assessment of the level of awareness of LP and LT, the level of adoption of LP and LT, the barriers, the measures of improving lean adoption and finally, the benefits of lean concepts in the SACI.

5.2 RATIONALE OF THE STUDY

The rationale of the research is to contribute to the body of knowledge on the subject of lean concepts in the CI by determining the level of awareness of lean principles and techniques, the level of adoption of lean principles and techniques, the barriers, the measures of improving lean adoption and the benefits of lean concepts in the SACI.

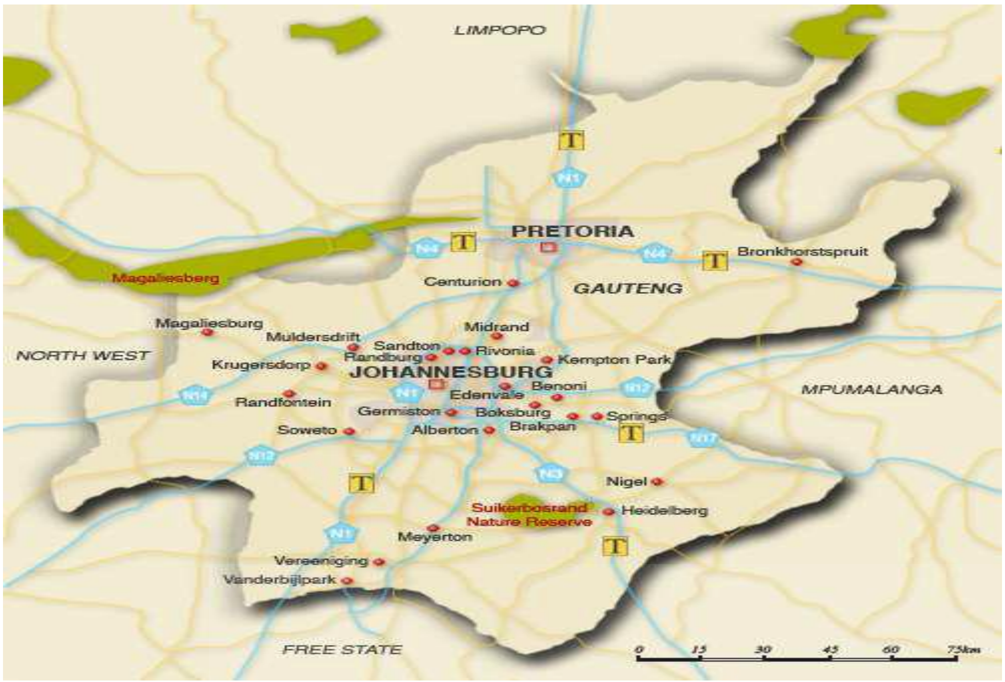
5.3 RESEARCH APPROACH AND DESIGN

According to Teddlie and Tashakkori (2009:5), quantitative research is the investigation of statistical information utilizing procedures defining the phenomenon of interest and trying to find critical contrasts between teams or among factors.Grove et al., (2014:32) also define quantitative research as a formal, objective, thorough, methodical method conducted to define, inspect and test connections, reasons among factors. A quantitative research is a survey used to acquire data from subjects or study participants (sample) by means of individual report objectively. The study participants reply to questions posed to them by the researcher (Grove et al., 2014:33). Qualitative research is inductive in nature, and the researcher generally explores meanings and insights in a given situation (Strauss & Corbin, 2008; levitt et al., 2017). It refers to a range of data collection and analysis techniques that use purposive sampling and semi-structured, open-ended interviews (Dudwick et al., 2006, Gopaldas, 2016). Zohrabi, (2013) also define qualitative research as a form of social action that stresses on the way of people interpret, and make sense of their experiences to understand the social reality of individuals. It makes the use of interviews, diaries, journals, classroom observations and immersions; and open-ended questionnaires to obtain, analyze, and interpret the data content analysis of visual and textual materials, and oral history. The purpose of qualitative research is to describe and interpret issues or phenomena systematically from the point of view of the individual or population being studied, and to generate new concepts and theories. The choice of methodology is directed by the questions being raised (Viswambharan and Priya, 2016).

Therefore quantitative research method was embraced in this study in order to carry out the assessment of the level of awareness of lean principles and techniques, the level of adoption of lean principles and techniques, the barriers, the measures of improving lean adoption and the benefits of lean concepts in the SACI. A quantitative approach was chosen for its level of objectivity and because of its ability to gather a wide range of views from South African construction industry.Etikan, Musa and Alkassim (2016:3) emphasized that the quantitative approach aims at attaining a breadth of understanding of the subject under study, whereas the qualitative approach mainly results in a deeper understanding of the subject under study (Patton, 2002:340). Therefore, this research study gathered data through a means of well-structured questionnaire which was circulated to the study respondents by the researcher.

5.4 RESEARCH AREA

The research was conducted in Gauteng Province, SA. The province was chosen for the this study since it remains the most populous province, the biggest contributor to South Africa's GDP, and home to major construction activities, professional bodies and stakeholders (Government of South Africa, 2016).



Map 5. 1 Map of Gauteng Province, Republic of South Africa

Source: Rooms for Africa (2016)

5.5 TARGET POPULATION

Grove et al. (2014) defined a population as the totality of individuals possessing certain attributes which are of utmost interest to the researcher, meeting the sample yardstick for addition in a study. However, target population is described as individuals or groups with the ability to provide responses to the questions posed and to whom the results of the study apply (Ledwaba, 2012).

The targeted populations were construction professionals who are involve in construction projects in Gauteng province, South Africa. The main respondents were architects, quantity surveyors, civil engineers, electrical engineers, mechanical engineers, structural engineers, and construction project managers, project managers from the government departments, consultant companies and contractors' firms. The list of construction professionals who work within the province of Gauteng was obtained from the various professional councils and the council of built environment namely: The South African Council for the Project and Construction Management Professions (SACPCMP), South African Council for the Quantity Surveying Profession (SACQSP), Engineering Council of South Africa (ECSA), South African Council for the Architectural Profession (SACAP). Google Forms survey was distributed through emails to different professionals working in the construction industry around Gauteng. Hard copies of a questionnaire were distributed to the nearest respondents in Gauteng Province of SA.

5.6 SAMPLE

Tailor (2005:186) defines a sample as a portion taken from a specific population. The study adopted a convenience sampling approach, which is also known as non-random sampling method. Non-random sampling ensures that samples are grouped in a procedure that does not give each respondent an equal chance to participate. Research methodology (2016) asserts that convenience sampling is a method used to collect data from desired respondents who are readily accessible to contribute to the study. However**,** all the conveniently selected respondents had to fall within the parameters of professionals working in construction industry around Gauteng Province.

A convenience sampling technique was chosen because it is simple and inexpensive (Etikan, Musa and Alkassim, 2016:2). In addition, the method was chosen because it could receive data within a short period .Further, for physical distribution, a convenience sampling method was used since the researcher has access to the desired participants willing to participate (Etikan, Musa and Cheng, 2007:165) Saunders, Lewis and Thornhill (2012:210) mention that the convenience sampling method, like any other sampling method, has a number of disadvantages. , Tese includes high sampling error, bias and its lack of ability to generalise research findings.

5.7 SAMPLE SIZE

Kothari (2004:56) described a sample size as the number of perceptions to be chosen from the universe to establish a numerical sample. Some authors suggested between 300-150 as sufficient sample size. However, it is recommended that a 10:1 ratio, that is, ten cases for each item to be examined is significant while five cases for each item is also further suggested (Pallant, 2007:181). The sample size of the respondents for this study was extracted from a populace of professionals, mainly architects, quantity surveyors, civil engineers, electrical engineers, mechanical engineers, structural engineers, construction project managers and project managers from the government departments, consultant companies and contractors' firms. Since the highest number of item in the research questionnaire is 22, it was then multiplied with an average scale of 5 to get the minimum questionnaires to be distributed which was 110. In order to get a higher number of respondents for the survey, two hundred (200) questionnaires (online and physical) were distributed to respondents (construction professionals in the SACI).

5.8 DATA COLLECTION

Primary data was collected using two forms of closed-ended questionnaires, namely the physical copy comprising questionnaires on lean concepts in the SACI and the online questionnaire (Google Forms) comprising the same information. Out of thirty-nine (39) physical copies of the questionnaire distributed to the respondents, only thirty-seven (37) were returned, while out of one hundred and sixty-one (161) sent on email via Google Forms, only one hundred and fifteen were returned. The online questionnaire, which took approximately 15 minutes to complete, was distributed to selected respondents. As shown in Table 6.1, two hundred (200) questionnaires were distributed to different respondents. However, only one hundred and fifty-two (152) were returned over a period of two months and only one hundred and fifty-one (151) were usable. This gave a 75.5% response rate, which, according to Moser and Kalton (1971), indicates a credible study.

Table 5. 1 Questionnaire survey

Survey Responses	Respondents
Questionnaire distributed	200
Questionnaire collected	152
Usable Questionnaires	151
Response rate (%)	75.5%

5.9 INSTRUMENT OF DATA COLLECTION

The primary instrument of data collection for this research study is a questionnaire. According to Kothari (2004:101) and Grove et al. (2014), a questionnaire is a self-report form intended to deduce data through recorded responses of the subject, characterised by easy accessibility of respondents, ample time to respond and free from bias. The questionnaire aided data collection in identifying the level of awareness of lean principles and techniques, the level of adoption of lean principles and techniques, barriers to the adoption of lean concepts, measures of improving lean adoption and benefits of lean concepts in the South African construction industry.

There are two kinds of questionnaires, namely the closed-ended and the open-ended questionnaires. The open-ended questionnaire requires the respondents to answer in their own words after being given a common guide on the sort of data required while the close-ended questionnaire has all questions and answers specified with respondent's response kept to the minimum or limited to the stated alternatives (Kothari,2004:101). A close-ended questionnaire was therefore embraced as it makes it at ease to determine, manage and examine.

The questionnaire was designed and administered in English language as all the respondents are educated. The respondents were guaranteed of the privacy of their responses. The survey comprised of five sections, namely A, B, C, D and E. Section A consists of questions targeted at gaining background information such as professional qualification, level of education, and years of experience. The responses from this section would help the researcher when explaining the results. Section B was aimed at assessing the knowledge and the frequency of use regarding lean principles and techniques used in construction projects. Section C was targeted at exploring the potential barriers that can hinder the adoption of lean concepts in the CI. Section D was aimed at exploring the measures of improving lean adoption in the SACI. Finally, Section E of the questionnaire explored the potential benefits of adopting lean concepts in the South African construction industry. Guidelines and rules were attached to the surveys to direct the respondents on how to answer the surveys. Anonymity and voluntary participation were amongst the highlighted ethical considerations.

The following Likert scales were used to answer the questions appropriately: 1 = Not all aware ; 2 = Slightly aware; 3 = Somewhat aware ;4 = Moderately aware; 5 = Very aware and 1 = Never; 2 = Almost never; 3 = Sometimes; 4 = Almost every time; 5 = Every time and 1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree .

5.10 PERIOD OF DATA COLLECTION

The period of data collection by the researcher was between the months of March and May, 2016. This represent about two months, as the respondents were afforded the opportunity of taking their time in completing the questionnaires without any form of coercion.

5.11 DATA ANALYSIS

According to Kothari (2004:122), data analysis involves the working out of particular methods together with looking for relationship patterns that occur between information groups and in the procedure, revealing the relations or variances assisting or clashing with original in order to define what usable information shows the study conclusion. The exploration is undertaken with the purpose of organising and summarising the gathered information in a way that it answers the research questions.

From the one hundred and fifty-two (152) questionnaires returned, one hundred and fifty-one (152) were analysed. Before the commencement of the analysis, cleaning and screening of the data was undertaken. The Stastical Package for Social Sciences (SPSS) computer software version 25.0 was utilised to conduct data analysis. Based on the data received from the respondents, the software was further used to tabulate the given variables according to their mean items scores and standard deviations in their descending order. Moreover, with the use of the SPSS exploratory factor analysis (EFA) was carried out to group the variables according to their variances.

5.11.1 Frequency

Frequencies were used to populate the data received in the background section. The Australian Bureau of Statistics (2013) defines frequency as a rate utilised to identify the number of times a particular value for data item has been observed to occur.

5.11.2 Mean item score (MIS) and standard deviation (SD)

Mean item scores and standard deviations were utilised to rank the variables (in descending order) according to the responses received from the participants, using the five-point Likert scale indicated in the questionnaire. A higher mean item score represented a higher ranking; however, that may not indicate that the respondents agree with the question at hand. For instance, a higher ranking MIS 1.00 does not necessarily signify agreement with the question asked.

The MISs were obtained from the total of the received questionnaires relating to the overall responses for each question. This was centred on the guideline that respondents' totals on all the chosen standards, considered together, are the empirically determined guides of virtual significance. The list of MISs of a specific component is the total of the respondents' actual scores (on the 5-point scale) as a proportion of the total of all potential maximum scores on the 5-point scale. A weighting was allocated too each response ranging from one to five (Polit and Hunger, 1995:33). Table 6.2 presents the Likert scale employed in the study.

This can be expressed mathematically as:

$$MIS = \frac{1n1 + 2n2 + 3n3 + 4n4 + 5n5}{\Sigma N} \text{ .... } \textbf{Equation 1.0}$$

where:

n1 = Number of respondents for Not all aware, Never and Strongly disagree

n2 = Number of respondents for Slightly aware, Almost never or Disagree

n3 = Number of respondents for Somewhat aware, Sometimes or Neutral

n4 = Number of respondents for Moderately aware, Almost every time or Agree

n5 = Number of respondents for Very aware, Every time or Strongly agree

N = Total number of respondents

After the mathematical computations have been carried out, the individual criteria are then ranked in descending order of their MIS which is from the highest to the lowest.

The standard deviation was also used to rank the variables that had the same mean item score. This can be mathematically represented as:

$$SD = \sqrt{\Sigma (-\bar{x})^2 N - 1} \text{ .... } \textbf{Equation 2.0}$$

Where: *SD* – Standard deviation

$\sum$ = Summation symbol;

x = Value in the sample;

$\bar{x}$ = Mean of the values;

N = Sample size

Table 5. 2 Likert scales used

1	Not all aware	Never	Strongly disagree
2	Slightly aware	Almost never	Disagree
3	Moderately aware	Sometimes	Neutral
4	Aware	Almost every time	Agree
5	Very aware	Every time	Strongly agree

5.11.3 Factor analysis

In addition, the study employed factor analysis. Yong and Pearce (2013:79) claim that the main drive for factor analysis is to reduce data based on shared variance so that patterns and relationships can be easily read and comprehended. Factor analysis reduces a large number of factors to a reasonable measure (Tucker and MacCallum, 1997). The significance of the groups compared with one another is not catered for in this form of analysis. There are four phases included in factor analysis: evaluation of the suitability of the information for factor analysis, factor extraction and factor rotation and factor interpretation (Pallant, 2010:185).

Suitability of the information includes verifying the sample size. For credible results, a larger sample is required. When smaller samples are used, the correlation coefficient of the items is less reliable. Further, the suitability of the data involves verifying the strength of the inter-correlations among the variables. If no correlations go beyond 0.30, the usage of factor analysis is disputed (Tabachnick and Fidell, 2001:12). Additionally, for factor analysis to be appropriate, Bartlett's test of sphericity should be less than 0.05 (Bartlett.1954:297), and the Kaiser-Meyer-Olkin (KMO) must have a minimum index of 0.6 (Kaiser, 1974:33; 1970:410). Factor extraction follows assessment of the suitable data. During this phase, the factors that can be utilised to indicate the inter-relationships amongst the items are determined .Forms of factor extraction include: principal components, image factoring, alpha factoring and principal factors (Tabachnick and Fidell, 2001:12; Child, 2006:72-88). The last phase of factor analysis is factor rotation and interpretation. Once the components have been defined, the following stage is to interpret them. For this, SPSS rotates and combines the items into groups (Yong and Pearce, 2013:86). Groups can be represented either as orthogonal (uncorrelated) or oblique (correlated). Orthogonal results are much easier to interpret than oblique (Rummel, 1970:1).

The theorem of factor analysis is illustrated as:

$$\mathbf{R_{m\times m} - U^2_{m\times m} = F_{m\times p}F'_{p\times m}} \text{ .... … } \textbf{Equation 3.0}$$

Where: $R_{m\times m}$ = shows the correlation matrix

$U^2_{m\times m}$ = the diagonal matrix of unique variances of each variable

$F_{m \times p}$ - connotes the common factor loadings

Factor analysis can be utilised for either confirmatory or exploratory purposes. This study adopted the exploratory factor analysis (EFA) as it is a broadly used and applied statistical technique in the social sciences. As stated by Osborne and Costello (2009:2), EFA is preferable because it proposes to demonstrate any hidden factors that can make the visible factors to co-vary. The common variance of a factor is separated from its unique and error variance during factor extraction in order to reveal the original factor structure, thereby exposing only common variance in the result.

The EFA was utilised in this study to confirm the consistency and validity of the level of awareness of lean principles and techniques, the level of adoption of lean principles and techniques, barriers to the adoption of lean concepts, measures of improving lean adoption and benefits of lean concepts in the SACI. The EFA was undertaken using version 25.0 of the SPSS software.

5.11.4 Reliability

Drost (2011:106) refers to reliability as the level to which quantities are duplicable when individuals implement the same process under various circumstances and various conditions, but using the same research instrument. The reliability, specifically internal consistency of the study, was determined. It ultimately measures the degree to which the items that make up the scale all measure the same primary aspect (Pallant, 2010:6). For simplicity, internal consistency can be measured using Cronbach's coefficient alpha. This shows the average correlation of all items that make up the scale. Cronbach's coefficient alpha mainly depends on the number of items presented in the questionnaire; the fewer the items, the lower the value of Cronbach's alpha. According to Pallant (2007:98), values above 0.7 are considered acceptable but values above 0.8 are most preferable. Therefore, the study based, on the values of Cronbach's alpha, shows that the questionnaire used was reliable with all the assessed objectives have an alpha value of above 0.90.

Alpha (α) can be mathematically represented as:

$$\alpha = \frac{kr}{1+(k-1)r}$$ ……….. **Equation 4.0**

Where: α = Symbol for Cronbach's coefficient alpha

k - Items (variables) in the scale;

r =− Average of the inter-item correlations

Table 5. 3 Cronbach's alpha on variables analysed using descriptive analysis

	Cronbach's Alpha	No. of items
Level of awareness of lean principles and techniques	0.966	22
Level of usage of lean principles and techniques	0.934	22
Barriers of lean concepts	0.910	20
Measures for improving lean concept adoption	0.931	14
Benefits of lean concepts	0.944	18

5.11.5 Validity

Pallant (2010:7) defines validity as the extent to which it measures what it is actually supposed to measure. Drost (2011:114) adds that validity refers to the relevance of the research components, whether they are measuring what is actually intended. Churchill and McLaughlin (2001:1) and Lacity and Jansen (1994) maintain that face validity is evaluating the research instrument by looking at it, and giving personal opinions (common sense). According to them, it does require any scientific test to ensure the validity of the research instrument. Secolsky (1987:82) explains face validity as the suitability of the content of items for an intended objective. Because of time constraints, only face validity was adopted in the study. A questionnaire instrument was distributed to different professionals. The main aim of the process was to define the importance of the research components, whether the researcher is measuring what is intended by simply going through the questionnaire.

This research study adopted the principal axis factoring as the extraction method used for the data. The data also underwent both the 1st order factor analysis and 2nd order factor analysis. However, the rotation method used for the 1st order factor analysis was varimax with Kaiser Normalisation while Oblimin with Kaiser Normalisation was used for the 2nd order factor analysis.

5.11 LIMITATIONS OF THE STUDY

Limitations are referred to as those attributes that restrict the scope of and explicate the extremities of the research study (Simon, 2011). The respondents for the study were essentially construction professionals (architects, quantity surveyors, civil engineers, electrical engineers, mechanical engineers, structural engineers, construction project managers, and project managers) in the Gauteng Province of SA. The choice of Gauteng Province was made for the current study because it remains the most populous province, the biggest contributor to SA's GDP, and home to major construction activities, professional bodies and stakeholders (Government of South Africa, 2016). This study only explored the extent of awareness of lean principles and techniques, as well as the extent of adoption of lean principles and techniques. The study further determined the barriers to the adoption of lean concepts. Lastly, the study, explored the measures of improving lean adoption and the benefits of lean concepts in the SACI.

5.13 ETHICAL CONSIDERATION

It is noteworthy that this research study did not encounter any form of ethical issues as the researcher took into account the ethical considerations. The researcher ensured that various authors and researchers whose works constituted the literature reviewed were properly acknowledged and cited. The confidentiality and anonymity of the respondents were maintained as the inputs and responses cannot be traced to anyone of them. According to Grove et al. (2014), anonymity is a situation whereby the respondents cannot be linked to their individual responses, even by the researcher. Also, the respondents were afforded enough time and freedom to answer any of the questions in the questionnaires with no form of pressure whatsoever. Lastly, a written cover letter of approval to carry out this research study was acquired from the University of Johannesburg, Department of Construction Management and Quantity Surveying, Doornfontein Campus. This letter was affixed to all the questionnaires administered. The letter also informed the respondents about the essence of the research study and how long it would take to answer the questions and assured them of their confidentiality and anonymity.

5.15 CHAPTER SUMMARRY

This section defines the research methodology embraced in this research, including the population, sample, data collection and approaches utilised to ensure ethical standards. The next section presents the data analysis and the explanation of the results of the study.

CHAPTER SIX

DATA ANALYSIS AND INTERPRETATION

6.1 INTRODUCTION

This section presents the findings of information acquired from the survey questionnaires which were distributed to the following respondents: architects, quantity surveyors, civil engineers, electrical engineers, mechanical engineers, structural engineers, project managers and construction managers in the SACI. The analysis of the information and explanation of the findings were acquired from the survey study and functioned as the base of this quantitative information gathering. All the questions within the survey were responded to. Two hundred (200) questionnaires were distributed. However, one hundred and fifty-two (152) were returned and of those, one hundred and fifty-one (151) were usable for analysis. This reflects a seventy-six percent (76%) response rate.

6.2 SECTION A: BIOGRAPHICAL DATA ANALYSIS

This section reveals background data of the respondents with respect to their demographics, namely highest qualification, professional qualification, years of experience and employment organisation.

6.2.1 Distribution of sample according to educational qualification

The distribution of the sample according to the educational qualifications of respondents is shown in figure 6.1. This reveals that majority of the respondents possess a bachelor's degree representing 46.4%, followed by honour's degree representing 22.5%. Those with a master's degree represent 17.9%; those who hold a diploma represent 11.3% and while 2% are in possession of a doctorate. Based on the findings, it can be deduced that the population for the study had adequate educational backgrounds that helped them to complete the survey.

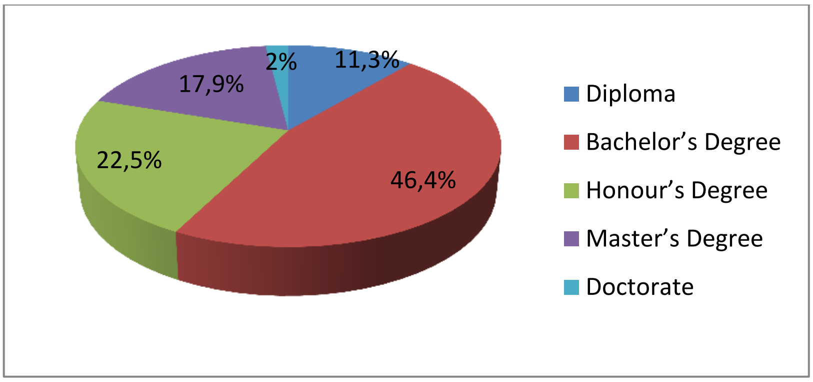


Figure 6. 1 Respondents' educational qualifications

6.2.2 Distribution of sample according to professional qualification

The distribution of the sample according to respondents' professional qualifications is presented in Fig 6.2. This reveals that 25.2% of the respondents were quantity surveyors, 21.2% were construction project managers, 14.6% were architects, 13.2% were project managers, 8.6% were electrical engineers, 6.6% were civil engineers, 6.0% were mechanical and 4.6% were structural engineers. Based on the findings, it can be deduced that the population for the study are all well represented within the sample collected.

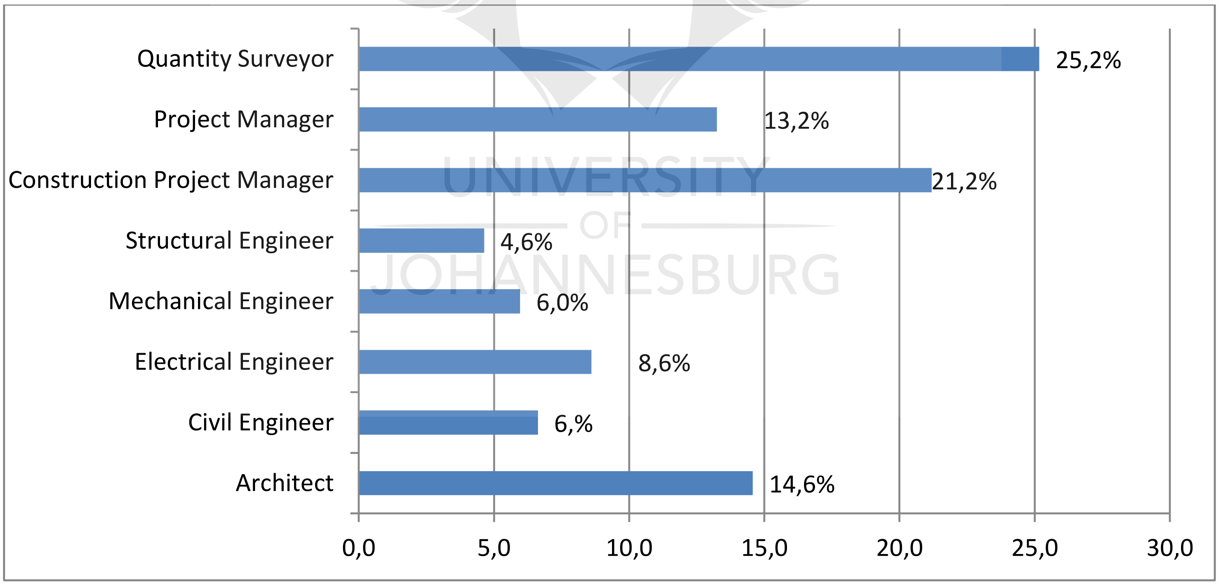


Figure 6. 2 Respondents' professional qualifications

6.2.3 Distribution of sample according to years of experience

The distribution of the sample according to respondents' years of experience is presented in Fig 6.3. This shows that 29.8% of the respondents had experience that ranged between 6-10 years, 29.1% had experience between 11-15 years, 25.2% had experience between 1-5 years, 10.6% had experience between 16-20 years and 8% had more than 20 years of experience. Based on the average number of years of experience which is 9.89 years, it can be deduced that the respondents have a high range of experience in the construction industry and their responses can be relied upon based on their experience.

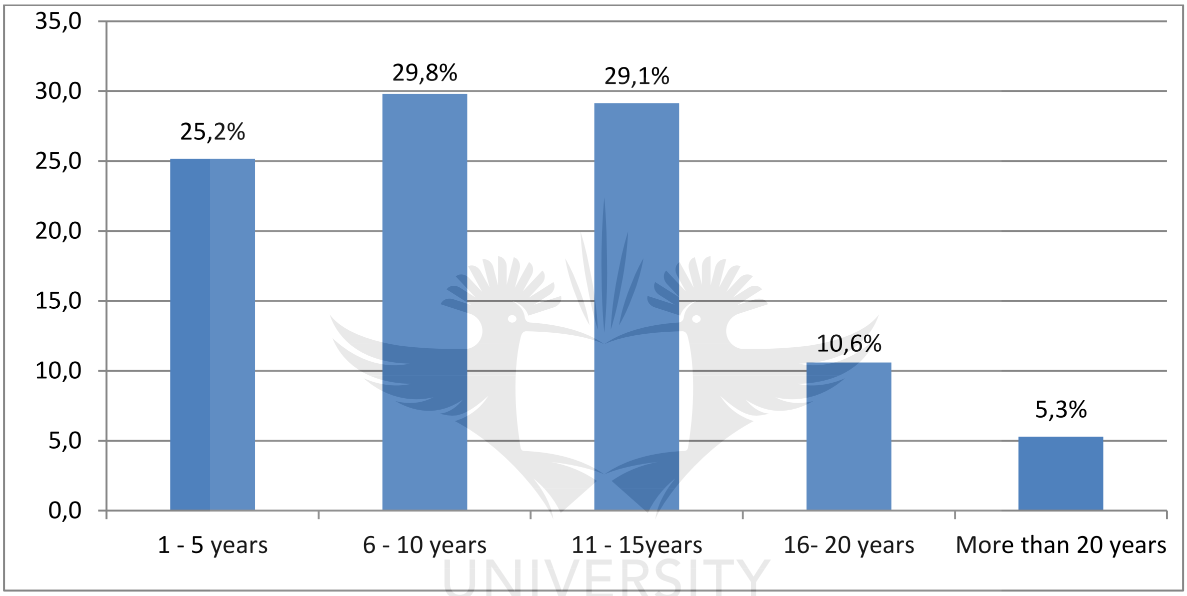


Figure 6. 3 Respondents' years of experience

6.2.4 Distribution of sample according to employment organisation

The distribution of the sample according to organisations to which the respondents' belong is presented in Fig 6.4. This shows that 39.1% were employees of consultancy firms/companies, 39.1% were government employees, and 21.9% were employees of contractors. Based on the findings, it can be deduced that the population for the study are all represented within the sample collected.

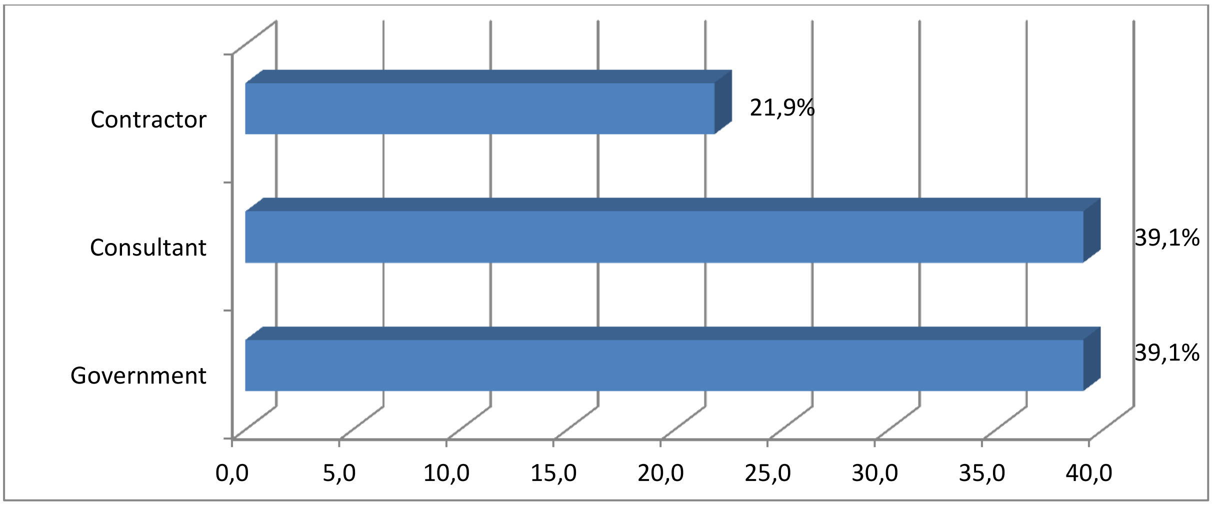


Figure 6. 4 Respondents 'current employers

6.3. LEAN PRINCIPLES AND TECHNIQUES FOR CONSTRUCTION PROJECTS

This section presents the findings obtained on the level of awareness and usage of LP and LT within the CI.

6.3.1 Level of awareness of lean principles and techniques

The ranking of the levels of awareness of LP and LT is presented in Table 6.1. Respondents were required to indicate their level of awareness of LP and LT for construction projects, utilising a five-point scale: 1 = Not all aware, 2 = Slightly aware, 3 = Somewhat aware, 4 = Moderately aware and 5 = Very aware . The table firstly shows that the lean principle which ranked first was 'Identifying value' with a mean item score (MIS) of 3.87 and standard deviation (SD) of 1.196. The level of awareness of the LP, 'Identify value for a construction project', was high. The principle, 'Pursuing perfection', was ranked second with an MIS of 3.68 and SD of 1.283, 'Achieving flow in the process' was ranked third with an MIS of 3.65 and SD of 1.239, and'Allowing customer to pull' was ranked fourth with an MIS of 3.60 and SD of 1.297. 'Adopting value stream mapping' was the lowest ranked principle with an MIS of 3.52 and SD of 1.280. Overall, the average level of awareness of LP among SA construction participants is 3.66. It can therefore be concluded that there is high level of awareness of LP in the SACI.

Furthermore, in relation to the level of awareness of LT for construction projects, the table shows that the LT ranked first was 'Total quality management (TQM)' with an MIS of 3.77 and SD of 1.163 which indicates the high level of usage of TQM technique for construction projects. ‘Waste elimination’ was ranked second with an MIS of 3.36 and SD of 1.363; ‘first run studies (plan, do, check and act)’ was also ranked second with an MIS of 3.36 and SD of 1.353. ‘Prefabrication’ was ranked third with an MIS of 3.31 and SD of 1.328; standardisation’ was ranked fourth with an MIS of 3.22 and SD of 1.301, and ‘Increased visualisations (visual management)’ was ranked fifth with an MIS of 3.15 and SD of 1.264. Furthermore, ‘5s process (Sort, Set in order, Shine, Standardize and Sustain)’ was ranked sixth with an MIS of 3.14 and SD of 1.347; ’Value stream mapping(VSM)’ was ranked seventh with an MIS of 3.13 and SD of 1.411, ‘Kaizen (Continuous improvement)’ was ranked eight with an MIS of 3.04 and SD of 1.418; ‘Five why’s’ was ranked ninth with an MIS of 3.02 and SD of 1.444 and ‘Just-in-time (JIT)’ was ranked tenth with an MIS of 2.99 and SD of 1.339. In addition, ‘Error proofing /fail safe for quality and safety (poka-yoke)’ was ranked eleventh with an MIS of 2.91 and SD of 1.336, ‘Last planner system (LPS)’ and ‘Ishikawa diagram’ were both ranked twelfth with an MIS of 2.88 (SD =1.390), and an MIS of 2.88 (SD =1.428) respectively; ‘Failure mode, effects and criticality analysis (FMECA)’ (MIS=2.85; SD=1.422, ‘Kanban (pull system)’ (MIS=2.68; SD=1.387) were ranked thirteenth and fourteenth respectively. ‘Pareto analysis’ was ranked fifteenth with an MIS of 2.64 and SD of 1.382. The level of awareness of LT from second to fifteenth for construction projects was average. Overall, the average level of awareness of LT among SA construction participants is 3.07. It can therefore be concluded that there is average level of awareness of LT within the SACI.

Table 6. 1 Level of awareness of lean principles and techniques

Lean principles and techniques			
Lean principles	**x̅**	σX	**R**
Identify value	3.87	1.196	1
Pursuing perfection	3.68	1.283	2
Achieving flow	3.65	1.239	3
Allowing customer to pull	3.60	1.297	4
Adopting value stream mapping	3.52	1.280	5
Average	**3.66**		
Lean techniques			
Total quality management (TQM)	3.77	1.163	1
Waste elimination	3.36	1.363	2
First run studies (plan ,do, check and act)	3.36	1.353	2
Prefabrication	3.31	1.328	3
Standardisation	3.22	1.301	4
Increased visualisations(visual management)	3.15	1.264	5
5s process (Sort, Set in order, Shine, Standardize and Sustain)	3.14	1.347	6
Value stream mapping(VSM)	3.13	1.411	7
Kaizen (Continuous improvement)	3.04	1.418	8
Five why's	3.02	1.444	9
Just-in-time (JIT)	2.99	1.339	10
Error proofing /fail safe for quality and safety (Poka-yoke)	2.91	1.336	11
Last planner system (LPS)	2.88	1.390	12
Ishikawa diagram	2.88	1.428	12
Failure mode, effects and criticality analysis (FMECA)	2.85	1.422	13
Kanban (pull system)	2.68	1.387	14
Pareto analysis	2.64	1.382	15
Average	**3.07**		

x̅ = Mean item score; σX = Standard deviation; R = Rank

6.3.2 Level of usage of lean principles and techniques

The ranking of the levels of usage of LP and LT is presented in Table 6.1. Respondents indicated the levels of usage for LP and LT within construction projects using a five-point scale: of 1 =Never; 2 = Almost never; 3 = Sometimes; 4 = Almost every time; 5 = Every time.

The table shows that the LP 'Pursuing perfection' with a mean item score (MIS) of 3.56 and standard deviation (SD) of 1.615 was ranked first, followed by 'Identify value' which was ranked second with an MIS of 3.48 and SD of 1.300. The level of usage of lean principles from first to second was high within construction projects. 'Achieving flow in a process' was ranked third with an MIS of 3.20 and SD of 1.685. 'Allowing customers to pull' with an MIS of 3.05 and SD of 1.663 and 'Adopting value stream mapping' with an MIS of 2.89 and SD of 1.670 were ranked fourth and fifth respectively. The level of usage of LT from third to fifth was average within construction projects. Overall, the average level of usage of lean principles among SA construction participants is 3.24. It can therefore be concluded that there is average level of usage of LT within the SACI

The table further shows that the LT ranked first was TQM with an MIS of 3.57 and SD of 1.647.The level of usage of TQM technique was high. ‘First run studies (plan, do, check, act)’ was ranked second with an MIS of 3.03 and SD of 1.720, ‘Waste elimination’ was ranked third with an MIS of 2.95 and SD of 1.668, ‘Standardisation’ was ranked fourth with an MIS of 2.75 and SD of 1.732, ‘The 5s process (Sort, Set in order, Shine, Standardize and Sustain)’ was ranked fifth with an MIS of 2.67 and SD of 1.692. Further, ‘Prefabrication’ was ranked sixth with an MIS of 2.65 and SD of 1.698, ‘Kaizen (Continuous improvement)’ was ranked seventh with an MIS of 2.54 and SD of 1.719, and ‘Increased visualisations’ was ranked eighth with an MIS of 2.50 and SD of 1.599. The level of usage of lean techniques from second to eighth was average within construction projects. ‘Value streaming mapping’ was ranked ninth with an MIS of 2.44 and SD of 1.643, ‘Five why’s’ was ranked tenth with an MIS of 2.36 and SD of 1.671, and ‘Error proofing /fail safe for quality and safety (poka-yoke)’ was ranked eleventh with an MIS of 2.24 and SD of 1.652. ‘Just-in-time’ with an MIS of 2.22 and SD of 1.531 was ranked twelfth. ‘Failure mode, effects and criticality analysis (FMECA)’ with an MIS of 2.15 and SD of 1.582 was ranked thirteenth, ‘Ishikawa’ was ranked fourteenth with an MIS of 2.04 and SD of 1.478, ‘Last planner analysis’ with an MIS of 2.01 and SD of 1.428, ‘Pareto analysis’ with an MIS of 1.95 and SD of 1.406 and Kanban (pull system) with an MIS of 1.92 and SD of 1.393 were ranked fifteenth, sixteenth and seventeenth respectively. Overall, the average level of usage of LP among SA construction participants is 2.47. It can therefore be concluded that there is a low level of usage of LT within the SACI.

Table 6. 2 Level of usage of lean principles and techniques.

Lean principles and techniques			
Lean principles	**x̄**	σX	**R**
Pursuing perfection	3.56	1.615	1
Identify value	3.48	1.300	2
Achieving flow in process	3.20	1.685	3
Allowing customer to pull	3.05	1.663	4
Adopting value stream mapping	2.89	1.670	5
Average	**3.24**		
Lean techniques			
Total quality management (TQM)	3.57	1.647	1
First run studies(plan ,do, check and act)	3.03	1.720	2
Waste elimination	2.95	1.668	3
Standardisation	2.75	1.732	4
5s process (Sort, Set in order, Shine ,Standardize and Sustain)	2.67	1.692	5
Prefabrication	2.65	1.698	6
Kaizen (Continuous improvement)	2.54	1.719	7
Increased visualisations(visual management)	2.50	1.599	8
Value stream mapping(VSM)	2.44	1.643	9
Five why's	2.36	1.671	10
Error proofing /fail safe for quality and safety (Poka-yoke)	2.24	1.652	11
Just-in-time (JIT)	2.22	1.531	12
Failure mode, effects and criticality analysis (FMECA)	2.15	1.582	13
Ishikawa diagram	2.04	1.478	14
Last planner system (LPS)	2.01	1.428	15
Pareto analysis	1.95	1.406	16
Kanban (pull system)	1.92	1.393	17
Average	**2.47**		

x̄ = Mean item score; σX = Standard deviation; R = Rank

6.4. BARRIERS TO THE ADOPTION OF LEAN CONCEPTS IN THE CONSTRUCTION INDUSTRY

Table 6.3 reveals the respondents' ranking of obstacles to the adoption of lean concepts in the CI. Respondents were required to indicate the level of agreement using a five-point scale of 1 = strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree and 5 = Strongly agree. The table 6.3 shows that 'Lack of appropriate lean training' was ranked first with a mean item score (MIS) of 4.32 and standard deviation (SD) of 0.929, 'Lack of adequate lean awareness' was ranked second with an MIS of 4.28 and SD of 0.892, 'Lack of lean understanding' was ranked third with an MIS of 4.27 and SD of 0.851, 'Lack of top management commitment' was ranked forth with an MIS of 4.23 and SD of 0.944 and 'Absence of a lean culture' was ranked fourth with an MIS of 4.23 and SD of 0.927. Furthermore, 'Poor communication among stakeholders' was ranked fifth with an MIS of 4.21 and SD of 0.859,'Lack of organisational culture that supports lean' was ranked sixth with an MIS of 4.20 and SD of 0.993, 'Lack of lean specialists and expertise' was also ranked sixth with an MIS of 4.20 and

SD of 0.900, 'Lack of adequate time for innovation' was ranked seventh with an MIS of 4.11 and SD of 0.879, and 'Human resistance to change' was also ranked seventh with an MIS of 4.11 and SD of 1.056. Furthermore, 'Lack of government support' was ranked eighth with an MIS of 4.09 and SD of 1.045, 'Inadequate pre-planning' was ranked ninth with an MIS of 4.07 and SD of 0.981, 'Lack of interest from clients' was ranked tenth with an MIS of 4.04 and SD of 1.048, and 'Inaccurate and incomplete designs' was ranked eleventh with an MIS of 4.01 and SD of 1.059. In addition, 'Lack of agreed implementation methodology' was ranked twelfth with an MIS of 3.99 and SD of 0.889, 'Poor standardized procurement techniques' was ranked thirteenth with an MIS of 3.87 and SD of 0.872, 'Lack of prefabrication techniques was ranked fourteenth with an MIS of 3.75 and SD of 0.912, 'Insufficient financial resources' was ranked fifteenth with an MIS of 3.66 and SD of 1.051, 'Uncertainty in supply chain' was ranked sixteenth with an MIS of 3.56 and SD of 1.105, and finally, 'High cost of lean training' was ranked seventeenth with an MIS of 3.53 and SD of 1.115.

Table 6. 3 Barriers to the adoption of lean concepts in the construction industry

Barriers of lean concepts	$\bar{x}$	σX	**R**
Lack of appropriate lean training	4.32	0.929	1
Lack of adequate lean awareness	4.28	0.892	2
Lack of lean understanding	4.27	0.851	3
Lack of top management commitment	4.23	0.944	4
Absence of a lean culture	4.23	0.927	4
Poor communication among stakeholders	4.21	0.859	5
Lack of organisational culture that supports lean	4.20	0.993	6
Lack of lean specialists and expertise	4.20	0.900	6
Lack of adequate time for innovation	4.11	0.879	7
Human resistance to change	4.11	1.056	7
Lack of government support	4.09	1.045	8
Inadequate pre-planning	4.07	0.981	9
Lack of interest from clients	4.04	1.048	10
Inaccurate and incomplete designs	4.01	1.059	11
Lack of agreed implementation methodology	3.99	0.889	12
Poor standardize procurement techniques	3.87	0.872	13
Lack of prefabrication techniques	3.75	0.912	14
Insufficient financial resources	3.66	1.051	15
Uncertainty in supply chain	3.56	1.105	16
High cost of lean training	3.53	1.115	17

6.4.1 Exploratory factor analysis for barriers to the adoption of lean concepts

EFA was conducted on barriers of lean concepts in the CI. Tables 6.4 – 6.9 and figure 6.5 shows the results obtained from EFA. None of the twenty (20) variables were omitted during EFA. Principal component analysis (PCA) was utilised to analyse the twenty-two variables, using SPSS version 25 software .Table 6.4 presents the codes and their definitions used for the analysis.

Table 6. 4 Definitions

Code	Barriers
C1	Lack of lean understanding
C2	Lack of adequate lean awareness
C3	Lack of adequate time for innovation
C4	Poor standardize procurement strategies
C5	Inaccurate and incomplete designs
C6	Lack of top management commitment
C7	Lack of appropriate lean training
C8	Lack of interest from clients
C9	Poor communication among stakeholders
C10	Lack of agreed implementation methodology
C11	Lack of prefabrication techniques
C12	Uncertainty in supply chain
C13	Absence of a lean culture
C14	Inadequate pre-planning
C15	Human resistance to change
C16	Lack of organizational culture that supports lean
C17	High cost of lean training
C18	Lack of lean specialists and expertise
C19	Insufficient financial resources
C20	Lack of government support

Before carrying out the PCA, the suitability of the information for factor analysis was evaluated. Briggs and Cheek (1986) recommended an ideal variety for the inter-item correlation of 0.2 to 0.4. Inspection of the correlation matrix for this study showed the existence of a co-efficient of over 0.30 back up for most of the variables, which was suitable for factor analysis, as presented in Table 6.5.

Table 6. 5 Inter-item correlation matrix

	C1a	C2a	C3a	C4a	C5a	C6a	C7a	C8a	C9a	C10a	C11a	C12a	C13a	C14a	C15a	C16a	C17a	C18a	C19a	C20a
C1a	**1,000**	0,769	0,470	0,238	0,406	0,448	0,602	0,459	0,488	0,121	0,251	0,009	0,663	0,415	0,411	0,422	0,112	0,532	0,103	0,256
C2a	0,769	**1,000**	0,534	0,211	0,350	0,437	0,566	0,448	0,372	0,199	0,143	-0,011	0,563	0,348	0,322	0,471	0,089	0,573	0,220	0,369
C3a	0,470	0,534	**1,000**	0,372	0,204	0,331	0,408	0,405	0,193	0,253	0,288	0,060	0,336	0,271	0,294	0,329	0,194	0,370	0,222	0,323
C4a	0,238	0,211	0,372	**1,000**	0,393	0,219	0,162	0,297	0,336	0,392	0,458	0,465	0,326	0,317	0,250	0,271	0,270	0,216	0,300	0,158
C5a	0,406	0,350	0,204	0,393	**1,000**	0,660	0,409	0,433	0,607	0,289	0,214	0,238	0,379	0,579	0,329	0,365	0,160	0,432	0,219	0,312
C6a	0,448	0,437	0,331	0,219	0,660	**1,000**	0,609	0,514	0,639	0,295	0,200	0,298	0,457	0,587	0,478	0,495	0,196	0,462	0,346	0,510
C7a	0,602	0,566	0,408	0,162	0,409	0,609	**1,000**	0,489	0,466	0,121	0,208	0,105	0,625	0,380	0,404	0,502	0,100	0,585	0,214	0,463
C8a	0,459	0,448	0,405	0,297	0,433	0,514	0,489	**1,000**	0,595	0,205	0,210	0,182	0,506	0,443	0,506	0,472	0,231	0,519	0,325	0,435
C9a	0,488	0,372	0,193	0,336	0,607	0,639	0,466	0,595	**1,000**	0,296	0,321	0,330	0,535	0,544	0,389	0,279	0,102	0,459	0,234	0,301
C10a	0,121	0,199	0,253	0,392	0,289	0,295	0,121	0,205	0,296	**1,000**	0,465	0,402	0,062	0,230	0,190	0,281	0,318	0,100	0,301	0,157
C11a	0,251	0,143	0,288	0,458	0,214	0,200	0,208	0,210	0,321	0,465	**1,000**	0,410	0,288	0,350	0,369	0,303	0,276	0,119	0,276	0,165
C12a	0,009	-0,011	0,060	0,465	0,238	0,298	0,105	0,182	0,330	0,402	0,410	**1,000**	0,217	0,360	0,348	0,209	0,397	0,050	0,407	0,132
C13a	0,663	0,563	0,336	0,326	0,379	0,457	0,625	0,506	0,535	0,062	0,288	0,217	**1,000**	0,523	0,451	0,400	0,164	0,572	0,143	0,360
C14a	0,415	0,348	0,271	0,317	0,579	0,587	0,380	0,443	0,544	0,230	0,350	0,360	0,523	**1,000**	0,481	0,280	0,146	0,399	0,314	0,379
C15a	0,411	0,322	0,294	0,250	0,329	0,478	0,404	0,506	0,389	0,190	0,369	0,348	0,451	0,481	**1,000**	0,608	0,268	0,386	0,322	0,386
C16a	0,422	0,471	0,329	0,271	0,365	0,495	0,502	0,472	0,279	0,281	0,303	0,209	0,400	0,280	0,608	**1,000**	0,406	0,452	0,249	0,392
C17a	0,112	0,089	0,194	0,270	0,160	0,196	0,100	0,231	0,102	0,318	0,276	0,397	0,164	0,146	0,268	0,406	**1,000**	0,234	0,488	0,107
C18a	0,532	0,573	0,370	0,216	0,432	0,462	0,585	0,519	0,459	0,100	0,119	0,050	0,572	0,399	0,386	0,452	0,234	**1,000**	0,296	0,361
C19a	0,103	0,220	0,222	0,300	0,219	0,346	0,214	0,325	0,234	0,301	0,276	0,407	0,143	0,314	0,322	0,249	0,488	0,296	**1,000**	0,371
C20a	0,256	0,369	0,323	0,158	0,312	0,510	0,463	0,435	0,301	0,157	0,165	0,132	0,360	0,379	0,386	0,392	0,107	0,361	0,371	**1,000**

The Kaiser–Meyer–Olkin (KMO) extent of sampling suitability and Bartlett's test of sphericity were as well utilised to check the factorability of the information collected. Pallant (2005) recommended that the Bartlett's test of sphericity has to be significant ($P < 0.05$) for FA to be considered suitable. Findings in Table 6.6 displays a KMO value of 0.847 and a significant level of 0.000 for the Bartlett's test. These findings combined with the 0.910 result acquired from the reliability test carried out through the usage of Cronbach's α test indicate that utilising FA for the information collected is suitable.

Table 6. 6 KMO and Bartlett's test for barriers of lean concepts in the construction industry

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,847
Bartlett's Test of Sphericity	Approx. Chi-Square	1474,624
	Df	190
	Sig.	0,000

Zhao (2008) conducted a study for the minimum test measure in FA and discovered that various researchers have recommended a number of sample sizes. Preacher and MacCullum (2002:155) proposed that as long as the communalities are high, the number of anticipated components is moderately less, and model mistake is small, researchers and commentators should not be stressed around a small sample size.

Table 6. 7 Communalities

	Initial	Extraction
Lack of lean understanding	0,741	0,786
Lack of adequate lean awareness	0,728	0,706
Lack of adequate time for innovation	0,491	0,412
Poor standardize procurement strategies	0,507	0,498
Inaccurate and incomplete designs	0,611	0,545
Lack of top management commitment	0,721	0,733
Lack of appropriate lean training	0,637	0,611
Lack of interest from clients	0,567	0,509
Poor communication among stakeholders	0,678	0,705
Lack of agreed implementation methodology	0,423	0,367
Lack of prefabrication techniques	0,469	0,469
Uncertainty in supply chain	0,527	0,555
Absence of a lean culture	0,672	0,584
Inadequate pre-planning	0,576	0,543
Human resistance to change	0,570	0,448
Lack of organisational culture that supports lean	0,636	0,531
High cost of lean training	0,477	0,429
Lack of lean specialists and expertise	0,557	0,533
Insufficient financial resources	0,492	0,432
Lack of government support	0,424	0,380

As the information collected met all the fundamental necessity, FA was carried out utilising PCA with varimax rotation. Findings in Table 6.8 revealed that four factors with eigenvalues bigger than 1 were extracted utilising the factor loading of 1.0 as the cut-off point. The total variance described by each factor extracted is as follows: factor 1 with 36.5%, factor 2 with 9.2 per cent, factor 3 with 4.6 per cent and factor 4 with 3.6 per cent. The final statistics of the PCA and the factors extracted accounted for almost 53.89 per cent of the total cumulative variance. This accomplishes the requirements of components explaining at least 50 per cent of the variation as indicated by Stern (2010).

Table 6. 8 Total variance explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**7,731**	38,657	38,657	7,301	36,505	36,505	3,642	18,208	18,208
2	**2,306**	11,532	50,189	1,836	9,181	45,685	3,166	15,831	34,039
3	**1,352**	6,760	56,949	0,920	4,602	50,287	2,278	11,388	45,428
4	**1,205**	6,023	**62,972**	0,721	3,604	53,891	1,693	8,463	**53,891**
5	0,912	4,558	67,530						
6	0,836	4,182	71,712						
7	0,791	3,957	75,669						
8	0,641	3,205	78,874						
9	0,584	2,920	81,795						
10	0,566	2,831	84,626						
11	0,502	2,511	87,137						
12	0,467	2,335	89,472						
13	0,419	2,095	91,567						
14	0,402	2,009	93,577						
15	0,294	1,469	95,046						
16	0,268	1,338	96,384						
17	0,234	1,171	97,555						
18	0,193	0,964	98,519						
19	0,161	0,807	99,326						
20	0,135	0,674	100,000						

Scree plot

According to Velicer and Jackson (1990), the scree test includes analyzing the chart of the eigenvalues (accessible through each software package) and trying to find the common bend or break point within the information where the curve straightens out. Velicer and Jackson (1990) further explain that the number of data points beyond the 'break' is ordinarily the number of components to keep, even though it can be uncertain whether there are data points grouped together near the curve. The scree plot in figure 6.5 shows a break after the fourth factor. The steep slope shows the larger factor while the gradually decreasing factor presents the rest of variables that have eigenvalues lower than 1.

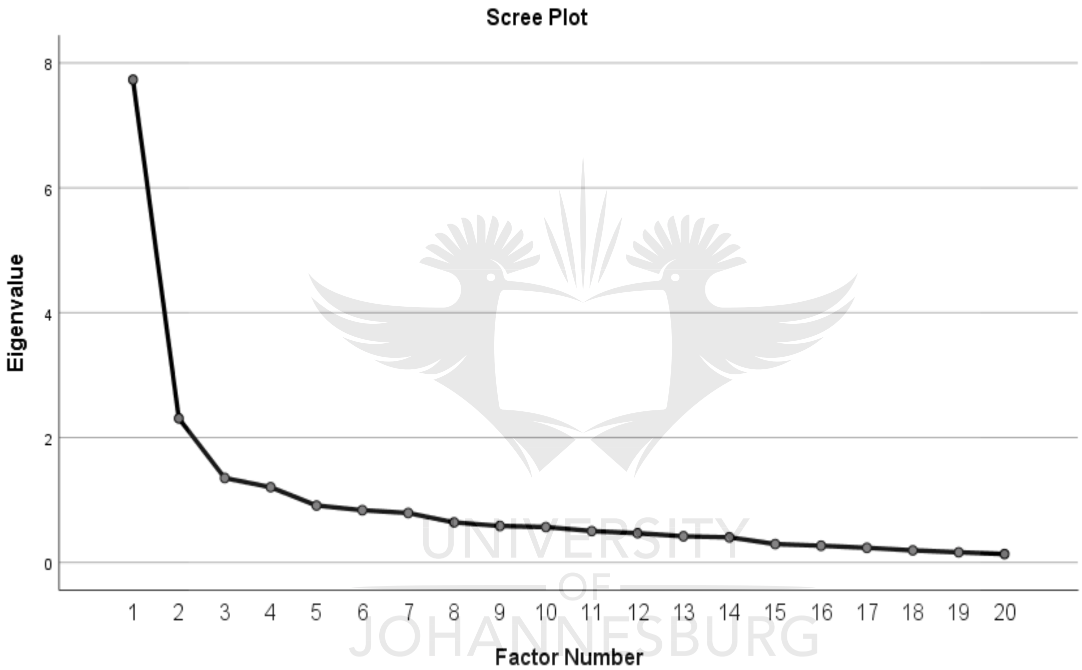


Figure 6. 5 Scree plot for barriers of lean concepts in the construction industry

Varimax rotation was conducted to interpret the four groups of barriers of lean. This offered an increase to the pattern matrix presented in table 6.9.

Table 6. 9 Rotated factor matrix

Barriers	1	2	3	4
Lack of lean understanding	**0,827**			
Lack of adequate lean awareness	**0,807**			
Absence of a lean culture	**0,606**			
Lack of appropriate lean training	**0,604**			
Lack of lean specialists and expertise	**0,567**			
Lack of adequate time for innovation	**0,563**			
Poor communication among stakeholders		**0,749**		
Lack of top management commitment		**0,717**		
Inaccurate and incomplete designs		**0,661**		
Inadequate pre-planning		**0,623**		
Lack of interest from clients		**0,453**		
Poor standardize procurement strategies			**0,654**	
Lack of prefabrication techniques			**0,645**	
Uncertainty in supply chain			**0,632**	
Lack of agreed implementation methodology			**0,562**	
Insufficient financial resources				**0,533**
Lack of organisational culture that supports lean				**0,507**
High cost of lean training				**0,502**
Lack of government support				**0,418**
Human resistance to change				**0,408**

6.4.2.1 Factor analysis presenting the four groups

Understanding of lean concept. From Table 6.9, it is clear that the first barrier factor has the highest factor loading for a group of six components. These variables include lack of lean understanding, lack of adequate lean awareness, lack of adequate time for innovation, absence of a lean culture, lack of lean specialists and expertise lack of appropriate lean training. These barriers account for 36.5% of the total variance described. After a basic analysis of the features of these barriers, it was detected that these strategies relate to absence of knowledge about lean concepts, hence it was named as ‘understanding of lean concept’.

Stakeholders and construction process barriers. The second principal factor accounts for 9.2% of the total variance explained. The factor includes obstacles such as poor communication among stakeholders, lack of interest from clients, inaccurate and incomplete designs, inadequate pre-planning and lack of top management commitment. This factor was further named ‘managerial and stakeholders barriers’.

Procurement and technical barriers. The third principal factor extracted accounts for 4.6 per cent of the variance described. The barriers in this factor comprise poor standardized procurement strategies, lack of prefabrication techniques, uncertainty in supply chain, and lack of agreed implementation methodology. Bearing in mind the latent features of these barriers, this component was therefore titled ‘procurement barriers’.

Government support and organisational barriers. The fourth principal factor accounts for 3.6 per cent of the variance explained. Obstacles under this factor include insufficient financial resources, human resistance to change, high cost of lean training, lack of government support, and lack of organisational culture that supports lean. These factors were therefore called ‘financial barriers.

6.5 MEASURES FOR IMPROVING LEAN ADOPTION IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY

Table 6.10 reveals the respondents’ ranking of measures for improving lean adoption in the construction industry. Respondents were required to indicate the level of importance using a five-point scale of 1 = Strongly disagree, 2 = Disagree; 3 = Neutral, 4 = Agree and 5 = Strongly agree. The table shows that ‘lean awareness’ with a mean item score (MIS) of 4.48 and standard deviation (SD) of 0.815 was ranked first and ‘top management commitment’ was ranked second with an MIS of 4.46 and SD of 0.831. The measures from first to second ranking in table 6.10 were relatively very high for improving the lean adoption in the CI. ‘Availability of lean experts’ was ranked third with an MIS of 4.45 and SD of 0.822, ‘employee training and development’ was ranked fourth with an MIS of 4.42 and SD of 0.787, and ‘lean education in higher institutes’ was ranked fifth with an MIS of 4.40 and SD of 0.888.’Government support’ was ranked sixth with an MIS of 4.31 and SD of 0.918, ‘efficient communication system’ was also ranked seventh with an MIS of 4.28 and SD of 0.896, ‘client support’ was ranked eighth with an MIS of 4.23 and SD of 0.983, ‘availability of required technology’ was ranked ninth with an MIS of 4.19 and SD of 0.900, favourable lean organisational culture was ranked tenth with an MIS of 4.13 and SD of 0.975, and ‘collaboration among stakeholders was also ranked tenth with an MIS of 4.13 and SD of 0.889. In addition, ‘mandatory lean policies and regulations’ was ranked eleventh with an MIS of 4.09 and SD of 0.948, ‘proper site management’ was ranked twelfth with an MIS of 3.92 and SD of 0.942 and ‘proper waste management’ was ranked thirteenth with an MIS of 3.92 and SD of 0.806. The measures from second to thirteenth ranking in table 6.10 were relatively high for improving the lean adoption in the CI.

Table 6. 10 Measures for improving lean adoption in the construction industry

Measures for improving lean adoption in the construction industry	**$\bar{x}$**	**Σx**	**R**
Lean awareness	4.48	0.815	1
Top Management commitment	4.46	0.831	2
Availability of lean experts	4.45	0.822	3
Employee training and development	4.42	0.787	4
Lean education in higher institute	4.40	0.888	5
Government support	4.31	0.918	6
Efficient communication system	4.28	0.896	7
Client support	4.23	0.983	8
Availability of required technology	4.19	0.900	9
Favourable lean organisational culture	4.13	0.975	10
Collaboration among stakeholders	4.13	0.889	10
Mandatory lean policies and regulations	4.09	0.948	11
Proper site management	3.92	0.942	12
Proper waste management	3.87	0.806	13

$\bar{x}$ = Mean item score; σX = Standard deviation; R = Rank

6.5.2 Exploratory factor analysis for measures for improving lean adoption in the construction industry

EFA was conducted on lean principles and techniques for construction projects. Tables 6.12 – 6.19 and figure 6.6 show the results obtained from EFA. None of the fourteen (14) variables were omitted during EFA. Principal component analysis (PCA) was utilised to analyse the twenty-two variables, using SPSS version 25 software. Table 6.11 presents the codes and their definitions used for the analysis.

Table 6. 11 Definitions

	Measures for improving lean adoption in the construction industry
D1	Lean awareness
D2	Lean education in higher institute
D3	Employee training and development
D4	Availability of lean experts
D5	Top management commitment
D6	Efficient communication system
D7	Government support
D8	Mandatory lean policies and regulations
D9	Favourable lean organisational culture
D10	Collaboration among stakeholders
D11	Proper waste management
D12	Client support
D13	Proper site management
D14	Availability of required technology

Before carrying out the PCA, the suitability of the information for factor analysis was evaluated. MacCallum and Tucker (1991) suggested an optimum range for the inter-item correlation of 0.2 to 0.4. Inspection of the correlation matrix for this study revealed the presence of a co-efficient of over 0.30 in all of the variables, which was suitable for factor analysis as presented in Table 6.12.

Table 6. 12 Inter-item correlation matrix

	D1a	D2a	D3a	D4a	D5a	D6a	D7a	D8a	D9a	D10a	D11a	D12a	D13a	D14a
D1a	**1,000**	0,671	0,649	0,523	0,469	0,456	0,584	0,469	0,402	0,560	0,340	0,410	0,267	0,392
D2a	0,671	**1,000**	0,736	0,662	0,639	0,604	0,589	0,343	0,441	0,602	0,383	0,442	0,405	0,495
D3a	0,649	0,736	**1,000**	0,734	0,636	0,655	0,591	0,564	0,504	0,590	0,352	0,510	0,406	0,487
D4a	0,523	0,662	0,734	**1,000**	0,561	0,616	0,555	0,442	0,503	0,560	0,322	0,472	0,417	0,558
D5a	0,469	0,639	0,636	0,561	**1,000**	0,587	0,570	0,402	0,380	0,597	0,421	0,545	0,337	0,460
D6a	0,456	0,604	0,655	0,616	0,587	**1,000**	0,567	0,472	0,502	0,575	0,347	0,494	0,469	0,603
D7a	0,584	0,589	0,591	0,555	0,570	0,567	**1,000**	0,649	0,500	0,589	0,381	0,629	0,306	0,387
D8a	0,469	0,343	0,564	0,442	0,402	0,472	0,649	**1,000**	0,557	0,500	0,331	0,471	0,359	0,386
D9a	0,402	0,441	0,504	0,503	0,380	0,502	0,500	0,557	**1,000**	0,612	0,352	0,519	0,359	0,367
D10a	0,560	0,602	0,590	0,560	0,597	0,575	0,589	0,500	0,612	**1,000**	0,479	0,500	0,307	0,470
D11a	0,340	0,383	0,352	0,322	0,421	0,347	0,381	0,331	0,352	0,479	**1,000**	0,452	0,592	0,495
D12a	0,410	0,442	0,510	0,472	0,545	0,494	0,629	0,471	0,519	0,500	0,452	**1,000**	0,387	0,439
D13a	0,267	0,405	0,406	0,417	0,337	0,469	0,306	0,359	0,359	0,307	0,592	0,387	**1,000**	0,742
D14a	0,392	0,495	0,487	0,558	0,460	0,603	0,387	0,386	0,367	0,470	0,495	0,439	0,742	**1,000**

The KMO extent of sampling adequacy and Bartlett's test of sphericity conducted presented a 0.893 value for KMO and substantial level of 0.000 for Bartlett's test. Tabachnick and Fidell (2007) indicated that the KMO index ranges from 0 to 1, with 0.6 recommended as the lowest value for a decent factor analysis. These findings together with the 0.931 findings acquired from the reliability test conducted through the usage of Cronbach's α test indicate that the use of FA for the information collected is applicable.

Table 6. 13 KMO and Bartlett's test for measures for improving lean adoption in the construction industry

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,893
Bartlett's Test of Sphericity	Approx. Chi-Square	1372,668
	Df	91
	Sig.	0,000

Table 6.14 shows the communality of variables. This is the variance accounted for by all the extracted factors.

Table 6. 14 Communalities

	Initial	**Extraction**
Lean awareness	0,572	0,516
Lean education in higher institute	0,719	0,621
Employee training and development	0,745	0,714
Availability of lean experts	0,634	0,590
Top management commitment	0,581	0,538
Efficient communication system	0,605	0,583
Government support	0,673	0,630
Mandatory lean policies and regulations	0,597	0,421
Favourable lean organisational culture	0,534	0,424
Collaboration among stakeholders	0,638	0,602
Proper waste management	0,497	0,400
Client support	0,528	0,458
Proper site management	0,670	0,955
Proper site management	0,681	0,659

Since the information collected met all the fundamental requirements, FA was conducted utilizing PCA with varimax rotation. Findings in Table 6.14 indicate that two factors with eigenvalues greater than 1 were extracted utilising the factor loading of 1.0 as the cut-off point. The total variance described by each factor extracted is as follows: factor 1 with 50.5 per cent and factor 2 with7.3 per cent. The final statistics of the PCA and the components extracted accounted for around 57.93 per cent of the overall total variance. This satisfies the basis of variables explaining at least 50 per cent of the variety as expressed by Tabachnick and Fidell (2001).

Table 6. 15 Total variance explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**7,491**	53,506	53,506	7,076	50,541	50,541	5,508	39,344	39,344
2	**1,286**	9,185	**62,690**	1,035	7,391	57,933	2,602	18,589	**57,933**
3	0,955	6,819	69,510						
4	0,720	5,146	74,656						
5	0,626	4,474	79,130						
6	0,588	4,198	83,328						
7	0,455	3,253	86,581						
8	0,395	2,822	89,403						
9	0,336	2,397	91,800						
10	0,320	2,287	94,087						
11	0,292	2,087	96,174						
12	0,222	1,584	97,758						
13	0,168	1,197	98,956						
14	0,146	1,044	100,000						

Scree plot

The scree plot in figure 6.6 reveals a break after the second factor. The steep slope shows the larger factor while the gradually decreasing factor presents the rest of the variables that have eigenvalue lower than 1. The two groups located on the steep slope were retained.

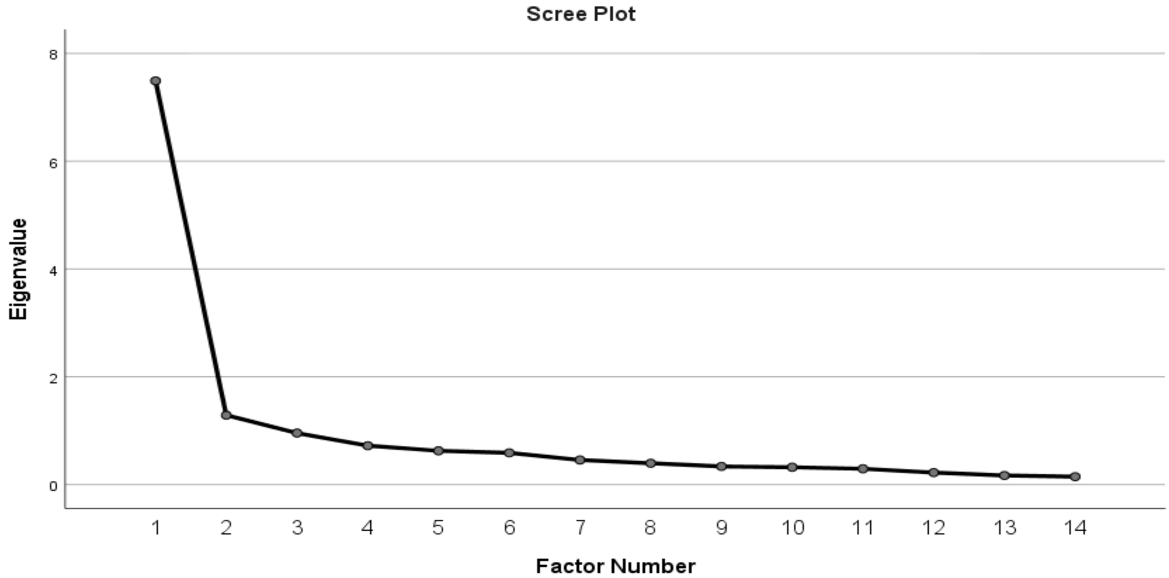


Figure 6. 6 Scree plot for measures for improving lean adoption in the construction industry

Varimax rotation was carried out to interpret the two groups of measures for improving lean implementation in the CI. This gave rise to the pattern matrix presented in table 6.16

Table 6. 16 Rotated factor matrix a

	1	2
Employee training and development	0,801	
Government support	0,770	
Lean education in higher institute	0,735	
Collaboration among stakeholders	0,732	
Lean awareness	0,700	
Availability of lean experts	0,695	
Top management commitment	0,679	
Efficient communication system	0,650	
Mandatory lean policies and regulations	0,599	
Favourable lean organisational culture	0,593	
Client support	0,592	
Proper site management		0,966
Availability of required technology		0,717
Proper waste management		0,536

6.5.2.1 Factor analysis presenting the two groups

Knowledge and organizational measures. From Table 6.15, it is clear that the initial measure factor has the highest factor loading for a group of eleven factors. These factors consist of employee training and development, government support, lean education in higher institute, collaboration among stakeholders, lean awareness, availability of lean experts, top management commitment, efficient communication system, client support, favourable lean organisational culture, and mandatory lean policies and regulations. These measures account for 50.5 per cent of the total variance described. After a basic analysis of the features of these measures, it was perceived that these strategies relate to knowledge of lean concepts and management of the organisations; hence they are named as 'knowledge and management measures'.

Operations measures. The next principal factor accounts for 7.3 per cent of the total variance described. The factor consists of proper site management, availability of required technology and proper waste management. This factor was therefore named 'operations measures'.

6.6 BENEFITS OF ADOPTING LEAN CONCEPTS IN THE CONSTRUCTION INDUSTRY

Table 6.17 reveals the respondents' ranking of the benefits of adopting lean concepts in the CI. Respondents were required to indicate the extent of agreement using a five-point scale of 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree and 5 = Strongly agree. The table shows that 'improves quality' with a mean item score (MIS) of 4,39and standard deviation (SD) of 0.840 was ranked first, 'reduction of waste' was ranked second with an MIS of 4,36and SD of 0.927,' improves target costing and value' was ranked third with an MIS of 4,33 and SD of 0.862, 'increases the productivity' was ranked fourth with an MIS of 4.32 and SD of 0.899, and 'meets clients' needs in higher institute' was ranked fifth with an MIS of 4,26and SD of 0.913. Moreover, 'improves safety (reduced trip hazards and fatigue)' was ranked sixth with an MIS of 425 and SD of 0.848, 'encourages collaboration' was ranked seventh with an MIS of 4,23 and SD of 0.890, 'improves effective communication' was ranked eighth with an MIS of 4,22and SD of 0.886, 'improves environmental performance' was ranked ninth with an MIS of 4,21 and SD of 0.859 , and 'decreases defects' was ranked tenth with an MIS of 4.17 and SD of 1,031. In addition, 'reduces project duration' was ranked eleventh with an MIS of 4.11 and SD of 0.928, 'reduces project cost' was ranked twelfth with an MIS of 4.07 and SD of 0,880, 'efficiency of equipment' was ranked thirteenth with an MIS of 4.04 and SD of 0,804, 'encourages the use of relevant equipment' was ranked fourteenth with an MIS of 4.03 and SD of 0,816, and 'decreases the chance of accidents on site' was ranked fifteenth with an MIS of 4.02 and SD of 0,804. Furthermore, 'maximises the usage of multi-skilled employees' was ranked sixteenth with an MIS of 3.93 and SD of 0,780, 'minimises double handling and movement of labourers and tools' was ranked seventeenth with an MIS of 3.92 and SD of 0.821 and 'reduced inventory' was ranked eighteenth with an MIS of 3.79 and SD of 0.838. The level of agreement for all the rankings in table 6.10 was relatively high for benefits of lean concepts in the CI.

Table 6. 17 Benefits of adopting lean concepts in the construction industry

Benefits of adopting lean concepts	$\bar{x}$	Σx	**R**
Improves quality	4,39	0,840	1
Reduces waste	4,36	0,927	2
Improves target costing and value	4,33	0,862	3
Increases the productivity	4,32	0,899	4
Meets clients' needs	4,26	0,913	5
Improves safety (reduced trip hazards and fatigue)	4,25	0,848	6
Encourages collaboration	4,23	0,890	7
Improves effective communication	4,22	0,886	8
Improves environmental performance	4,21	0.859	9
Decreases defects	4,17	1,031	10
Reduces project duration	4,11	0,928	11
Reduces project cost	4,07	0,880	12
Efficiency of equipment	4,04	0,804	13
Encourages the use of relevant equipment	4.03	0.816	14
Decreases the chance of accidents on site	4.02	0.804	15
Maximises the usage of multi-skilled employees	3.93	0.780	16
Minimises double handling and movement of labourers and tools.	3.92	0.821	17
Reduces inventory	3.79	0.838	18

6.6.2 Exploratory factor benefits of adopting lean concepts

EFA was conducted on lean principles and techniques for construction projects. Tables 6.19 – 6.23 and figure 6.7 show the results obtained from EFA. None of the eighteen (18) variables were omitted during EFA. PCA was utilised to analyse the twenty-two variables using SPSS version 25 software.Table 6.2 presents the codes and their definitions used for the analysis.

Table 6. 18 Definitions

	Benefits of adopting lean concepts
E1	Improves safety (reduced trip hazards and fatigue)
E2	Improves environmental performance
E3	Reduces waste
E4	Reduces project duration
E5	Increases the productivity
E6	Minimises double handling and movement of labourers and tools.
E7	Meets clients' needs
E8	Improves target costing and value
E9	Decreases the chance of accidents on site
E10	Efficiency of equipment
E11	Encourages the use of relevant equipment
E12	Improves quality
E13	Reduces inventory
E14	Maximises the usage of multi-skilled employees
E15	Reduces project cost
E16	Decreases defects
E17	Improves effective communication
E18	Encourages collaboration

Before carrying out the PCA, the suitability of the information for factor analysis was evaluated. Phelan and Wren (2018) suggested an optimum range for the inter-item correlation of 0.15 to 0.50. Inspection of the correlation matrix for this study shows the existence of a co-efficient of over 0.3 for most of the variables, which was suitable for factor analysis as presented in Table 6.19.

Table 6. 19 Inter-item correlation matrix

	E1a	E2a	E3a	E4a	E5a	E6a	E7a	E8a	E9a	E10a	E11a	E12a	E13a	E14a	E15a	E16a	E17a	E18a
E1a	**1,000**	0,620	0,420	0,431	0,420	0,335	0,469	0,481	0,560	0,381	0,395	0,463	0,252	0,377	0,405	0,416	0,531	0,498
E2a	0,620	**1,000**	0,570	0,568	0,505	0,445	0,506	0,587	0,453	0,337	0,539	0,603	0,308	0,454	0,540	0,572	0,514	0,595
E3a	0,420	0,570	**1,000**	0,471	0,545	0,459	0,700	0,607	0,375	0,316	0,296	0,629	0,486	0,421	0,466	0,582	0,527	0,567
E4a	0,431	0,568	0,471	**1,000**	0,604	0,450	0,501	0,545	0,355	0,364	0,410	0,533	0,254	0,416	0,668	0,614	0,505	0,453
E5a	0,420	0,505	0,545	0,604	**1,000**	0,451	0,572	0,480	0,416	0,410	0,306	0,555	0,331	0,449	0,501	0,508	0,589	0,530
E6a	0,335	0,445	0,459	0,450	0,451	**1,000**	0,482	0,414	0,356	0,523	0,541	0,509	0,421	0,471	0,423	0,339	0,354	0,482
E7a	0,469	0,506	0,700	0,501	0,572	0,482	**1,000**	0,789	0,538	0,461	0,447	0,711	0,334	0,380	0,549	0,696	0,639	0,656
E8a	0,481	0,587	0,607	0,545	0,480	0,414	0,789	**1,000**	0,500	0,389	0,528	0,667	0,264	0,350	0,548	0,730	0,577	0,612
E9a	0,560	0,453	0,375	0,355	0,416	0,356	0,538	0,500	**1,000**	0,497	0,517	0,482	0,392	0,363	0,413	0,511	0,471	0,469
E10a	0,381	0,337	0,316	0,364	0,410	0,523	0,461	0,389	0,497	**1,000**	0,640	0,473	0,266	0,517	0,432	0,460	0,431	0,419
E11a	0,395	0,539	0,296	0,410	0,306	0,541	0,447	0,528	0,517	0,640	**1,000**	0,500	0,242	0,526	0,434	0,533	0,342	0,450
E12a	0,463	0,603	0,629	0,533	0,555	0,509	0,711	0,667	0,482	0,473	0,500	**1,000**	0,308	0,436	0,520	0,722	0,628	0,653
E13a	0,252	0,308	0,486	0,254	0,331	0,421	0,334	0,264	0,392	0,266	0,242	0,308	**1,000**	0,448	0,301	0,305	0,359	0,379
E14a	0,377	0,454	0,421	0,416	0,449	0,471	0,380	0,350	0,363	0,517	0,526	0,436	0,448	**1,000**	0,492	0,478	0,465	0,473
E15a	0,405	0,540	0,466	0,668	0,501	0,423	0,549	0,548	0,413	0,432	0,434	0,520	0,301	0,492	**1,000**	0,574	0,578	0,574
E16a	0,416	0,572	0,582	0,614	0,508	0,339	0,696	0,730	0,511	0,460	0,533	0,722	0,305	0,478	0,574	**1,000**	0,630	0,632
E17a	0,531	0,514	0,527	0,505	0,589	0,354	0,639	0,577	0,471	0,431	0,342	0,628	0,359	0,465	0,578	0,630	**1,000**	0,755
E18a	0,498	0,595	0,567	0,453	0,530	0,482	0,656	0,612	0,469	0,419	0,450	0,653	0,379	0,473	0,574	0,632	0,755	**1,000**

Pallant (2005) recommended that the Bartlett's test of sphericity has to be significant ($P < 0.05$) for FA to be considered suitable. Findings in Table 6.6 display a KMO value of 0.847 and a significant level of 0.000 for the Bartlett's test. These findings combined with the 0.910 result acquired from the reliability test carried out through the usage of Cronbach's α test indicate that the utilisation of FA for the information collected is suitable.

KMO extent of sampling suitability and Bartlett's test of sphericity were as well utilised to check the factorability of the information collected. Cerny and Kaiser (1977) recommended that the Bartlett's test of sphericity of between 0.8 and 1 shows that the sampling is acceptable and values less than 0.6 shows that the sampling is inadequate and that corrective measures should be taken. Results in Table 6.20 indicate a KMO value of 0,893 and a substantial level of 0.000 for the Bartlett's test. These findings combined with the 0.944 finding acquired from the reliability test conducted through the usage of Cronbach's α test indicate that the use of FA for the information collected is correct.

Table 6. 20 KMO and Bartlett's test for benefits of adopting lean concepts

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,916
Bartlett's Test of Sphericity	Approx. Chi-Square	1827,924
	Df	153
	Sig.	0,000

Table 6.21 shows the communality of variables. This is the variance accounted for by all the extracted factors.

Table 6. 21 Communalities

	Initial	Extraction
Improves safety (reduced trip hazards and fatigue)	0,542	0,388
Improves environmental performance	0,662	0,542
Reduces waste	0,657	0,604
Reduces project duration	0,639	0,477
Increases the productivity	0,557	0,531
Minimises double handling and movement of labourers and tools.	0,567	0,488
Meets clients' needs	0,774	0,727
Improves target costing and value	0,730	0,767
Decreases the chance of accidents on site	0,539	0,426
Efficiency of equipment	0,567	0,531
Encourages the use of relevant equipment	0,667	0,945
Improves quality	0,680	0,671
Reduces inventory	0,414	0,370
Maximises the usage of multi-skilled employees	0,518	0,547
Reduces project cost	0,584	0,507
Decreases defects	0,740	0,703
Improves effective communication	0,695	0,624
Encourages collaboration	0,693	0,633

Findings in Table 6.14 indicate that two factors with eigenvalues greater than 1 were extracted utilising the factor loading of 1.0 as the cut-off point. The total variance described by each factor extracted is as follows: factor 1 with 50.5 per cent and, factor 2 with7.3 per cent. The final statistics of the PCA and the components extracted accounted for around 57.93 per cent of the overall total variance. This satisfies the basis of variables describing at slightest 50 per cent of the variety as expressed by Tabachnick and Fidell (2001).

Since the information collected met all the fundamental necessity, FA was carried out utilizing PCA with varimax rotation. Findings in Table 6.22 indicate that three factors with eigenvalues greater than 1 were extracted utilising the factor loading of 1.0 as the cut-off point. The total variance described by each factor extracted is as follows: factor 1 with 49.6 per cent, factor 2 with 5.3 per cent, factor 3 with 3.3 per cent and factor 4 with 8.46 per cent. The final statistics of the PCA and the components extracted accounted for around 58.229 per cent of the total cumulative variance. This satisfies the basis of variables describing at least 50 per cent of the variety as expressed (Tabachnick and Fidell (2001).

Table 6. 22 Total variance explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**9,325**	51,805	51,805	8,926	49,591	49,591	5,572	30,953	30,953
2	**1,271**	7,061	58,866	0,955	5,304	54,895	2,502	13,898	44,851
3	**1,030**	5,724	**64,590**	0,600	3,334	58,229	2,408	13,378	**58,229**
4	0,883	4,907	69,497						
5	0,816	4,536	74,033						
6	0,696	3,864	77,897						
7	0,618	3,434	81,331						
8	0,589	3,273	84,604						
9	0,490	2,724	87,328						
10	0,400	2,224	89,552						
11	0,340	1,890	91,442						
12	0,320	1,776	93,218						
13	0,300	1,669	94,887						
14	0,232	1,289	96,176						
15	0,194	1,078	97,255						
16	0,183	1,019	98,274						
17	0,159	0,883	99,157						
18	0,152	0,843	100,000						

Scree plot

The scree plot in figure 6.7 shows a break after the third factor. The steep slope shows the larger factor while the gradually decreasing factor presents the rest of the variables that have eigenvalues lower than 1. The three groups located on the steep slope were retained. Varimax rotation was carried out to interpret the three groups of benefits of lean concepts. This gave rise to the pattern matrix shown in figure 6.7.

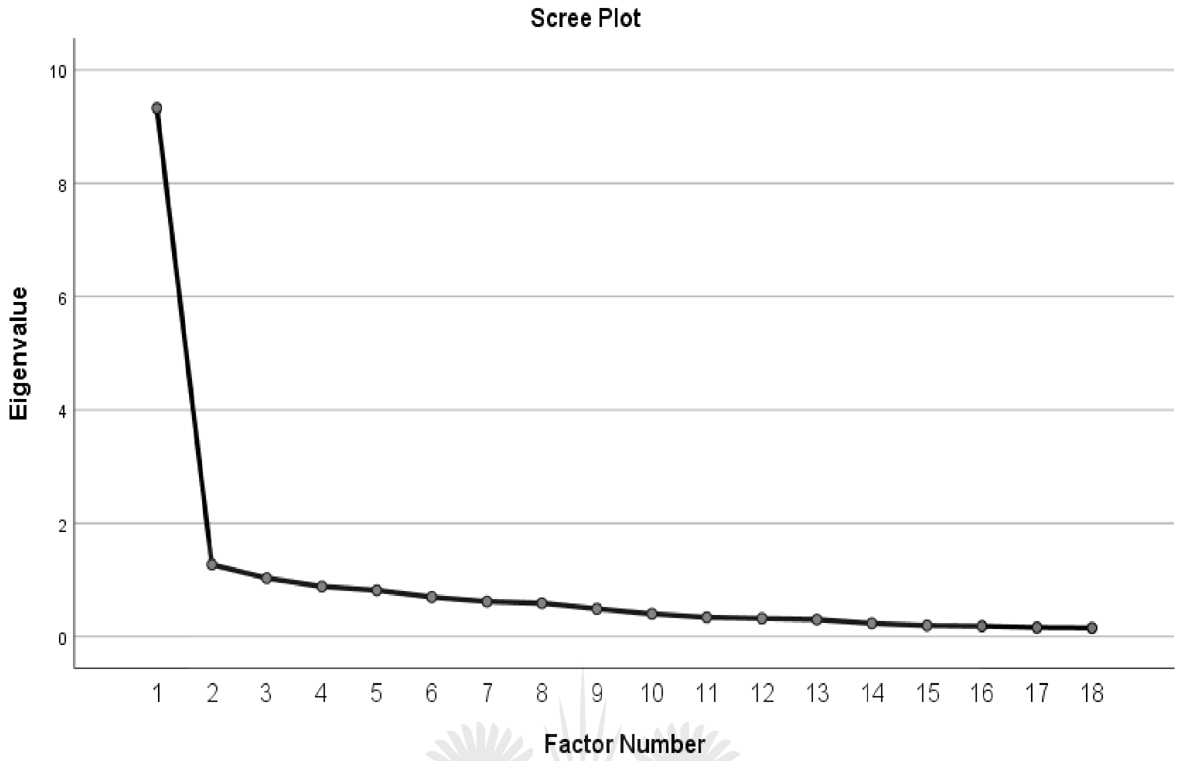


Figure 6. 7 Scree plot for benefits of lean concepts

Table 6. 23 Rotated factor matrix a

Improves target costing and value	**0,817**		
Meets clients' needs	**0,785**		
Decreases defects	**0,752**		
Improves quality	**0,710**		
Improves effective communication	**0,665**		
Encourages collaboration	**0,651**		
Reduces waste	**0,633**		
Improves environmental performance	**0,579**		
Reduces project duration	**0,557**		
Reduces project cost	**0,543**		
Increases the productivity	**0,534**		
Improves safety (reduced trip hazards and fatigue)	**0,479**		
Decreases the chance of accidents on site	**0,435**		
Encourages the use of relevant equipment		**0,926**	
Efficiency of equipment		**0,594**	
Maximises the usage of multi-skilled employees			**0,566**
Reduces inventory			**0,560**
Minimises double handling and movement of labourers and tools.			**0,490**

6.6.2.1 Factor analysis presenting the three groups of benefits of lean concepts

Improved construction delivery benefits. From Table 6.23, it is clear that the initial benefit component has the highest factor loading for a group of eleven variables. These variables include 'improves target costing and value', 'meets clients' needs', 'decreases defects', 'improves quality', 'improves effective communication', 'encourages collaboration' ,'reduces waste', 'improves environmental performance' , 'reduce project duration', 'reduces project cost', 'increases the productivity', 'decreases the chance of accidents on site' and 'improves safety (reduced trip hazards and fatigue)' .These benefits account for 30.95 % of the total variance explained. After a basic analysis of the features of these benefits, it was perceived that these benefits relate to sustainable construction, hence it is named 'sustainable construction benefits'.

Equipment efficiency benefits. The second principal factor accounts for 13.89 % of the total variance described. The factor consists of 'encourages the use of relevant equipment' and 'efficiency of equipment'. This factor was named 'equipment benefits'.

Labourers' efficiency benefits. The third principal factor accounts for 13.38 % of the total variance described. The components includes 'maximises the usage of multi-skilled employees', 'reduces inventory', and 'minimises double handling and movement of labourers and tools'. This factor was named 'labourers' benefits.

6.8 CHAPTER SUMMARY

This section presents and analyses the information acquired from the questionnaires distributed to various construction participants in South Africa. The analysed data is displayed using tables, figures, graphs and pie charts for simple interpretation. Descriptive and exploratory factor analyses were conducted on the data captured. The next chapter discusses the data analysed in relation to the literature reviewed in chapters two, three and four.

CHAPTER SEVEN

DISCUSSION OF FINDINGS

7.1 INTRODUCTION

This section discusses the results recorded in chapter six in relation to the reviewed literature. In the discussion of findings, the reviewed literature is taken into consideration. This is to ascertain whether the research questions have been answered. The results in this chapter are presented in relation to the research questions that have guided this study and the relevant data required.

The study answers the following questions:

- What is the level of awareness of lean principles and techniques in the South African construction industry?
- What is the level of usage of lean principles and techniques in the South African construction industry?
- What are the barriers to the adoption of lean concepts in the South African construction industry?
- What are the measures for improving the adoption of lean concepts in the South African construction industry?
- What are the benefits of adopting lean concepts in the South African construction industry?

7.2 BACKGROUND INFORMATION

The first section of the questionnaire discusses the background of the respondents about their demographic aspects, namely highest educational qualification, profession, years of experience and employment organisation.

7.2.1 Background information results

From the 151 usable questionnaires, the following data was collected: 46.4%, 22.5%, 17.9%, 11.3%, 2% of the respondents possess a bachelor's degree, honour's degree, master's degree, diploma, and doctorate respectively. This indicates that most of the respondents hold a bachelor's degree while the fewest have a doctorate. Furthermore, 25.2% of the respondents were quantity surveyors, 21.2% were construction project managers, 14.6% were architects, 13.2% were project managers, 8.6% were electrical engineers, 6.6% were civil engineers, 6.0% were mechanical engineers and 4.6% were structural engineers. This indicates that most of the respondents were quantity surveyors while structural engineers were the fewest. Findings concerning years of experience reveal that respondents with between six (6) and ten (10) years of experience dominated with a percentage of 29.8%, followed by respondents with between 11 and 15 years with a percentage of 29.1%. These were followed by the 25.2% of respondents with between one (1) and five (5) years of experience, followed by the 10.6% of respondents with between 16 and 20 years of experience. Respondents with experience of more than 20 years represent the lowest percentage of 8%.

From the 151 usable questionnaires returned, 39.1% of the respondents were employees of consultancy firms/companies. Furthermore, 39.1% were government employees, while the lowest numbers of employees were contractors with a percentage of 21.9%. Based on the findings, it can be deduced that the population for the study are all represented within the sample collected.

7.3 LEVEL OF AWARENESS OF LEAN PRINCIPLES AND TECHNIQUES IN THE CONSTRUCTION INDUSTRY

RQ1: What is the level of awareness of lean principles and techniques in the South African construction industry?

Results from the descriptive analysis were used in answering this research question.

7.3.1 Findings

The level of awareness of the following LP was highly rated: identifying value pursuing (MIS=3.87; SD=1.196; R=1), pursuing perfection (MIS=3.68; SD=1.283; R=2), achieving flow in the process (MIS=3.65; SD=1.239; R=3), allowing customer to pull (MIS=3.60; SD=1.297; R=4) and adopting value stream mapping (MIS =3.52; SD =1.280; R=5). The level of awareness of lean principles ranking from one to two for construction projects was relatively high.

Ranking the level of awareness of LT in the SACI indicates that the LT total quality management (TQM) (MIS=3.77; SD=1.163; R=1) was highly recognized with a relatively high level of awareness in the CI. Other LTs included waste elimination, first run studies (plan, do, check and act), prefabrication, standardisation, increased visualisations (visual management), 5s process, VSM, Kaizen (continuous improvement), five why's, just-in-time (JIT), error proofing /fail safe for quality and safety (poka-yoke), LPS, ishikawa diagram, failure mode, effects and criticality analysis, Kanban (pull system) and pareto analysis. The level of awareness of LT ranking from second to fifteenth in the SACI is average. The findings of the study fundamentally supports the study conducted by Antillón, (2010:19) who reveals that there are various lean techniques encountered in the construction industry, namely 5s process (Sort, Set in order, Shine, Standardize and Sustain), just-in-time, increased visualisations(visual management), kaizen (continuous improvement) waste elimination, prefabrication, standardisation, value stream mapping (VSM), Kaizen (continuous improvement), five why's, just-in-time (JIT), error proofing (fail safe for quality and safety).

In support of the survey findings, Sarhan and Fox (2012) discovered that there looks to be progressive awareness of LT and LP in the construction sector. However, the absence of understanding of how to effectively execute lean concepts in particular construction procedures was also revealed. Furthermore, the study also supports the findings by Johansen et al. (2002) which stated that since 1998, efforts to empower the utilization of lean concepts in construction over most geographic areas have been growing. The establishment of the Lean Construction Institute and a few LC consultancy and promotional companies has moreover helped to improve awareness of LC. A few organizations and universities presently offer LC education, which has been supportive in moving lean concepts into the standard of construction education.

7.3.2 Implications of the results

The theoretical review is consistent with the empirical results of this research study. The empirical findings reveal that the level of awareness of LP is relatively high. Respondents assert that LPs such as identify value, pursuing perfection, achieving flow in the process, allowing customer to pull and adopting value stream mapping are relatively well known in the SACI. In keeping with the level of awareness of LT, LTs such as TQM were highly rated with high level of awareness amongst the other techniques in the CI for construction projects. Regardless of the level of awareness of LP and LT, projects continue to fail, ultimately go beyond the contracted period and do not fulfil quality standards owing to poor project management approaches.

7.4 LEVEL OF USAGE OF LEAN PRINCIPLES AND TECHNIQUES IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY

RQ2: What is the level of adoption of lean principles and techniques in the South African construction industry?

Results from the descriptive analysis were used in answering this research question.

7.4.1 Findings

The level of usage of the following LP was highly rated: pursuing perfection (MIS=3.56; SD=1.615; R=1) and identify value (MIS=3.48; SD=1.300; R=2).Other LPs which were rated average are achieving flow, allowing customers to pull, and adopting value stream mapping. The level of usage of LP ranking three to five for construction projects was average.

Ranking the level of usage of LT in the SACI indicates that the lean technique total quality management (TQM) (MIS=3.57; SD=1.647; R=1) was highly recognized with a relatively high level of usage in the construction industry. First run studies (plan, do, check, act), waste elimination, standardisation, the 5s process (Sort, Set in order, Shine, Standardize and Sustain), prefabrication, Kaizen (continuous improvement) and increased visualisations were lean techniques rated as average. The level of usage of lean techniques from second to eighth for construction projects were rated as average. The findings from the survey support the study by Albliwi et al. (2017). This study reveals that the foremost adapted practices to be implemented within the construction recorded are total quality management (TQM), the 5S process, first-run studies (plan, do, check, act), waste elimination, prefabrication and Kaizen (continuous improvement).

Lastly, value streaming mapping, five why's, error proofing(fail safe for quality) and safety (poka-yoke), just-in-time, failure mode, effects and criticality analysis (FMECA), ishikawa, last planner analysis, pareto analysis, and kanban (pull system) were rated as low. The level of usage of lean techniques for construction projects from ninth to seventeenth was low. Based on the general view, the average level of usage of lean principles among South African construction participants from the survey results is 2.47, which indicates a low level of usage for lean techniques within the SACI.

The findings from the questionnaire further support the study of lean concepts in the CI by Shakantu and Emuze (2012). This study supports the findings that building material and waste removal operations and prefabrications could be improved by the use of reverse logistics in a construction context through the application of LC techniques. However, it is evident that although lean is being utilized globally, the concept is not adopted in South Africa. Furthermore, the findings were also similar to those of Matias and Cachadinha (2010) who revealed that, although LC ideas have lately received attention as an advanced method of improving construction execution and work efficiency, the construction industry in SA is slow in taking up lean concepts.

7.4.2 Implications of the results

The theoretical review is consistent with the empirical results of this study. The empirical findings reveal that the level of usage of the lean principles of pursuing perfection and identify value is relatively high. Respondents assert that lean principles, such as achieving flow in the process, allowing customer to pull and adopting value stream mapping are relatively well known in the CI.

In relation to the level of usage of lean techniques, a lean technique such as total quality management (TQM) was highly rated with a high level of usage among the other techniques in the CI for construction projects. The lean techniques such as first run studies (plan, do, check, act), waste elimination, standardisation, the 5s process (Sort, Set in order, Shine, Standardize and Sustain), prefabrication, Kaizen (continuous improvement), increased visualisations were lean techniques rated as average. Furthermore, value streaming mapping, five why's, error proofing /fail safe for quality and safety (poka-yoke), just-in-time, failure mode, effects and criticality analysis (FMECA), ishikawa, last planner analysis, pareto analysis, and kanban (pull system) lean techniques were rated as low.

Based on the general view, the average level of usage of lean principles among SACI is low. Hence, the issue does not fundamentally lie with the level of utilization of lean principles and techniques in the SACI because there is a continuous issue of projects failing as a result of exceeding time, poor management and not complying with quality standards. It is therefore of utmost importance for the government and other stakeholders in the SACI to encourage and support the usage of lean concepts in the CI which is believed will be a giant stride towards achieving the industry's sustainability goal. It is imperative to promote, encourage and ensure the acceptability and implementation of lean principles and techniques for construction projects of the SACI.

7.5 BARRIERS TO THE ADOPTION OF LEAN CONCEPTS IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY

RQ3: What are the barriers to the adoption of lean concepts in the South African construction industry?

7.5.1 Findings

Results from the descriptive and exploratory factor analysis were used in answering this research question.

Based on the rankings and utilising the calculated standard deviation and mean item scores of the recorded obstacles to the adoption of lean concepts in the construction industry, the most significant obstacles hindering the adoption of lean concepts were lack of appropriate lean training, lack of adequate lean awareness, lack of lean understanding, lack of top management commitment, absence of a lean culture and poor communication among stakeholders. Other barriers include lack of organisational culture, lack of lean specialists and expertise, lack of adequate time for innovation, human resistance to change, lack of government support, inadequate pre-planning, lack of interest from clients, inaccurate and incomplete designs, lack of agreed implementation methodology, poor standardize procurement, lack of prefabrication techniques, insufficient financial resources, uncertainty in supply chain, and the high cost of lean training.

Results from exploratory factor analysis

Findings from the factor analysis identified the following four factors:

Factor one: Understanding of lean concept barriers

Lack of lean understanding returns (0,827), lack of adequate lean awareness(0,807), absence of a lean culture (0,606), lack of appropriate lean training (0,604), lack of lean specialists and expertise (0,567), lack of adequate time for innovation (0,563) with a total variance of 36.5 % of the total variance explained. Four loadings of the items in factor one (equity limitations) exceed 0.60, indicating a strong relationship between the items. Additionally, loadings of two of the items exceed 0.55, which still indicates a good relationship between them. The items loaded on factor one relates to obstacles facing the adoption of lean concepts in the CI. The results from the study fundamentally supports the study conducted by Common et al., (2000) which indicates that the lack of concentration and commitment from top management, troubles in understanding the idea of LC, absence of training, lack of enthusiasm from the customer, absence of exposure on the need to implement the lean development idea, lack of appropriate training, weak communication among customers, consultants and contractual workers are obstacles hindering the adoption of lean concepts in the CI. The findings were also similar to those of Adegbembo et al. (2016) who stated that the need for LC knowledge and consciousness amongst professionals is the main obstruction to its usage. A study conducted in Canada by Bicheno and Holweg (2009:44) was similarly in agreement with the findings. It showed that the greatest barriers of implementing LC are lack of understanding lean construction process and going back to the traditional ways of doing things. Furthermore, these results were similar to the study by Kim (2002:7) who stated that lean practices can be a complex and complicated system and that understanding the application of lean tools and principles and making sure that all those involved in the process require the support of top management.

Factor two: Stakeholders and construction process barriers

This factor loads poor communication among stakeholders (0,749), lack of top management commitment (0,717), inadequate pre-planning (0,623), inaccurate and incomplete designs (0,661) and lack of interest from clients (0,453), with a total variance of 9.2 per cent. Four loadings of the items in factor two (public challenges) exceed 0.60, signifying a strong relationship between the items. Additionally, loading of one of the items exceeds 0.45, which asserts a fair relationship. The items on factor two have a close relation to the management hindering the adoption of lean concepts in the CI. This is corroborated by the study of Aigbavboa et al. (2016:200) that confirms that there are numerous boundaries to the implementation of LC in SACI. The maintop obstacles include poor communication, lack of interest from clients, absence of client and supplier participation, lack of long-term commitment, lack of technical skills and inadequate exposure to the requirements of LC. The findings are similar to those of Salem et al., (2005:52) who stated that top management of each organisation plays a major part in accomplishing a fruitful application of advanced approaches and further showed that the achievement of lean practice lies in their commitment in evolving and executing an operative plan. Furthermore, the study by Common et al. (2000) confirms that the absence of concentration and commitment from top management, absence of training, lack of interest from clients, and weak communication among customers, consultants and contractual workers are some of the key barriers to the adoption of lean concepts in the construction industry. These findings were also similar to those of the study by Sarhan and Andrew (2012) which showed that inadequate planning, inaccurate and incomplete designs are the barriers to the adoption of lean concepts in the construction industry.

Factor three: Procurement and technical barriers

This factor loads poor standardize procurement strategies (0,654), lack of prefabrication techniques (0,645), uncertainty in supply chain (0,632), and lack of agreed implementation methodology (0,562), with a total variance of 4.6 per cent. The three loadings of the items in factor three (Procurement barriers) exceed 0.60, which is evidence of a strong relationship between the items. In addition, there is one item that ranges above 0.50, which still shows a good relationship between the items. The items of component three have a close relation to the procurement methods of construction projects. Ballard and Howell (1998) confirm that lack of agreed implementation methodology, lack of prefabrication, and uncertainty in supply chain are amongst the main obstacles to the adoption of lean concepts in the CI. Alinaitwe et al. (2009) further confirmed this by carrying out a study around the obstructions to the implementation of LC and the following were the findings: lack of standardized procurement strategies and lack of control over factors of supply chain management are amongst top obstacles to the adoption of lean concepts.

Factor four: Government support and organisational barriers

This factor loads insufficient financial resources (0,533), lack of organisational culture that supports lean (0,507), high cost of lean training (0,502), lack of government support (0,418) and human resistance to change (0,408), with a total variance of 3.6 per cent. The three loadings of the items in factor three (Financial barriers) exceed 0.50, which is evidence of a strong relationship between the items. In addition, there are two items that range above 0.450, which shows a poor relationship between the items. The items of component three have a close relation to the financial matters of construction projects. Al-Aomar (2012) pointed out that "inadequate training and the expensive lean training" and "absence of lean professionals and organisational culture that supports lean" are the main barriers s to embracing LC concepts in the CI. Moreover, Neeraj et al. (2016) detailed that the major boundaries within the USA construction industry are "insufficient money related resources" and "lack of government support" which were the same as in other emerging states.

7.5.2 Implication of the results

The theoretical review is consistent with the empirical findings of this research study with a lack of appropriate lean training, lack of adequate lean awareness, lack of lean understanding, lack of top management commitment, absence of a lean culture being identified in the empirical findings as major obstacles to the implementation of lean concepts in the CI. Hence, there is a need to encourage lean concepts awareness through training, workshops, as well as integration into university curricula and continuing professional development (CPD) activities of professionals in the CI. Government should also encourage the implementation of lean concepts in the CI that will result in delivering projects in time, at agreed cost and within quality standard.

7.6 MEASURES FOR IMPROVING THE ADOPTION OF LEAN CONCEPTS IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY

RQ4: What are the measures for improving the adoption of lean concepts in the South African construction industry?

7.6.1 Findings

Based on the rankings and using the calculated standard deviation and mean item scores of the recorded measures for enhancing the adoption of lean concepts, the most significant measures for improving the adoption include lean awareness, top management commitment, availability of lean experts, employee training and development, and lean education in higher institute. Other measures include government support, efficient communication systems, client support, availability of required technology, favourable lean organisational culture, collaboration among stakeholders, and mandatory lean policies and regulations, Proper site management and proper waste management.

Results from the factor analysis identified the following four factors:

Factor one: Knowledge and organizational measures

These variables include: Employee training and development (0,801) ,government support (0,770), lean education in higher institute (0,735), collaboration among stakeholders (0,732), lean awareness (0,700), availability of lean experts (0,695), top management commitment (0,679), efficient communication system (0,650), client support (0,592), favourable lean organisational culture (0,593), and mandatory lean policies and regulations (0,599), with a total variance of 50.5 per cent. The findings were related to the results in the study by

Aigbavboa et al. (2016:200) which reveals that for the successful implementation of LC in SA, there has to be a sufficient level of awareness and commitment among construction stakeholders, including understanding the underlying concepts. Moreover, stakeholders should be trained on lean construction owing to observed complications of the practice. This further corroborate the findings of the study of Emuze and Ungerer (2014) which mentioned that lean awareness and enlightenment campaigns are necessary to sensitize stakeholders in the CI of the opportunities and benefits of lean implementation within the industry. And also relates to a study by Alarcon and Seguel (2002:8) which acknowledged that the training of staff at levels of LC can improve the production and performance of construction projects. In addition, the engagement of competent site operators, knowledgeable professionals, the introduction of the lean concept into school curriculum, and the promotion of the concept to companies, and professional bodies and main stakeholders in the CI funding workshops and research seminars to encourage the sharing of knowledge on LC is the measures of improving the adoption of lean construction

The study findings also align with those of Olatunji (2008:292) as they indicate that various government-related measures such as government reorientation in their approach to projects' execution, provision of basic infrastructure and an enabling environment favourable to lean, the establishment of standards for construction, a favourable government policy, and a change in the organisational culture of stakeholders (e.g. bureaucracy, power culture) can help in advancing the adoption of lean concepts in the CI.

Factor two: Operations measures

These variables include the second principal factor that accounts for 7.3 per cent of the total variance described. The factor consists of proper site management (0,966), availability of required technology (0,717) and proper waste management (0,536) with a total variance of 50.5 per cent. The results were related to the results in the study by Li et al. (2012:49). This study confirms that proper site management, the availability of the required technology, proper waste management and a good relationship with suppliers can also improve the application of LC practices in the organisation.

7.6.2 Implication of the results

The theoretical review is consistent with the empirical results of this research study. Findings from this study revealed that lean awareness, top management commitment, availability of lean experts, employee training and development and lean education are important measures for improving the adoption of lean concepts in the SACI. By creating awareness, training, workshops and education, lean concepts will be well disseminated across board, hence encouraging the adoption and implementation.

7.7 BENEFITS OF ADOPTING LEAN CONCEPTS IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY

RQ5: What are the benefits of adopting lean concepts in the South African construction industry?

In answering this research question, results from the descriptive and exploratory factor analysis were used.

7.7.1 Findings

Through the use of rankings of the listed benefits that can be gained through the adoption of lean concepts, which were ranked through the calculated standard deviations and mean item scores, the study reveals that construction firms can expect to improve quality, reduce waste, improve target costing and value, increase the productivity and meet clients' as the main benefits of adoption of LC. Other benefits include improved safety (reduced trip hazards and fatigue), effective collaboration, improved effective, improved environmental performance, decreased defects, reduced project duration, reduced project cost, efficiency of equipment, enhanced use of relevant equipment, decreased chance of accidents on site, maximised usage of multi-skilled employees, minimised double handling and movement of labourers and tools and reduced inventory.

Results from the factor analysis are categorised into three factors.

Factor one: Improved construction delivery

These variables include improved target costing and value (0,817), meeting clients' needs (0,785),decreased defects (0,752), improved quality (0,710), improved effective communication (0,665), effective collaboration (0,651), reduction of waste (0,633), improve environmental performance (0,579), reduce project duration (0,557), reduced project cost (0,543), increase the productivity (0,534) ,improved safety (reduced trip hazards and fatigue)(0,479) and decreased chance of accidents on site (0,435), with a total variance of 30.95%.

This conforms to the findings of Aigbavboa et al. (2016:200) who affirmed that lean, if fully implemented in construction projects, will help in waste reduction, improved communication systems, as well as improved productivity customer focus, employee empowerment and sharing of knowledge. This further corroborates the findings of this study which identified increased productivity, improved reliability, improved quality, more client satisfaction, increased predictableness, shortened schedules, less waste, reduced costs ,and enhanced buildability enhancements to design as some of the cogent benefits of lean concepts in the CI as established by the study of Mossman (2009:26).

Factor two: Equipment efficiency

The factor includes increased use of relevant equipment (0,926) and efficiency of equipment (0,594) with a total variance of 13.898 per cent. This relates to the findings of Salem et al., (2005) which stated that LC results are efficiency of equipment, sufficient skilled operators, the use of relevant equipment and high performance of adequate equipment.

Factor three: Labourers' efficiency

The factor include: maximised usage of multi-skilled employees (0,566), reduced inventory (0,560) and minimised double handling and movement of labourers and tools (0,490), with a total variance of 13.38 per cent. This is corroborated by the study of Aziz and Hafez (2013) that identifies the maximised use of multi-skilled employees and labour reduction while maintaining or increasing throughput as some of the benefits of lean concepts in the CI. This is supported by a study by BPP Learning Media (2014) which reveals that LC helps organisations to deliver on request, reduce inventory, maximise the usage of multi-skilled employees, flatten the management structure and focus resources.

7.7.2 Implication of the results

From the findings, it was discovered that the implementation of lean concepts is beneficial in all facets of sustainability i.e. environmental, social and economic. The study has established that lean concepts helps in improving the quality of works, reducing waste, improving target costing and value, increasing productivity, meeting client's' needs and also improving safety (reduced trip hazards and fatigue). Practising lean concepts will reduce the waste in the CI, thereby improving the productivity and overall quality of human life.

7.8 CHAPTER SUMMARY

The data obtained from the questionnaires as responded to by the respondents were presented and analysed in relation to the research questions and literature review of the study. The data related to the level of awareness of lean concepts, level of usage of lean concepts, barriers to the adoption of lean concepts, measures of improving the adoption of lean concepts and the benefits of lean concepts in the SACI. The findings that emerged from the data provide the answers to the research questions of the study. The next chapter discusses the conclusions and recommendations of this research in relation to the research objectives of the study.

CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

8.1 INTRODUCTION

The objective of the research study was to assess the lean concepts in the SACI. In this chapter, the conclusions and recommendations of the research study are presented and discussed in relation to the stated objectives of the study. The purpose of the study was to:

- investigate the level of awareness of lean concepts in the South African construction industry;
- explore the level of adoption of lean concepts in the South African construction industry;
- identify the barriers to the adoption of lean concepts in the South African construction industry;
- determine the measures for improving lean concepts' adoption in the South African construction industry; and
- Identify the benefits of adopting lean concepts in the South African construction industry.

8.2 LEVEL OF AWARENESS OF LEAN CONCEPTS IN THR SOUTH AFRICAN CONSTRUCTION INDUSTRY

The first objective was to investigate the level of awareness of lean concepts in the South African construction industry.

From the literature, it was established that one of the approaches to the sustainability of the CI is the continuous use of lean principles and techniques. Literature also revealed that lean principles and techniques possess sustainable identifications. A list of lean principles, techniques and their implementation in the CI was compiled. .

Results from the questionnaire survey obtained from the respondents showed that the lean principle which is 'identifying value' was highly recognized with a relatively high level of awareness. Other lean principles recognized include pursuing perfection, achieving flow in the process, and allowing customer to pull and adopting value stream mapping. Based on the general view, the average level of awareness of lean principles in the SACI is relatively high. Further, findings also revealed that the lean techniques total quality management, waste elimination, first run studies (plan, do, check and act), prefabrication, standardisation, increased visualisations (visual management), 5s process (Sort, Set in order, Shine, Standardize and Sustain), value stream mapping (VSM), Kaizen (continuous improvement) and five why's, are the ten most significant lean techniques of which SACI participants are aware. From the results, it can be deduced that the construction participants in South Africa are aware of the lean principles. Therefore the research objective was met.

8.3 LEVEL OF ADOPTION OF LEAN CONCEPTS IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY

The second objective was to explore the level of adoption of lean concepts in the South African construction industry.

From the literature, it was also discovered that building material, waste removal operations and prefabrications could be improved by the use of reverse logistics in a construction context through the application of LC principles and techniques. However, it is clearly evident that although lean is being utilized globally, the concept is not utilized in SA. Furthermore, the results also showed that, even though LC ideas have recently received attention as an advanced method of improving construction execution and work efficiency, the construction industry is slow in taking up lean concepts. Also, it was discovered that the foremost adapted techniques to be applied within the construction recorded are total quality management (TQM), the 5S process, first-run studies (plan, do, check, and act), waste elimination, prefabrication and Kaizen (continuous improvement).

Results from the questionnaire review indicated that the level of usage of the lean principle pursuing perfection and identifying value was relatively high. Achieving flow, allowing customers to pull and adopting value stream mapping were lean principles rated as average. It can be deduced from the average result that the level of the usage of lean principles is high in the SACI. It can also be deduced from the result that the level of the use and implementation of lean techniques is low in the SACI.

8.4 BARRIERS TO THE ADOPTION OF LEAN CONCEPTS IN THE SOUTH AFRICAN CONSTRUCTION INFDUSTRY

The third objective was to identify the barriers to the adoption of lean concepts in the South African construction industry.

The results from the primary data reveal that lack of lean understanding, lack of adequate lean awareness, lack of adequate time for innovation, poor standardized procurement strategies, inaccurate and incomplete designs, lack of top management commitment, lack of appropriate lean training, lack of interest from clients, poor communication among stakeholders are the top ten barriers to the adoption of lean concepts. Additional barriers recognised are lack of agreed implementation methodology, lack of prefabrication techniques, uncertainty in supply chain, absence of a lean culture, inadequate pre-planning, human resistance to change, lack of organisational culture that supports lean, high cost of lean training, lack of lean specialists and expertise, lack of government support, insufficient financial resources

Results gathered through conducting a questionnaire survey revealed that the barriers to the adoption of lean concepts can be categorised into four (4) factors. The first understands of lean concept barriers. The key element of this factor include lack of lean understanding, lack of adequate lean awareness, lack of adequate time for innovation, absence of a lean culture, and lack of lean specialists and expertise. The second factor relates to stakeholders and construction process barriers, the key elements of which include poor communication among stakeholders, lack of interest from clients, inaccurate and incomplete designs, inadequate pre-planning and lack of top management commitment. The third factor comprises procurement and technical barriers, the key element of which are poor standardized procurement strategies, lack of prefabrication techniques, uncertainty in supply chain, and lack of agreed implementation methodology. The fourth and final factor is government support and organisational related barriers. Obstacles under this factor include insufficient financial resources, human resistance to change, high cost of lean training, lack of government support, and lack of organisational culture that supports lean.

8.5 MEASURES FOR IMPROVNG LEAN CONCEPTS ADOPTION IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY

The fourth objective was to determine the measures for improving lean concepts' adoption in the South African construction industry.

From the literature, lean awareness, lean education in higher institutes, the availability of the required technology, the availability of lean experts, top management commitment, efficient communication systems, government support, mandatory lean policies and regulations, a favourable lean organisational culture, collaboration among stakeholders, proper waste management, client support, proper site management, and employee training and development are the identified benefits of lean concepts in the CI.

Results gathered through conducting a questionnaire survey revealed that the measures for improving adoption of lean concepts can be categorised into two (2) factors, namely knowledge and organizational measures. The key elements of the knowledge factor include employee training and development, government support, lean education in higher institute, collaboration among stakeholders and lean awareness. The key element of the organizational measures factor include proper site management, availability of required technology and proper waste management.

8.6 IDENTIFY THE BENEFITS OF ADOPTING LEAN CONCEPTS IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY

The fifth objective was to identify the benefits of adopting lean concepts in the South African construction industry

From the literature, improved safety (reduced trip hazards and fatigue),improved environmental performance, reduction of waste, reduced project duration, increased productivity, minimised double handling and movement of labourers and tools, clients' needs met, improved target costing and value, decreased chance of accidents on site, efficiency of equipment, efficient use of relevant equipment, improved quality, reduced inventory, maximised usage of multi-skilled employees, reduced project cost, decreased defects, improved effective communication, and effective collaboration are the identified benefits of lean concepts in the CI.

Results gathered through conducting a questionnaire survey revealed that the benefits of adopting lean concepts can be categorised into three (3) factors, the first of which is improved construction delivery benefits. The key elements of this factor include improved target costing and value, clients' needs being met, decreased defects, improved quality and improved effective communication. The second factor refers to equipment efficiency benefits, the key elements of which include efficient use of relevant equipment and efficiency of equipment. The third factor comprises labourers' efficiency benefits, the components of which include maximised usage of multi-skilled employees, reduced inventory and minimised double handling and movement of labourers and tools.

8.7 GENERAL RESEARCH CONCLUSIONS

The main aim of this research study was to assess the lean concepts in SACI. This has been achieved by investigating the level of awareness of lean concepts within CI, exploring the level of usage of lean concepts, identifying the barriers to the adoption of lean concepts, determining the measures for improving lean concepts adoption and identifying the benefits of adopting lean concepts in the SACI.

The following conclusions were reached from the research study:

- The application of lean concepts has been found to be most successful in the areas of construction innovation. However, the awareness level of these principles and techniques is both at an average level in the SACI. Furthermore, the usage level of these principles and techniques is at lowest in the SACI. The usage of these principles and techniques need to be increased among the professionals and stakeholders in the SACI. Government and respective professional bodies in the SACI should encourage the implementation of lean principles and techniques. By doing this, the unsustainable project management approach that have been utilised in the industry will be replaced by the lean concept approach.
- The barriers to the adoption of lean concepts in the SACI can be categorised as the understanding of the lean concept, stakeholders and construction process, procurement, technical as well as government support and organisational related issues.
- To improve the adoption of the lean concept in the SACI, factors related to knowledge, as well as organizational and operational measures are crucial.

- If the concept of lean is adopted in the SACI, significant benefits relating to improved construction delivery, equipment efficiency and labourers' efficiency can be achieved.

8.8 RECOMMENDATIONS

This research study has assessed the lean concepts in South African construction industry. This has been achieved by investigating the level of awareness of lean concepts within CI, exploring the level of usage of lean concepts, identifying the barriers to the adoption of lean concepts, determining the measures for improving lean concepts adoption and identifying the benefits of adopting lean concepts in the SACI. Hence, the following recommendations were made:

- It is recommended that for construction practices to optimise lean concepts in the SACI, government, relevant professional bodies and stakeholders should embrace and encourage the adoption across the board through awareness, education, and training on its principles and approaches.
- It is recommended that the inclusion of lean concepts in the university curriculum should be fully supported by the government and relevant professional bodies in the SACI.
- Government should invest in innovative ways of improving the adoption of lean concepts through the use of technology. Research needs to detail innovative ways in which technology can be used to improve the adoption of lean concepts in the SACI.
- From the results, it is evident that clear policy and legislation should be formulated to support the implementation of lean concepts in the CI.
- Lastly, campaigns should be launched to educate communities and the necessary stakeholders about the importance of adopting lean concepts in the CI. These awareness campaigns should lead to an increased level of investment that will also create employment for citizens.

8.9 RECOMMENDATIONS FOR FURTHER RESEARCH

This research study further recommends the following areas for further research:

- Research can be undertaken to identify the risks associated with implementation of lean concepts in the CI.

- Further research can be conducted into achieving a larger research area and number of respondents. This will give a deeper understanding of how lean concepts are perceived by construction professionals and stakeholders for optimising sustainable construction practice in the construction industry.
- A research about innovative ways of improving the adoption of lean concepts in the CI should be carried out.
- Lastly, a research study regarding a lean concept model or framework for the construction industry is recommended. It is believed this will offer construction professionals and stakeholders a comprehensive tool and guideline to achieving sustainable outcomes in their practices.

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APPENDIX 1: QUESTIONNAIRE COVER LETTER

University of Johannesburg
Faculty of Engineering and the Built Environment
Department of Construction Management and Quantity Surveying
Doornfontein
2028
MARCH 2019

TO WHOM IT MAY CONCERN

Dear Sir/Madam

LETTER OF INVITATION FOR RESEARCH SURVEY

The Department of Construction Management and Quantity Surveying at the University of Johannesburg is conducting a research on: **"ASSESSMENT OF LEAN CONCEPTS IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY"**

Therefore, we kindly request that you complete the following short questionnaire. It should take not more than 15 minutes of your time. Your response is of the utmost importance to us and it will be kept confidential. To protect your anonymity, please do not enter your name or contact details on the questionnaire.

A summary of the results of this research will be available at the Department of Construction Management and Quantity Surveying in July, 2019.

Should you have any queries or comments regarding this survey, you are welcome to contact me telephonically at +27797408074 or email: dpramaru@gmail.com.

Thank you in advance

P.Ramaru

APPENDIX 2: QUESTIONNAIRE

<u>QUESTIONNAIRE ON THE ASSESSMENT OF LEAN CONCEPTS IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY</u>

<u>INSTRUCTIONS:</u>

PLEASE ANSWER THE FOLLOWING QUESTIONS BY CROSSING (X) ON THE RELEVANT BLOCK

EXAMPLE of how to complete this questionnaire:

Your gender?
If you are female:

Male	1
Female	2 (X)

<u>SECTION A - BACKGROUND INFORMATION</u>

This section of the questionnaire refers to background or biographical information. Although we are aware of the sensitivity of the questions in this section, the information will allow us to compare groups of respondents. Once again, we assure you that your response will remain anonymous. Your cooperation is appreciated.

1. State your highest educational qualification.

Diploma	1
Bachelor's degree	2
Honour's degree	3
Master's degree	4
Doctorate	5

2. What is your profession?

Architect	1
Civil Engineer	2
Electrical Engineer	3
Mechanical Engineer	4
Structural Engineer	5
Construction Project Manager	7
Project Manager	8
Quantity Surveyor	9

3. How many years of experience do you have in the construction industry?

1 - 5 years	1
6 - 10 years	2
11 - 15years	3

16- 20 years	4
More than 20 years	5

4. To which organisation do you belong?

Government	1
Consultant	2
Contractor	3

SECTION B - LEAN PRINCIPLES AND TECHNIQUES FOR CONSTRUCTION PROJECTS

This section explores your knowledge regarding lean principles and techniques within construction projects.

Mossman (2009:27) defined lean construction as a "method to plan construction frameworks to limit time, effort, and waste of materials. It ensures that a project is quickly done, and minimizing costs involved during construction project maintenance, design, planning and activation".

Please indicate your answers using the following 5-point scale where: 1 =Not all aware ; 2=Slightly aware; 3 = Somewhat aware ;4 = Moderately aware; 5 = Very aware .

5a.To what extent are you aware of the following lean principles and techniques within construction projects?

	Lean construction principles and techniques	**Level of Awareness**				
		Not all aware	**Slightly aware**	**Somewhat aware**	**Moderately aware**	**Very aware**
	Lean construction principles					
BA1	Identifying value	1	2	3	4	5
BA2	Adopting value stream mapping	1	2	3	4	5
BA3	Achieving flow in process	1	2	3	4	5
BA4	Allowing customer (client) to pull	1	2	3	4	5
BA5	Pursuing perfection	1	2	3	4	5
	Lean construction techniques					
BA6	Just-in-time (JIT)	1	2	3	4	5
BA7	Kanban (Pull system)	1	2	3	4	5
BA8	The 5s process (Sort, Set in order ,Shine, Standardize and Sustain)	1	2	3	4	5
BA9	Increased visualisations (Visual management)	1	2	3	4	5
BA10	Standardisation (Standard operating strategies)	1	2	3	4	5
BA11	Prefabrication	1	2	3	4	5
BA12	Last Planner System (LPS)	1	2	3	4	5
BA13	Value stream mapping (VSM)	1	2	3	4	5
BA14	Waste elimination (Muda)	1	2	3	4	5
BA15	Kaizen (Continuous improvement)	1	2	3	4	5
BA16	First-run studies (plan, do, check, act)	1	2	3	4	5
BA17	Total quality management (TQM)	1	2	3	4	5
BA18	Error proofing / Fail safe for quality and safety (Poka-Yoke)	1	2	3	4	5
BA19	Ishikawa diagram (Fishbone diagram)	1	2	3	4	5
BA20	Pareto analysis	1	2	3	4	5

BA21	Failure mode, effects and criticality analysis (FMECA)	1	2	3	4	5
BA22	Five why's	1	2	3	4	5

Please indicate your answers using the following 5-point scale where: 1 =Never; 2=Almost never; 3 =Sometimes; 4 =Almost every time; 5 =Every time.

5b.Please indicate your frequency of use of the following lean principles and techniques within your construction projects:

	Lean construction principles and Technique	Extent of usage				
		Never	**Almost Never**	**Sometimes**	**Almost every time**	**Every time**
	Lean construction principles					
BB1	Identifying value	1	2	3	4	5
BB2	Adopting value stream mapping	1	2	3	4	5
BB3	Achieving flow in process	1	2	3	4	5
BB4	Allowing customer (client) to pull	1	2	3	4	5
BB5	Pursuing perfection	1	2	3	4	5
	Lean construction techniques					
BB6	Just-in-time (JIT)	1	2	3	4	5
BB7	Kanban (Pull system)	1	2	3	4	5
BB8	The 5s process (Sort, Set in order ,Shine, Standardize and Sustain)	1	2	3	4	5
BB9	Increased visualisations (Visual Management)	1	2	3	4	5
BB10	Standardisation (Standard operating strategies)	1	2	3	4	5
BB11	Prefabrication	1	2	3	4	5
BB12	Last Planner System (LPS)	1	2	3	4	5
BB13	Value stream mapping (VSM)	1	2	3	4	5
BB14	Waste elimination (Muda)	1	2	3	4	5
BB15	Kaizen (Continuous Improvement)	1	2	3	4	5
BB16	First-run studies (plan, do, check, act)	1	2	3	4	5
BB17	Total quality management (TQM)	1	2	3	4	5
BB18	Error proofing / Fail safe for quality and safety (Poka-Yoke)	1	2	3	4	5
BB19	Ishikawa diagram (Fishbone diagram)	1	2	3	4	5
BB20	Pareto analysis	1	2	3	4	5
BB21	Failure mode, effects and criticality analysis (FMECA)	1	2	3	4	5

SECTION C: BARRIERS TO THE ADOPTION OF LEAN CONCEPTS IN THE CONSTRUCTION INDUSTRY

This section of the questionnaire assesses the barriers to the adoption of lean concepts for construction projects.

Please indicate your answers using the following 5-point scale where: 1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree

6. To what extent do you agree that the following are the barriers to the adoption of lean concepts in the construction industry?

	Barriers of lean concepts	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
C1	Lack of lean understanding	1	2	3	4	5
C2	Lack of adequate lean awareness	1	2	3	4	5
C3	Lack of adequate time for innovation	1	2	3	4	5
C4	Poor standardized procurement strategies	1	2	3	4	5
C5	Inaccurate and incomplete designs	1	2	3	4	5
C6	Lack of top management commitment	1	2	3	4	5
C7	Lack of appropriate lean training	1	2	3	4	5
C8	Lack of interest from clients	1	2	3	4	5
C9	Poor communication among stakeholders	1	2	3	4	5
C10	Lack of agreed implementation methodology	1	2	3	4	5
C11	Lack of prefabrication techniques	1	2	3	4	5
C12	Uncertainty in supply chain	1	2	3	4	5
C13	Absence of a lean culture	1	2	3	4	5
C14	Inadequate pre-planning	1	2	3	4	5
C15	Human resistance to change	1	2	3	4	5
C16	Lack of organisational culture that supports lean	1	2	3	4	5
C17	High cost of lean training	1	2	3	4	5
C18	Lack of lean specialists and expertise	1	2	3	4	5
C19	Insufficient financial resources	1	2	3	4	5
C20	Lack of government support	1	2	3	4	5

SECTION D: MEASURES FOR IMPROVING LEAN ADOPTION IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY.

This section of the questionnaire explores the measures of improving lean adoption in the South African construction industry.

Please indicate your answers using the following 5-point scale where: 1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree

7. To what extent do you agree that the following are the measures to improve the adoption of lean concepts in the construction industry?

	Measures for improving lean adoption in the construction industry	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
D1	Lean awareness	1	2	3	4	5
D2	Lean education in higher institute	1	2	3	4	5
D3	Employee training and development	1	2	3	4	5
D4	Availability of lean experts	1	2	3	4	5
D5	Top management commitment	1	2	3	4	5
D6	Efficient communication system	1	2	3	4	5
D7	Government support	1	2	3	4	5
D8	Mandatory lean policies and regulations	1	2	3	4	5
D9	Favourable lean organisational culture	1	2	3	4	5
D10	Collaboration among stakeholders	1	2	3	4	5
D11	Proper waste management	1	2	3	4	5
D12	Client support	1	2	3	4	5
D13	Proper site management	1	2	3	4	5
D14	Availability of required technology	1	2	3	4	5

SECTION E: BENEFITS OF ADOPTING LEAN CONCEPTS IN THE CONSTRUCTION INDUSTRY.

This section of the questionnaire explores the benefits of adopting lean concepts in the South African construction industry.

Please indicate your answers using the following 5-point scale where: 1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree

8. To what extent do you agree that the following are the benefits of adopting lean concepts in the construction industry?

	Benefits of adopting lean concepts	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
E1	Improves safety (reduced trip hazards and fatigue)	1	2	3	4	5
E2	Improves environmental performance	1	2	3	4	5
E3	Reduces waste	1	2	3	4	5
E4	Reduces project duration	1	2	3	4	5
E5	Increases the productivity	1	2	3	4	5
E6	Minimise double handling and movement of labourers and tools.	1	2	3	4	5
E7	Meets client's needs	1	2	3	4	5
E8	Improves target costing and value	1	2	3	4	5
E9	Decreases the chance of accidents on site	1	2	3	4	5
E10	Efficiency of equipment/Uses equipment efficiently	1	2	3	4	5
E11	Encourages the use of relevant equipment	1	2	3	4	5
E12	Improves quality	1	2	3	4	5
E13	Reduces inventory	1	2	3	4	5
E14	Maximises the usage of multi-skilled employees	1	2	3	4	5
E15	Reduces project cost	1	2	3	4	5
E16	Decreases defects	1	2	3	4	5
E17	Improves effective communication	1	2	3	4	5
E18	Encourages collaboration	1	2	3	4	5

Thank you for your co-operation in completing this questionnaire.